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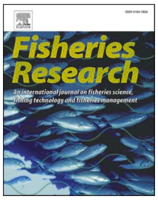

Designing a coastal monitoring marine biodiversity survey, using trammel nets and gillnets in Portugal

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ABSTRACT

Although coastal areas are of great importance, they often lack long term monitoring surveys, which are essential for effective management, fisheries sustainability, and marine spatial planning. To address this, we conducted two experimental surveys aimed at assessing communities and their biodiversity, with the objective of designing a monitoring program for marine coastal biodiversity, based on gear type, depth, sampling arrangement, total net length, and panel position within the haul. Depth was found to be the most important factor shaping biodiversity, while gear type had the greatest impact on assessing species richness. Overall, both number of species and diversity increased with depth, though significant differences were only found between hauls deployed at 10 m and deeper (30–50 m). Trammel nets caught a larger number of species compared to gillnets, and there was evidence of an interaction between depth and gear, in terms of abundance and at the community level; samples taken deeper than 10 m showed more gear-related differences. We found that neither the panel position within the haul nor the number of nets had any impact on species diversity or abundance. Similarly, there was no evidence for an effect related to the arrangement of nets, as results were consistent whether using separated or continuous net panels. However, the number of nets used as a sampling unit significantly influenced the results, as the variation in species abundance and diversity with depth and gear type was similar, when 20 or 30 nets were used, but became more variable when only 10 nets were used, even with increased replication. We concluded that both trammel nets and gillnets should be included in a coastal biodiversity monitoring program, as each catches a different set of species, including both demersal and pelagic taxa. Further, we recommend using a minimum of 20 nets (ideally 30+) per station, with replication. The evaluated monitoring system has a minimal impact on the ecosystem, can be easily deployed using commercial vessels and effectively captures a large number of species, being thus, highly recommended to be used in coastal monitoring surveys.

1. Introduction

Areas close to the shore represent vital transitions between land and the ocean, typically characterized by high biodiversity, and a refuge to many aquatic species, particularly during their early stages, making them sensitive to both human and environmental pressures. These are also the most heavily used marine areas, where over 80 % of the world's fishing fleets operate, especially small-scale fisheries (SSF) involving vessels smaller than 12 m in length, thus providing high societal value (Mallol and Goñi, 2019; Mantziaris et al., 2021).

Coastal areas are under multiple pressures, besides fishing, and are prone to ocean grabbing, with several stakeholders requiring more marine space (Batista et al., 2014). Despite their importance, long-term monitoring surveys on these areas, particularly those shallower than 50 m, are rare. Most existing monitoring programs focus on demersal resources (e.g. International Bottom Trawl Surveys, IBTS; International

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Bottom Trawl Survey in the Mediterranean, MEDITS), pelagic species (e.g. acoustic and egg surveys for small pelagic fish), or estuarine areas (e.g. monitoring of nursery grounds). These surveys provide fisheries-independent data, which are essential for assessing species status, evaluating communities and biodiversity spatio-temporal dynamics, and understanding responses to human impact, environmental fluctuations, or climate change. In Portugal, the Good Environmental Status (GES) of commercial fish stocks (Descriptor 3) was assessed under the Marine Strategy Framework Directive (MSFD, https://research-and-innovation.ec.europa.eu/research-area/environment/oceans-and-seas/eu-marine-strategy-framework-directive_en) in 2020 for less than 30 % of the total number of commercial species that represent 90 % of landings in value (Portuguese Ministry of the Sea, 2020). Many of these fishing resources are coastal species that remain unassessed due to the lack of information, which also limits the selection of coastal species to be assessed under Descriptor 1 (Biodiversity) of EU's Marine Strategy Framework Directive (MSFD), which includes ecologically important species with less or no commercial value (Portuguese Ministry of the Sea, 2020).

Monitoring is well known to be essential for fisheries sustainability, the development of management plans, and for marine spatial planning, including the identification of the best locations for implementing protected areas and evaluate its effectiveness over time. Unlike in offshore areas, the availability of environmental information for coastal areas is also constrained by limitations in satellite information within these zones (coastal mirror effect). Monitoring surveys are often developed using fishing gears similar to the ones used by commercial fisheries, but with different specificities, e.g. smaller mesh size for catching smaller individuals to evaluate recruitment (e.g. bivalve dredge survey mesh size) or shorter haul duration, as the objective is to collect a representative sample and not to catch large quantities.

Set nets (herein "nets"), including both trammel nets (GTR) and gillnets (GNS), are among the most important fishing gears operating in coastal areas, within small-scale fisheries in EU and around the globe (Lucchetti et al., 2020; Tzanatos et al., 2006). Both GNS and GTR are stationary fishing gears. Gillnets are bottom-set nets, composed by a single netting, kept vertical by a float line, and fixed to the sea floor by means of anchors or weights, in which fish get gill-entangled or enmeshed. Trammel nets are also bottom-set and kept vertical, but composed by three panels, the two outer panels being of a larger mesh size than the loosely hung inner netting panel; the fish get entangled in the inner small, meshed panel after passing through the outer one. These nets are known to be the less selective gears among SSF, thus, are also the ones generally catching a greater diversity of species, and therefore excellent for biodiversity monitoring (Castro et al., 2021; Teixeira and Silva, 2023).

Nets catch composition is variable and influenced by many factors, namely habitat and depth (Lyle et al., 2014; Sousa et al., 2018), mesh size (Erzini et al., 2006, 2003; Fabi et al., 2002; Fonseca et al., 2005; Karakulak and Erk, 2008), soaking time (immersion time, particularly when more than 24 h), hanging ratio (gillnets), vertical slack (trammel nets), and net length (Batista et al., 2009; Papageorgiou and Moutopoulos, 2023). In addition to geographical location, catch composition varies with season (namely due to the presence of juveniles of some species that tend to concentrate in shallower areas, in certain months, as the cuttlefish or sole) (Bousquet et al., 2022; Castro et al., 2021). However, the impact of these factors on species diversity of the catch has only been briefly addressed in a few studies (Fauconnet et al., 2015; Ragheb et al., 2022).

Portugal is located in a biogeographic transition zone between temperate and subtropical waters, where many species reach their southern or northern distribution limits. According to official landings data (Portuguese Directorate-General for Natural Resources Safety and Maritime Services, DGRM), over 250 taxa are landed by vessels using nets as main fishing gear. When using nets, fishers can vary net length, mesh size, soak time, setting location, gear type and depth, to optimize their catch or increase the capture of target species (Papageorgiou and Moutopoulos, 2023). Previous studies considering nets have primarily focused on evaluating discards and gear selectivity (Baeta et al., 2010; Batista et al., 2009; Castro et al., 2021; Gonçalves et al., 2007; Papageorgiou and Moutopoulos, 2023; Tzanatos et al., 2007). Both GTR and GNS have been proposed as excellent sampling devices for monitoring species and biodiversity, in face of the diversity of their catches, for being less expensive than other gears, easily deployed and retrieved, and for having a minimal environmental impact across a wide range of habitats (see, for example, Van der Mheen., 1995 and HELCOM guidelines https://www.helcom.fi/wp-content/uploads/2019/08/Guidelines-for-Coastal-fish-Monitoring-of-HELCOM.pdf). Acosta (1997) concluded that nets yielded 30 % more species than visual census in coral reefs and mangroves, and that GNS provided more accurate species parameters estimates. Similarly, Gray et al. (2005), in spite of having found no difference between catch composition of GNS and GTR, concluded that GNS is better suited for monitoring due to its higher precision of catch per unit effort (CPUE), lower sampling effort and easier handling. These authors further found that the species captured by each gear type were more closely related to the mesh size used, rather than with the type of net.

Rotherham et al. (2006) optimised soaking time (1–6 h) and panel length (20–120 m) in multi-mesh GNS to develop an optimal, representative, and standardised sampling methodology for fishery-independent surveys in southeast Australian estuary. These authors concluded that 20 m panels soaked for one hour would be ideal. Sousa et al. (2018) advocated the use of GTR to monitor biodiversity in sensitive areas, such as Marine Protected Areas (MPAs). They found a significant effect of protection level within an MPA (Professor Luiz Saldanha Marine Park in central Portugal) on fish biomass, although they stressed that substrate type and depth should always be considered in effective coastal monitoring surveys due to their even greater influence. Priester et al. (2021) further proposes the use of trammel nets as a monitoring tool in MPAs due to its low species- and size-selectivity, while causing little benthic disturbance. Since nets are stationary, the damage to the soft bottoms' benthic community is restricted to a minimal disturbance of the epibenthos during the nets' deployment and retrieval, and the impact on the soft-substrate fish community is also minimal.

The aim of this study is to optimize a sampling design for a coastal monitoring survey on soft substrates. For this, the research questions on the current work were to understand how the community composition, species and diversity changed in function of (1) gear type, specifically trammel nets (T100) and gillnets (E80), (2) depth (10 m, 30 m, and 50 m), (3) nets sampling arrangement, whether deployed as continuous segments or separated (e.g., one net with 30 panels versus three nets with 10 panels each), (4) nets total length, i.e., 10, 20 and 30 nets panels; and (5) the position of the panels within the haul.

2. Materials and methods

2.1. Sampling

Two experiments using two types of fishing nets were carried out to design a sampling strategy for species and biodiversity monitoring of coastal areas (Fig. 1). In both experiments, replicates of trammel nets and gillnets, similar to those commonly used by fisherman, were set on the same day, parallel to the coast, near the Sado river Estuary (Setúbal), an important fishing area on the central western coast of Portugal (Fig. 2).

The trammel nets (T100) consisted of three panels: a small-mesh inner panel flanked by two large-mesh outer panels. The outer panels were composed of three rows of 600 mm mesh, made from 0.45 mm diameter polyethylene monofilament. Each panel measured 38 m in length and 1.8 m in in height. The inner panel consisted of 50 rows of 100 mm mesh, made from 0.30 mm diameter polyethylene

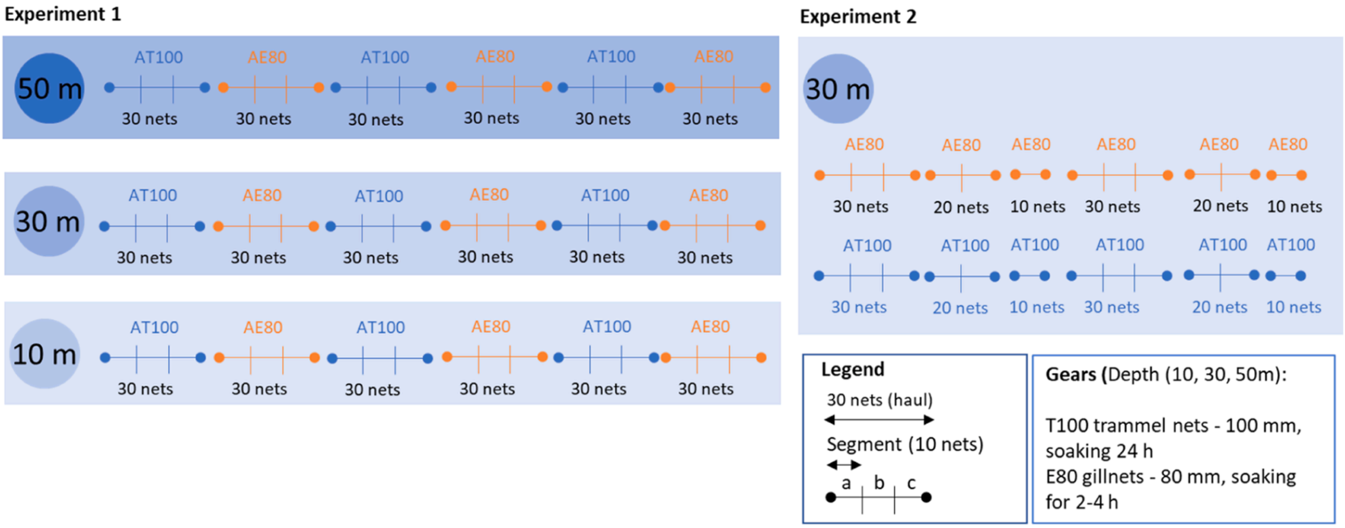


Fig. 1. Experimental design of the two experiments carried out. See the methods section for further details.

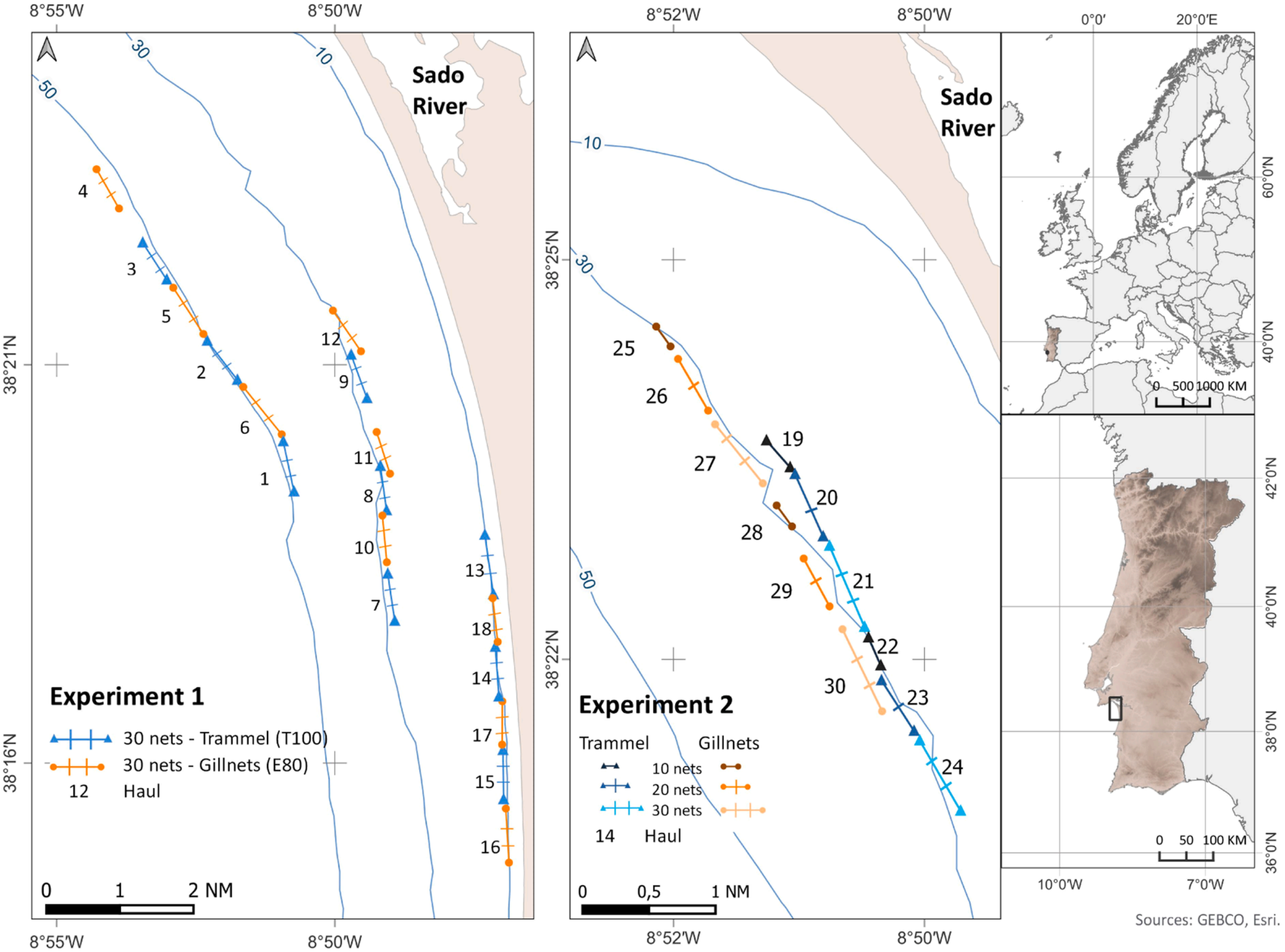


Fig. 2. Location of the sampling stations.

monofilament, with an overall height of 5 m. The trammel nets had a vertical slack ratio (inner panel stretched mesh height/outer panel stretched mesh height) of 2.77.The gillnets were made of 0.3 mm polyethylene monofilament, with a mesh size of 80 mm. The panels measured 100 m in length and 4 m in height, with a headrope length of 42.5 m, resulting in a hanging ratio (length of the headrope/length of the stretched mesh) of 0.43. The nets were deployed independently during each haul and were not connected to each other.

The experiments took place during April 2023, onboard a commercial vessel with 9.83 m length overall and an engine power of 41.19 kW. The nets were deployed by the vessel's skipper and an experienced crew. Trammel nets were soaked for 24 hours, while gillnets were soaked for 2–4 hours, as agreed between IPMA's experts and the skipper. All captured specimens were stored by haul and brought to the laboratory for subsequent species identification and sampling. Taxa names were matched with the World Register of Marine Species (WORMS, https://www.marinespecies.org/index.php) to extract AphiaID and confirm scientific names. Habitat information for each species was obtained from Fishbase (rfishbase package)(https://fishbase.se/search.php), and the list of landed taxa from the official Portuguese landings database (Portuguese Directorate-General for Natural Resources).

In the first experiment, a continuous net arrangement (E1_CNA) was set, with three replicates of 30 nets per haul, deployed at three different depth strata (10 m, 30 m, and 50 m). Within each haul of 30 nets, the catch was stored separately for each segment of 10 nets, resulting in three sampling units per haul (pseudo-replicates). This design allowed evaluating the changes in the catch associated with using 10, 20, and 30 nets (Fig. 1). For the second experiment, using an independent nets arrangement (E2_INA), two replicates of each haul composed by 10, 20, and 30 nets were deployed at a depth of 30 m to evaluate whether catch composition differed between continuous and separated net configuration (Fig. 1).

The analysis was carried out considering three levels: species, community composition, and biodiversity. Five factors were examined: (a) depth (10, 20, and 30 m), (b) gear type (trammel vs. gillnets), (c) gear length (number of panels: 10, 20, or 30 nets), (d) gear set up (continuous or independent) and (e) net position within the haul (left, middle, or right).

2.2. Statistical analysis

Both abundance and diversity indices were calculated as indicators of community structure. Species abundance was estimated as the sum of the number of individuals (nind) caught. Species richness (S) was calculated as the number of unique taxa. The Shannon-Wiener diversity index (H) was used to quantify biodiversity, while the probability of interspecific encounter (PIE) was calculated as a measure of community evenness (Gotelli et al., 2013). PIE represents the probability that two randomly sampled individuals from the community belong to different species (Gotelli et al., 2013), with higher values indicating more even communities. Additionally, taxa names were matched with landings tables to identify commercial species, and their abundance was estimated accordingly (nind.com). The identification of commercial species was further refined based on expert judgement. The average with respective bootstrap 95 % confidence interval were used to plot the indices by groups, e.g. depth, gear, number of nets to summarise the raw data.

2.3. Changes in community composition

A Redundancy Analysis (RDA) was carried out to visualise changes in community composition related to gear type (T100 and E80), depth (10, 20, or 30 m), and total number of nets per haul (10, 20, or 30, referred to as 'total_nets'). The analysis used pooled data from both experiments, based on complete hauls, ignoring segments. Prior to the analysis, the species abundance matrix was transformed using the Hellinger transformation (Gotelli et al., 2013), and species occurring only once per haul were excluded. The influence of collinearity was tested using variance inflation factors and all significance tests (analysis, main terms, and axis) were carried out using 10,000 permutations (vif.cca function). The R^2 value was estimated using RsquareAdj function, and the significance of the model, axes and terms, was evaluated using the anova.cca function.

Community composition differences were analysed using the adonis2 function (PERMANOVA), with 10,000 permutations. Post-hoc pairwise comparisons were performed using the pairwiseAdonis package (Martinez Arbizu, 2017).

To evaluate whether there were differences in community composition across different depth and gear type combinations ('depth.gear'), a multivariate analysis of variance (PERMANOVA) was done using Bray Curtis dissimilarity distance matrices (Gotelli et al., 2013). Before conducting PERMANOVA, the multivariate homogeneity of group dispersion across 'depth.gear' levels and 'total_nets' was tested using the betadisper function ('vegan' R package), to determine whether the differences observed were not due to different dispersions. Changes in community composition were tested using adonis2 function (PERMANOVA), with 10,000 permutations. Post-hoc pairwise comparisons were done using the pairwiseAdonis R package (Martinez Arbizu, 2017).

2.4. Indicator species

Indicator species are those used as ecological indicators of community or habitat types, environmental conditions, or changes in the environment. This method was applied to identify the key species to discriminate groups based on their relative abundance (De Cáceres et al., 2012, 2010; Dufrêne and Legendre, 1997). This analysis aimed to confirm which species were most strongly associated with each gear type, depth level, or the total number of nets (only for E2_INA experiment), using 10,000 permutations.

2.5. Effect of panel length and nets set up (continuous vs. separated)

To evaluate the effect of the number of sampled segments (sampling unit) relative to the total number of nets, species data was progressively pooled for the first 10, 20, and 30 nets segments. The diversity and abundance indices were then recalculated using the pooled species data and plotted accordingly, along with their respective bootstrap 95 % confidence intervals (95 % CI).

2.6. Changes in abundance, biomass, and diversity indices

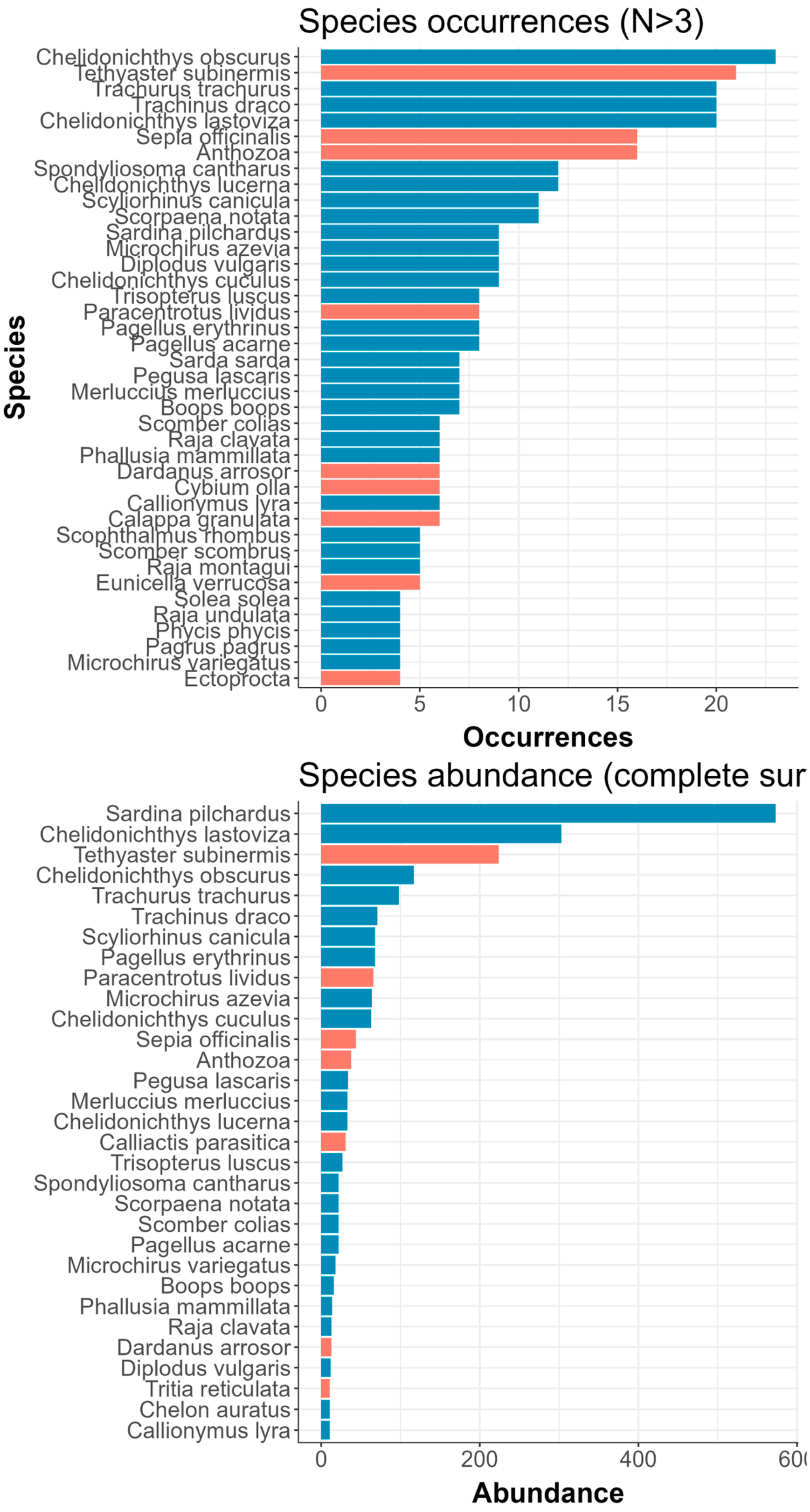
To assess the effect of the number of nets sampled, three sets of Generalized Linear Models (GLMs) were done, each considering a different number of nets per haul: (i) 10 nets, (ii) 20 nets, and (iii) 30 nets (species data accumulated for each haul). A fourth model was developed with an increased number of replicates, where each 10-net segment was treated as a sampling unit (10+) (i.e. each 30 nets haul would have 3 pseudo-replicates). Finally, a fifth set of GLMs was performed considering only full hauls. For each set, four models were developed, one for each index: nind, S, H, and PIE.

As both nind and S are count data (number of specimens and species, respectively), a Poisson distribution was used initially, in the GLM. However, due to overdispersion (check.dispersion function) in the total abundance model (nind), a negative binomial family was used instead. For PIE, a 0–1 index, a Beta error distribution was used (betareg, Cribari-Neto and Zeileis, 2010). In all cases, the appropriateness of the selected distributions was validated using the 'check_distribution' function (package performance, Lüdecke et al., 2021) and the residuals were examined using check_model.

Post-hoc comparisons of means were conducted using the emmeans package (Lenth, 2023), and marginal means for the main effects were estimated with the ggeffects package (Lüdecke, 2018).

All statistical analyses and visualizations were performed using R software (R Core Team, 2024).

For the first four models, the analysis began with a full model including all factors and the interaction between gear type and depth (equation: $y \sim depth*gear + exp + total\_nets$). For the fifth, the initial full model included all interactions with gear (equation: $y \sim (depth + exp + total\_nets) * gear$). Model selection was done using Akaike Information Criterion (AIC) and likelihood ratio tests ('compare_models' function and lrtest). The final best model was chosen for each case, with results summarised and interpreted accordingly. Prior to modelling, homogeneity of variances between groups was tested using Levene' test. In cases where multiple factors were significant in the fifth final models, both partial η2 (eta squared) (package effectsize, Ben-Shachar et al., 2020) and a model with only one main effect were used to find out the relative importance of each factor. Post-hoc comparisons of means were done using the emmeans package (Lenth, 2023), and predicted marginal



Species occurrences (N>3)

Species abundance (complete sur

Fig. 3. Occurrence (number hauls in which the species occurred) and abundance (number of specimens captured) of species sampled during the surveys. Left panel, shows only species occurring more than 3 times; right panel shows species with more than 10 individuals. Blue bars indicate vertebrates and pink bars, invertebrates.

means for the main effects were estimated using the ggeffects package (Lüdecke, 2018).

All statistical analyses and plots were performed using R software (R Core Team, 2024).

3. Results

Ninety-two taxa were identified in the two experiments, 33 invertebrates and 59 vertebrates, clearly dominated by fish species, belonging to 61 families (sup. 1Fig. 3). From these, only 50 taxa (54 %)

Table 1

Taxa names, abbreviations (code), total occurrences (Occ.), abundance (Abun), biomass (Biom), gear (T: T100 and E: E80), depth (10, 20 and 30 m depth) and experiment (Exp; 1: E1_CNA and 2: E2_INA) where each taxa was registered. 'Ind dep.gear' shows the factor level for which the species was found to be an indicator taxa, and 'Ind all' shows the results of the indicator species analysis for depth and gear separately. Occ stands for occurrence, i.e. number of hauls where the species occurred, abun stands for the number of individuals captured and Biom, for the weight. Taxa within the official landing statistics are presented in bold. Taxa within the Portuguese MSFD Descriptor 3 (D3) assessment list in 2020 are underlined.

Taxa name	code	Occ	Abun	Biom	Gear	Depth	Exp	Ind dep.gear	Ind all
Invertebrates									
Anthozoa	Anth	16	38		T, E	50, 30, 10	1, 2		
Calappa granulata	Cal.gra	6	10	998	T	50, 30	1, 2		T
Cybium olla	Cyb.oll	6	7	2593	T, E	50, 30	1, 2		
Dardanus arrosor	Dar.arr	6	13	1148	T, E	50, 30	1, 2	50 T	50
Echinocardium cordatum	Ech.cor	2	2	582	T	30	2		
Ectoprocta	Ecto	4	6	138	T, E	50, 30	1, 2		
Eunicella verrucosa	Eun.ver	5	8		T, E	30	2		
Holothuria tubulosa	Hol.tub	2	2	358	T, E	30	2		
Holothuroidea	Holo	2	4	925	T, E	30	2		
Homola barbata	Hom.bar	**2**	2	69	T, E	30	2		
Maja brachydactyla	Maj.bra	2	2		T	30	2		
Ophiuroidea	Ophi	2	2	5	T	30	1, 2		
Paracentrotus lividus	Par.liv	8	66	10403	T	50, 30	1, 2	30 T	T
Parastichopus regalis	Par.reg	2	2	649	T	50, 30	1, 2		
Pecten maximus	Pec.max	3	3	249	T	50	1	50 T	50
Phallusia mammillata	Pha.mam	6	14	2961	T, E	50, 30	1, 2		
Sepia officinalis	Sep.off	16	44	36372	T, E	50, 30, 10	1, 2	10 T,30 T,50 T	T
Tethyaster subinermis	Tet.sub	21	224		T, E	50, 30, 10	1, 2	30 T,50E,50 T	30,50 T
Vertebrates									
Balistes capriscus	Bal.cap	2	3	3102	T	10	1	10 T	
Boops boops	Boo.boo	7	16		E, T	50, 10, 30	1, 2	10 T	
Callionymus lyra	Cal.lyr	6	11	854	T, E	50, 30	1, 2		
Chelon auratus	Che.aur	2	11	5674	E	10	1	10E	
Chelidonichthys cuculus	Che.cuc	9	63		T, E	50, 30	1, 2	50E,50 T	50
Chelidonichthys lastoviza	Che.las	20	303		T, E	50, 30	1, 2	30 T,50E,50 T	50
Chelidonichthys lucerna	Che.luc	12	33		E, T	50, 30, 10	1, 2		
Chelidonichthys obscurus	Che.obs	23	117		T, E	50, 30, 10	1, 2		30,50
Citharus linguatula	Cit.lin	**2**	2	178	E	30, 10	1		
Diplodus vulgaris	Dip.vul	9	12	1842	E, T	50, 30	1, 2	30E,50E	E
Merluccius merluccius	Mer.mer	**7**	33		T, E	50, 10, 30	1, 2		
Microchirus azevia	Mic.aze	9	64		T, E	50, 30	1, 2		
Micromesistius poutassou	Mic.pou	2	2	120	T	50	1	50 T	
Microchirus variegatus	Mic.var	4	18		T	50, 30	1, 2	50 T	50
Pagellus acarne	Pag.aca	**8**	22		T, E	50, 30	1, 2	30 T,50 T	T
Pagellus erythrinus	Pag.ery	8	68		T, E	50, 30	1, 2	50E	50 E
Pagrus pagrus	Pag.pag	4	5		E, T	30	1, 2		
Pegusa lascaris	Peg.las	7	34		E, T	50, 30, 10	1, 2	10 T	10
					T, E	50, 30	1, 2		
Phycis phycis	Phy.phy	4	5		T	50, 30	1, 2		
Raja brachyura	Raj.bra	**3**	4		T	50, 30	1		
Raja clavata	Raj.cla	6	13		T, E	50, 30	1, 2		
Raja miraletus	Raj.mir	**3**	6		T, E	50	1		50
Raja montagui	Raj.mon	5	8		T, E	50, 30	1	50 T	50
Raja undulata	Raj.und	**4**	5		T	30, 10	1, 2		
Sardina pilchardus	Sar.pil	**9**	573		T, E	50, 10	1	10E,10 T	10
Sarda sarda	Sar.sar	**7**	7		E, T	50, 10, 30	1, 2	10E,50E	10,50
Scomber colias	Sco.col	6	22		E, T	50, 30, 10	1, 2		10
Scophthalmus maximus	Sco.max	3	3	3166	T	10, 30	1, 2		
Scophthalmus rhombus	Sco.rho	5	7		T	50, 10, 30	1, 2	10 T,50 T	T
Scomber scombrus	Sco.sco	5	5		E	50, 30, 10	1, 2		E
Scorpaena notata	Sco.not	11	22		T, E	50, 30	1, 2		
Scyliorhinus canicula	Scy.can	11	68		T, E	50, 30	1, 2		
Serranus cabrilla	Ser.cab	3	4	341	E	30	1, 2		
Solea solea	Sol.sol	**4**	4	1435	T	50, 30	1, 2		
Spondyliosoma cantharus	Spo.can	12	22		E, T	50, 30, 10	1, 2		E
Synapturichthys kleinii	Syna	3	4	1956	T	30	2		
Trachinus draco	Tra.dra	20	71		T, E	50, 30, 10	1, 2		30,50
Trachurus trachurus	Tra.tra	20	98		T, E	50, 30, 10	1, 2	10E,10 T,30E,50 T	
Trisopterus luscus	Tri.lus	**8**	27		T, E	50, 30	1, 2		
Trigla lyra	Tri.lyr	3	4		T, E	50, 30	1, 2	50 T	
Uranoscopus scaber	Ura.sca	2	2	1079	T	50, 30	1, 2		

have commercial interest and are regularly landed, i.e. can be considered commercial species and 21 are considered in the Data Collection Framework list of species for Portugal (DCF). On the other hand, among the 50 commercial taxa collected, 23 are part of the list of the most valuable fishing resources considered for GES in the MSFD Descriptor 3 (D3) assessment in 2020, representing 50 % of the total number of taxa in that list. Additionally, some of the identified taxa, are very valuable commercial species subject to a high rate of unreported catches (e.g. *Maja brachydactyla*, *Scophthalmus maximus*, and *S. rhombus*).

Overall, trammel nets captured 64 % more taxa than gill nets (E80, 46 taxa, T100, 83 taxa). In terms of invertebrates, 23 taxa were captured only in T100, and only one in E80, whereas for vertebrates, 24 taxa were exclusive of trammel nets and only eight of gillnets (see Table 1 for taxa names). Thus, 61 % of the taxa were exclusive of the gears, showing a substantial complementarity on the species caught.

Thirty six percent of benthic invertebrates caught by both gear types confirmed that these gears were able to sample both demersal and pelagic species. Within the vertebrates, 41 taxa were demersal species, 8 pelagic and 8 benthopelagic.

Hauls at 50 m depth resulted in the capture of 57 taxa, whereas at 30 m deep a total of 42 taxa and at 10 m deep a total of 30 taxa, if only considering data from the first experiment, E1_CNA, for comparability. The number of unique taxa in the second experiment, E2_INA increased slightly with the number of nets, from 10 nets (E80 = 13, T100 = 15), to 20 nets (E80 = 24, T100 = 23) and 30 nets (E80 = 21, T100 = 38). The total biomass caught increased about five times, from 5.62 kg to 26.6 kg, with the number of deployed nets.

3.1. *Community analysis*

3.1.1. *CCA results*

As there was a significant interaction between depth and gear (not shown for brevity), a new variable merging these two factors was used in the RDA (‘depth.gear’). Thus, the final model considering depth.gear and total_nets per haul explained 53 % of the inertia (R2= 23 %, F= 3.515, p <0.001), and both variables were significant (depth.gear: F = 4.267, p < 0.001; total_nets: F = 1.881, p = 0.016, respectively) (Fig. 4). The first RDA axis (33 %, F= 10.886, p <0.001) separated the community sampled at 10 m deep with both gears, from the remaining ones (right side of the plot), sampled at 30 and 50 m depth. The shallower community was characterized by the species *Sardina pilchardus, Trachurus trachurus* and *Pegusa lascaris*. The second axis of the RDA (1 1 %, F = 5.114, p < 0.001) separated the communities associated with hauls performed at 30–50 m depth, caught with the two different gears. Trammel nets (T100) were associated with the species *Paracentrotus lividus, Tethyaster subinermis, Sepia officinalis* and *Pagellus acarne*, whereas gillnets (E80) were associated with the species *Pagellus erythrinus, Scyliorhinus canicula, Chelidonichthys lastoviza* and *Chelidonichthys obscurus*. The number of nets used in each haul (total_nets) was relevant mostly in the third RDA axes (7 %, F = 3. 2 60, p = 0. 017), which separated the hauls that used 10 and 20 nets/haul from the 30 nets/haul deployed at 50 m deep with T100, thus not so important to the community structure as depth and gear (not shown for brevity).

Multivariate dispersion did not differ significantly between depth. gear groups (F = 1.299, p = 0.297) nor between total_nets (F=3.009, p=0.061). Permutational multivariate analysis of variance (permanova) showed that the communities differed significantly between depth.gear groups (F= 3.727, p<0.001) and between total_nets (F= 2.287,

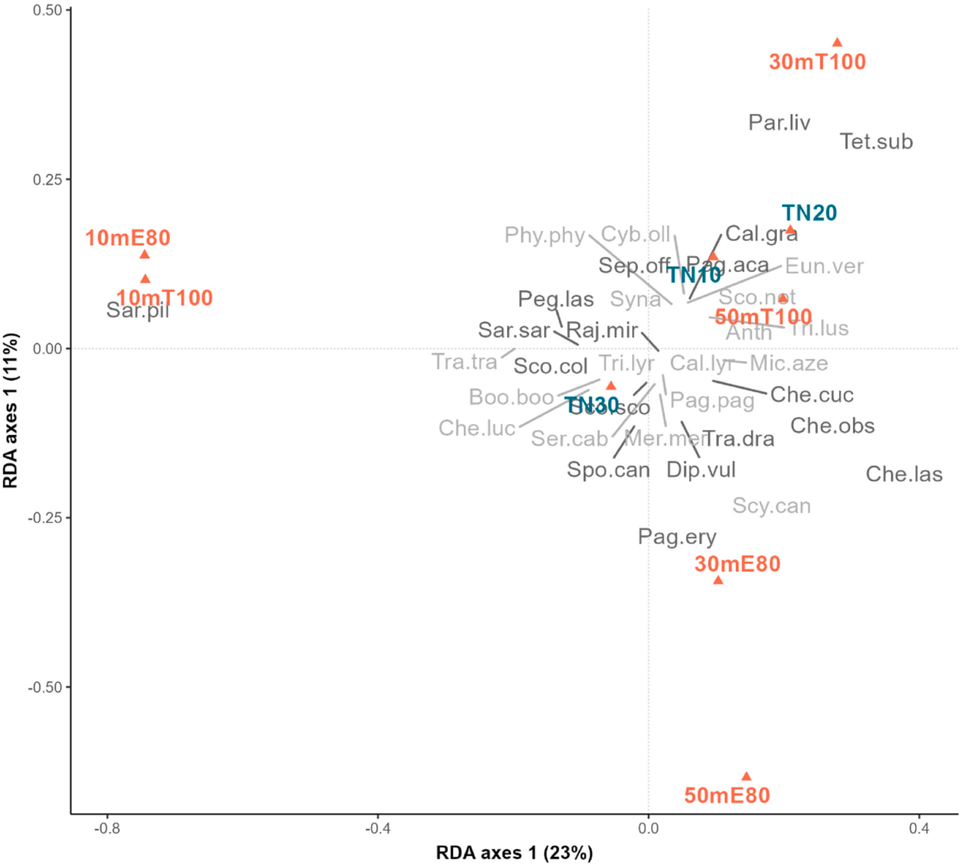


Fig. 4. Community composition in relation to total number of nets (TN10, TN20, or TN30), depth (10 m, 30 m, or 50 m) and gear type (T100 and E80), obtained by the redundancy analysis. Species labels with darker grey indicate these were significant in the indicator species analysis. Species scientific names are present in Table 1.

p=0.001). Pairwise comparisons confirmed that 10 T100 vs 10 E80 communities were similar (F=1.144, p=0.5), as well as 50 T100 vs 30 T100 (F = 1.812, p-value = 0.062) whereas most other groups were different, which is in accordance with the RDA results.

3.1.2. Indicator species

Indicator species analysis showed that *Pegusa lascaris, Sardina pilchardus, Sarda sarda*, and *Scomber colias* were associated with 10 m depth hauls, *Chelidonichthys obscurus, Tethyaster subinermis*, and *Trachinus draco* were significantly associated with 30 m depth, and *Chelidonichthys cuculus, Chelidonichthys lastoviza, Chelidonichthys obscurus, Dardanus arrosor, Microchirus variegatus, Pagellus erythrinus, Pecten maximus, Raja miraletus, Raja montagui, Sarda sarda, Tethyaster subinermis*, and *Trachinus draco* were the species significantly associated only with 50 m hauls. Additionally, *S. sarda* was associated with 10 and 50 m depth, whereas *C. obscurus, T. subinermis,* and *T. draco* were associated with 30 and 50 m depth.

In terms of gear type, the species *D. vulgaris, P. erythrinus, Scomber scombrus,* and *Spondyllosoma cantharus* were significantly associated with E80, whereas *Calappa granulata, Pagellus acarne, Paracentrotus lividus, Scophthalmus rhombus, Sepia officinalis*, and *Tethyaster subinermis* were associated with T100. In terms of the total number of nets, only *Chelidonichthys obscurus* was separated from other species when 20–30 nets were used. No other species characterised any of the other groups, considering only E2_INA experiment for comparability.

3.2. Indices

3.2.1. How many nets are required to sample these communities?

To estimate how the number of nets influenced the abundance and diversity indices, species abundance was pooled by net number – 10, 20, 30 nets, successively – for the E1_CNA and compared with the results from the E2_INA. Overall, the number of individuals captured (nind), species richness (S), and diversity (H) increased slightly with the number of nets used (from 10 to 30), both for the continuous or separated nets arrangement (E1_CNA and E2_INA, respectively), for all gears and depths considered, whereas evenness (PIE) decreased (Fig. 5). Only minor differences were observed between E1_CNA and E2_INA for the equivalent number of nets, except T100 (trammel nets), which captured more species in the separate nets' arrangement in deeper waters than in the continuous nets' arrangements (Fig. 5).

3.2.2. Effect of net's position within the haul

There was an extensive overlap between the results given by nets segments and no clear pattern was evident in net position, i.e. net 1, 2, or 3 within the haul, which implies that the nets on the outer part fished similarly to the nets in the middle (Fig. 6). Overall, sampling the complete set of 30 nets hauls ('all' label in Fig. 6, data from E1_CNA only), gave slightly higher values for the indices than sampling by 10 nets segments, but also showed higher variability. Of all indices considered, species richness and diversity showed the highest difference between 10 nets segments and complete nets.

3.2.3. Effects of the number of nets on modelling results

The linear models produced with the different number of nets considered as a sampling unit (10, 20, or 30 nets) showed a remarkable consistency on the results, except when only 10 nets were used which were more variable (Table 2, further results of the analysis not shown for brevity).

The total number of individuals caught (nind) only showed significant differences between depths when 20 nets were used, otherwise there was no significant effect of this variable (Table 2). Species richness (S) and H diversity were significantly smaller for hauls located at 10 m depth than at 30 or 50 m and gillnets (E80) captured significantly less species than trammel nets (T100), except when only 10 nets were used (Table 2). Evenness only varied significantly with depth, with communities located at 10 m being more evenly distributed than deeper communities (Table 2).

Notably, whatever the number of nets considered (i.e., 10, 20, or 30 nets), their arrangement (i.e. continuous or independent, variable experiment) or the total number of nets per haul were never significantly impacting abundance or diversity in any of the models produced.

3.2.4. Changes with depth and gear and the number of nets (complete hauls)

The models using all data, i.e. complete hauls, showed that the abundance was related to the number of nets and with the interaction between depth and gear (Table 2, Fig. 7). Hauls with a total of 10 nets fished significantly less individuals than the ones using 30 nets. The results of the significant interaction between depth and gear were due to the differences between gear types found only between hauls at 10 m depth (Fig. 7).

Species richness (S) varied with depth, gear type and total number of nets, showing no significant interaction among these factors (Nagelkerke's R2 = 92). Gear type was the most important factor explaining

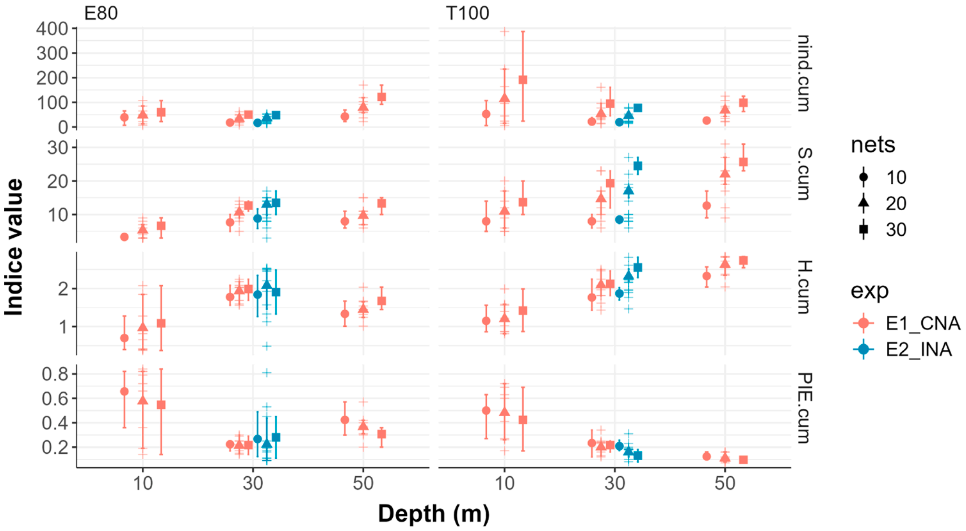


Fig. 5. Abundance and diversity indices (rows) estimated for the cumulative community sampled using 10, 20, and 30 nets in a continuous nets' arrangement (E1_CNA) and for the independent nets' arrangement (E2_INA) (exp), using trammel nets (T100) and gillnets (E80), at 10, 30, and 50 m depth.

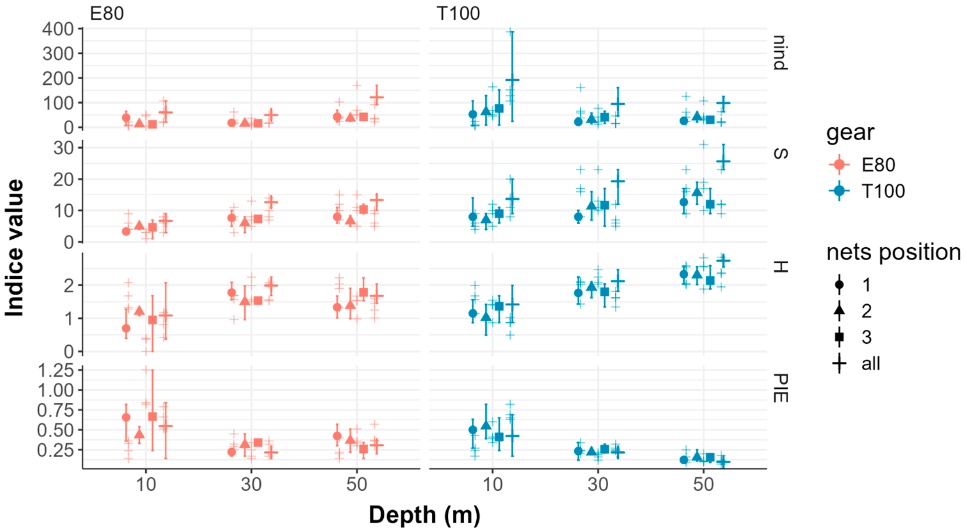


Fig. 6. Abundance and diversity indices (rows) estimated for each sampling unit (1, 2 or 3) and all these within each haul. One indicates the first 10 nets, 2 indicates the second 10 nets (i.e., 10–20) and 3, the third 10 nets in each haul. Hauls sampled using trammel nets (T100) and gillnets (E80), at 10, 30, and 50 m depth (plots columns).

Table 2
Summary of the five sets of GLMs produced, showing the significant main effects and results of the post-hoc comparisons. In each case, the significant effects are shown with + and not significant ones (p>0.05) are represented with -. The R2 is the one estimated for the final model. Nind represents the total number of individuals caught. In all cases where depth has '+', 10 m was different from 30 or 50 m depth (represented as '!='). In all cases where gear has a '+', T100 showed significantly different values from E80.

Y variable	Nº of nets	Depth	Gear	Interaction	Total_nets	R^2
nind	10	-	-	-	-	-
	20	10!= 30	-	-	-	36
	30	-	-	-	-	-
	10+	-	-	-	-	
	10,20,30	+	+	10 E80–10 T100; 30 E80–10 T100	10 != 30	
S	10	10!= 50	-	-	-	32
	20	10 != 30,50	T100!= E80	-	-	84
	30	10 != 30,50	T100!= E80	-	-	93
	10+	10 != 30,50	T100!= E80	-	-	58
	10,20,30	10 != 30,50	T100!= E80	-	10 != 20,30	92
H	10	10 != 30,50	-	-	-	32
	20	10 != 30,50	T100!= E80	-	-	56
	30	10 != 30,50	T100!= E80		-	54
	10+	10 != 30,50	T100!= E80	-	-	42
	10,20,30	10 != 30,50	T100!= E80	-	-	47
PIE	10	10 != 30,50	-	-	-	37
	20	10 != 30,50	-	-	-	42
	30	10 != 30,50	-	-	-	32
	10+	10 != 30,50	T100!= E80	-	-	40
	10,20,30	10 != 30,50	-		-	35

species richness (partial η2 = 0.46, R2=60 %), with T100 capturing more species than E80 (Fig. 7 and Table 2). The second most important factor was depth (partial η2 = 0.38, R2=48 %), with hauls carried out at 10 m catching significantly less species than those carried out at 30 or 50 m. The least important factor was the total number of nets per haul (partial η2 = 0.35, R2=43 %), with hauls using 10 nets catching significantly less species than hauls using 20 or 30 nets

Species diversity (H) final model only included depth and gear type, with no interaction (Fig. 7 and Table 2). Diversity increased with depth, with only 10 m hauls showing significantly less diversity than 30 and 50 m deep hauls, and T100 capturing higher diversity than E80. Depth was more important than the gear used (η2 depth = 0.41 R2=36 %, gear = 0.18 R2=11 %) for species diversity, unlike for species richness.

Evenness, measured as the probability of interspecific encounter (PIE) only varied significantly with depth (R2 = 35 %), with the species captured at 10 m being more evenly distributed than the ones captured at 30 or 50 m depth (Fig. 7 and Table 2).

4. Discussion

4.1. Number of species and depth

In the current study, 92 different taxa were identified, most of which to species level, in 30 hauls, which is a reduced sampling effort (including both fish and invertebrates). Forty-six taxa were captured using gillnets and 83, using trammel nets, which is within the limits reported in previous studies, for the area. This shows that this method would be valid for monitoring, as the number of taxa caught is high even with little effort. Stergiou et al. (2006) reported 32–49 species caught on average in the Basque country, 37–62 in the Algarve, 26–36 in the Gulf of Cádiz, captured at 10–30 m depth, and 18–43 species in the Cyclades, using trammel nets between 1999 and 2000. Fonseca et al. (2005) captured 88 species during the 2 years of surveys in Setúbal and Lisbon areas, using gillnets, deployed up to 100 m depth. Sousa et el. (2018) reported 72 distinct species caught with 183 trammel net sets, sampled during five years, in Costa Vicentina, a locality nearby the present study area. Batista et al. (2009) reported 112 taxa in a 136 trammel nets set, targeting soles and cuttlefish mostly, during one year in Setúbal region, which is the same area of our study.

Sousa et al. (2018) sampled the Arrábida area (West Portugal) with trammel nets and found that depth <19 m was the primary driver of the species abundance and biomass. Although these authors considered that

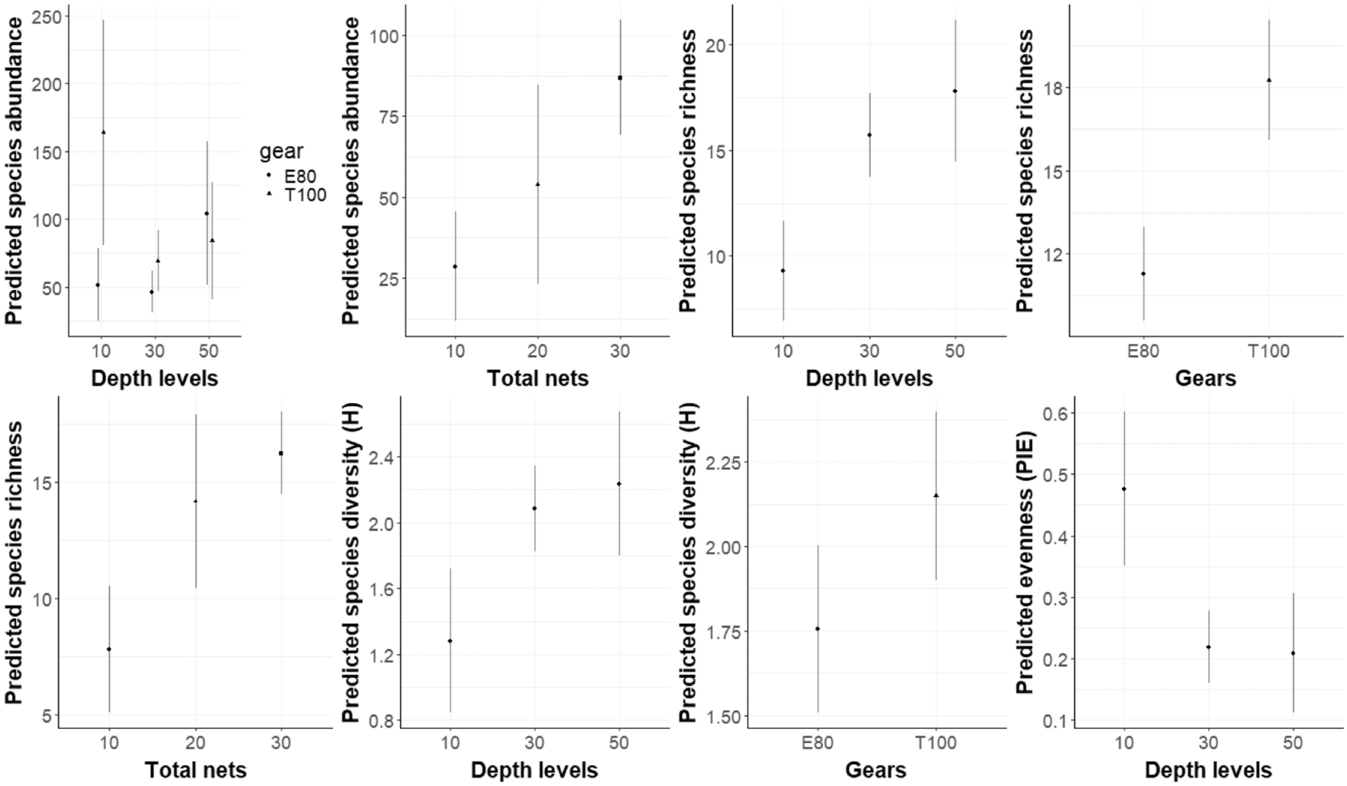


Fig. 7. General linear model predictions (ggaverage function), for each level of the significant main effects in each model (fifth set of models, using complete hauls only).

this difference is due to substrate type being sandy or muddy, and not directly with depth. In the present study, we also observed a change between the communities at 10 m and 30/50 m, with the latter ones being similar in terms of diversity (H), and although the substrate was not sampled, the maps available for the area showed that it was similar (EUNIS). Future work should include a proper characterization of the substrate in each sampling station (e.g. granulometry) along with other environmental variables (e.g. portable CTD), to better characterise the communities living in each habitat.

4.2. *Differences between gears*

Several previous studies have compared trammel and gillnets, mostly in the context of fisheries and not focusing on regular monitoring. Acosta (1997) concluded that gillnets, besides capturing more species, also showed lower variability. Karakulak and Erk (2008) and Fabi et al. (2002) observed that trammel nets showed lower selectivity and higher catch efficiency than gillnets and considered that this could be related to the additional trammelling mechanism. Gray et al. (2005) in spite of having found no difference between catch composition of gill or trammel nets when sampling community assemblages (30 m long panels), concluded that gill nets would be better suitable for monitoring in face of the respective estimates for catch per unit effort (CPUE) being more precise. In Cyprus, gillnets were found to be way more selective than trammel nets, although trammel nets showed higher diversity of species captured in part due to being more frequently used in the study area (Papageorgiou and Moutopoulos, 2023). However, this was not the case of the current work, where the number of nets sets for each gear was the same. Lucchetti et al. (2020) reviewing 26 studies carried out on nets selectivity in the Mediterranean, mentioned that trammel nets are usually considered less selective than gillnets due to their capture method. In the current work, we also found that trammel nets caught a larger diversity of species than gillnets, in particular in deeper hauls (interaction with depth). In summary, although results from other studies can be contradictory, it is known that catches may depend on many other aspects. Nevertheless, it is consensual that the species caught and targeted by each net type are different, thus both should be used for monitoring, simultaneously. Furthermore, although trammel nets are in general less selective (i.e. more suitable to sample diversity), gillnets have been reported to provide more accurate estimates of species biomass, thus requiring less replicates (Gray et al., 2005).

4.3. *Soaking time*

Another important aspect that impacts the diversity of species sampled by each gear is the soaking time. In the current study, trammel nets were left soaking for 6 times longer than gillnets, i.e. ∼24 h, unlike E80 which soaked only during ∼4 h, like traditional fisherman on the area do, thus, considering diversity per hour, T100 would have been more selective than E80. Although it is known to be an important variable, we did not address soaking time on our experimental set up, but rather followed fishers and scientists' expertise. Furthermore, if nets need to be left soaking for more than 4 h it is more operational to retrieve these in the following day (24 h), when the vessels leaves the port for setting different nets in other fishing locations. Borges et al. (2001) reported poor condition of the catch if nets were left soaking for periods of up to 12 h and Acosta (1994) showed that higher soak times do not represent higher diversity or efficiency as the proportion of dead fish and the degree of damage increases with increasing soak time. However, Batista et al. (2009) found that fishers from Sesimbra, a nearby area, left their nets at sea more than 48 h, although Castro et al. (2021) reported that most of the times when the nets were left for larger periods, it was due to severe weather conditions, like when the vessels could not leave the port. In fisheries monitoring surveys, as it is the objective of the current work, the fishing effort is generally reduced as compared to commercial fisheries. For example, in bivalve dredges monitoring surveys, hauls last for 10 min, whereas in the commercial activities, fishers might dredge during more than one hour, as the objective of the former is to sample and not to capture larger quantities. Thus the soak time used in the present work, which was similar to the one used in Sousa et al., (2018), for example, appears to be an excellent compromise and fully operational for future surveys. Nevertheless, this aspect should be further addressed in the future.

4.4. *Mesh size*

Nets efficiency also varies with mesh size, hanging ratio and twine thickness (Grati et al., 2015, and refs. therein; Lucchetti et al., 2020). Fabi et al. (2002) tested the effect of different mesh sizes (45, 70 and 90 mm) on trammel and gill net selectivity in the Adriatic and Ligurian Sea and concluded that 45 mm mesh size would be the most appropriate. Karakulak and Erk (2008) also tested different mesh sizes (16, 18, 20 and 22 mm) using the two gear types in the Aegean Sea (Turkey). Erzini et al. (2003) assessed gillnets' selectivity in the Algarve (South of Portugal) using 25, 30, 35, and 40 mm mesh sizes (bar length). Fonseca et al. (2005) compared gillnet selectivity in West Portugal (1994–1995), between 40 and 90 mm mesh sizes (stretched length) and made a summary review table with selectivity from previous works. Finally, Erzini et al. (2006) summarised several studies of size selectivity in South EU SSF. However, there is no further reference to species diversity in most of these studies, which were focused on selectivity. Thus, although we used a commercial mesh size in the current work for simplicity, using a smaller mesh size is also an aspect to consider in the future, especially if the objective is to sample juveniles for estimate recruitment, as it is often done in most monitoring surveys, where the mesh size is smaller than the ones commercially used.

4.5. *Cumulative effect of the number of nets*

In most works, the number of panels is addressed as nets length. Papageorgiou and Moutopoulos (2023) concluded that net length and soaking time, followed by gear type and seasonality, were the most important factors for nets discards in Cyprus, whereas latitude, longitude, depth, wind state, cloud coverage, season, moon visibility, moon phase and mesh size were not as important, using 20 + 81 gillnets (net length 1380 m, soak time 14 h or if monofilament, 2027 m 2 h soak time) and 88 trammel nets (2031 m length, soak time 7 h). Similarly, in the current work we also found net length to be a key factor shaping the diversity of catches, but less than depth or gear. The larger the number of nets used, the greater the number of individuals, richness, and diversity. However, within the number of nets considered (10, 20 or 30 nets), we did not observe a plateau on richness being reached. Thus, it would be important to consider the use of a greater number of nets in future trials).

4.6. *Position of the sampling unit within the haul*

The position of the nets within the haul did not show any clear pattern in the results, meaning that the beginning, the middle and end of the haul showed similar catches. This also implies that this type of data can be studied using 10 net segments, provided that they are properly addressed in future statistical analyses, that is, treating sampling units as nested within the hauls. However, we found some evidence that the sampling unit should be longer than 10 nets, as it appears to be insufficient to properly sample the communities. To the authors' best knowledge, this subject has not been addressed in previous works.

4.7. *Differences between the number of nets used: net length*

We found a remarkable similarity in the ability to detect the main significant effects, independently of the number of nets considered as sampling unit (10, 20 and 30) and the number of replicates (i.e. 10 and 10+ models). However, if considering only 10 nets as sampling unit, differences between gears were only detected by increasing the number of replicates in the analysis (10+). Nevertheless, in the current work, these were not treated as proper pseudo-replicates to make the models comparable and simpler, which may also affect the significance level observed. Further, the models using all data showed that hauls with a total of 10 nets fished significantly less individuals than the ones using 30 nets. This difference, however, could have been triggered by the unbalanced sampling design used.

4.8. *Final remarks*

Long-term monitoring is required to improve our understanding of sensitive and stressed environments and to effectively manage the marine space and reach fisheries sustainability (Batista et al., 2014). The use of minimal impact but efficient sampling gears in monitoring is advantageous for a plethora of reasons. Gillnets and trammel nets yielded 30 % more species than visual counts (Acosta, 1997), and do not have the environmental impact of trawls or dredges, which could be alternatives. Coleman et al. (2013) were able to address the physical impact of passive gears and found no ecological effect on the benthic communities and Blyth et al. (2004) observed that the diversity of these communities and the biomass of structural fauna were higher in the areas where only static gears (and not towed gears) were permitted. Additionally, Priester et al. (2021) conclude that trammel nets combine low size and low species-selectivity with a limited impact on benthos and a moderate mortality of the extracted fish, making the method suitable for the monitoring of entire assemblages where non-extractive techniques are ineffective. Known ecological issues related with the fishing gear per se, like for example, ghost fishing from lost gears (Erzini et al., 1997; Santos et al., 2003) can be sorted using, for example, electronic tags (Syversen and Vollstad, 2023) which can be tested for their operationality during the surveys. Based on the work developed, we suggest that monitoring programs using set nets should include both gill and trammel nets. Another advantage of using nets is the ability to deploy in different types of substrates, although this was out of the scope of the current work. Future studies should address other regions, seasons and depth levels, and perhaps complement the sampling with bivalve dredge to get a picture of the benthic invertebrate fauna also. This work could also be improved with a larger number of replicates and nets with more panels.

Monitoring programs are essential to manage the ecosystem and reassure the sustainability of the resources. Small-scale fisheries (SSF) are known to have a large quantity of unreported landings. For example, Mettling et al. (1995) estimated that 40 % of French SSF catches were unreported and Batista et al. (2009) considered that this percentage is not lower in Portugal. In this sense, long-term monitoring becomes the alternative to preserve the stocks and the ecosystems.

5. Conclusions

In the present work, an experimental study was carried out to further develop a sampling design for a coastal biodiversity monitoring survey on soft sediment bottoms. Although some of the species caught are also regularly taken in IBTS demersal surveys (e.g. *P. acarne, B. boops, S. cantharus*; Moura et al., 2020), fishing hauls held at depths smaller than 50 m are reduced in those surveys. Thus, this experiment showed that set nets have the potential to be used as a monitoring fishing gear both for biodiversity evaluation and for the assessment of fishing resources relevant for the Common Fisheries Policy and the MSFD, including species of commercial and non-commercial interest. We concluded that both trammel and gillnets should be used in monitoring, as both gears catch a distinct set of species, including demersal and pelagic taxa. Trammel nets (T100) caught a larger number of species then gillnets (E80). The gear was the most important factor in terms of the number of species, but depth was more relevant in shaping diversity. There was evidence of an interaction between depth and gear in terms of abundance and at the community level, with gear being the most important factor separating the communities in deeper waters, 30 and 50 m hauls, than at 10 m depth. Nevertheless, depth and gear were almost always important, both at the community level (RDA results) and in terms of abundance and diversity indices. Overall, the number of species and diversity increased with depth, but only differed significantly between hauls done at 10 m and the ones done at 30 and 50 m depth. The opposite pattern was observed in terms of evenness (PIE), with communities at 10 m depth being more evenly distributed, but no difference was observed in relation to the gear used. In face of these results, future work should evaluate the possibility of sampling at 20 m depth, instead of 30 m, as this latter one appeared to be more similar to the communities found at 50 m. Shallower depths can be more variable also due to the proximity of the depth of closure (5–17 m), which represents the point beyond which the beach profile experiences minimal morphological changes.

We further found that both panel position, i.e. left, middle or right within the haul, and the number of total nets, e.g. making a haul with 30 nets and only using 10 nets segments, had no major impact on the diversity and abundance sampled. Similarly, there was no evident effect of the nets arrangement, with similar results when using two sets of 10 nets separated (independent arrangement) or together (continuous arrangement). However, the number of nets used as sampling unit did have an impact in most of the aspects evaluated. The way species total abundance and diversity varied with depth and gear was similar, whether 20 or 30 nets were used, but more variable when only 10 nets were sampled, even if increasing the number of replicates.

Monitoring programs are essential to manage the ecosystem and reassure the sustainability of the resources. In the present study, alternative methods to the traditional bottom trawls were tested and discussed for future monitoring of coastal areas, particularly gillnets and trammel nets. Fishing trials showed that depth and gear type were the key factors shaping community composition, diversity, and species abundance. Species number and diversity increased with depth, especially between 10 m and 30–50 m. The gear type influenced species richness, with trammel nets catching more species than gillnets. However, panel position and the number of nets used did not affect the diversity or abundance. Net arrangement also showed no impact, but the number of nets used as sampling units mattered. Results were more consistent with 20 or 30 nets compared to 10 nets. Thus, the conclusion was that both trammel and gillnets should be used complimentary for monitoring, as these gears captured a different set of species. A minimum of 20 nets (ideally 30+) is recommended for effective monitoring, with replication in each station. This system is minimally invasive, deployable by commercial vessels, and effective for coastal monitoring surveys.

CRediT authorship contribution statement

Ana Moreno: Writing – review & editing, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization. **Marta Mega Rufino:** Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Catarina Maia:** Writing – review & editing, Investigation, Conceptualization. **Bárbara Serra-Pereira:** Writing – review & editing, Methodology, Investigation. **Miguel B. Gaspar:** Writing – review & editing, Methodology, Funding acquisition. **Rogélia Martins:** Writing – review & editing, Investigation. **Ivone Figueiredo:** Methodology, Funding acquisition. **Pedro Gomes:** Writing – review & editing, Investigation. **Ivania Quaresma:** Writing – review & editing, Investigation. **Teresa Moura:** Writing – review & editing, Investigation. **David Dinis:** Investigation, Conceptualization. **Inês Farias:** Writing – review & editing, Investigation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

The data that has been used is confidential.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.fishres.2024.107202.

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