Mapping of marine key habitats and assessing their vulnerability to fishing activities

in Cape Greco MPA, Cyprus

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Identification, quantification spatial
and **temporal distribution** of **commercial**
and **recreational fishing activities**
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1 INTRODUCTION

Coastal environments are under increasing pressure by a wide variety of impacts, originating from human activities and/or environmental variability. The main problem in disentangling the impact from the above-mentioned factors is the lack of baseline information to evaluate massive alterations (Dayton *et al.*, 2000). Despite the enforced European Union legislations, people in the southern Mediterranean countries are not aware of the status of endangered marine species. In recent years, the activities and interactions of small-scale fishery with fish resources and socio-economic issues were extensively studied in Western Mediterranean.

However, such information were lacking from the Eastern part of the Mediterranean basin (Tzanatos *et al.*, 2006; Roditi *et al.*, 2020) and especially from Levantine waters. The scarcity of the observations, the deficiencies in the poor monitoring by official authorities and the low economic value of bivalve catches make the use of non-conventional information such as Fishermen' Ecological Knowledge (FEK) as alternative sources of information when conventional data are not available. Despite its potential bias, FEK has been applied to supplement and validate the scientific knowledge in order to assess long-term changes in marine fisheries resources (i.e., Thurstan *et al.*, 2016).

In the present study, FEK information was implemented in parallel with historical information found in old archives, grey literature and official reported data. Such an integration and analysis of multidisciplinary information facilitates the definition of more pristine reference points and thus, the implementation of sustainable management (Sáenz-Arroyo *et al.*, 2005).

This mixture of methods has successfully contributed: (a) to a better understanding of the ecosystem baselines (Sáenz-Arroyo *et al.*, 2005), (b) to identify changes in exploited fish species biodiversity (Thaman *et al.*, 2017), and (c) to determine the effects of socio-ecological interactions on fisheries (Gonzalvo *et al.*, 2015).

To that end, a series of interviews were conducted to gain the fishermen's (i.e. professional and recreational) as well as fishery stakeholders' insights from problems raised in fisheries and changes in ecosystem status, and to identify the main management needs in Cape Greco.

In addition, these initiatives were promoted to increase marine conservation awareness in fishermen, by inviting them to reflect on issues that traditionally have been largely ignored by their community, and to gain their collaboration and support to promote adequate ecosystem-based management measures for the conservation of increasingly fragile coastal ecosystems, such as Cape Greco.

2
MATERIALS AND METHODS

2.1. Interview surveys

The on-the-spot interview survey was conducted between June and July 2020 targeting the local professional and recreational fishers operating at Cape Greco as well as the stakeholders working in fisheries sector of the area. Contact details of the licensed professional fishers were provided by the local fishery associations and the Department of Marine Fisheries and Marine Research (DFMR) which, is responsible for issuing the fishing licences. Although fishers were selected randomly, an attempt was made to include the participation of fishermen from different age groups. Prior to conducting private interviews, informative talks were given at the local fishermen associations to call for the collaboration of their members. Efforts were made to interview all the licensed professional fishers and the spotted illegal ones. Before starting the interview, fishers were informed that their participation was optional, and that personal data would remain confidential.

To stimulate fishermen's perceptions and minimize potential bias, all interviews were carried out by the same person, ensuring that questions were presented in an identical manner and freely answered with no prompt or influence. Interviews took place around fishers' mooring/landing sites, frequently on board of their own vessels while they were mending their nets or doing vessel maintenance before/after going out at sea to minimize disruption to their routines. These encounters lasted the minimum necessary, having an average duration of 16 minutes (±10 min.), and were held privately, on one-to-one sessions, to prevent influence or interference by other people. To avoid pseudoreplication, the professional fishers' respondents were exclusively owners of fishing vessels or captains, and no more than one questionnaire per fishing vessel was conducted. Researchers surveyed fishers using a tablet to record their responses and test the practicality of this tool for collecting data during interviews.

To avoid distrust, respondents were approached informally and asked if they were willing to answer a few questions about their fishing. Before any mention to the "delicate issue" of dolphins and depredation a series of pre-defined ice-breaking questions about their personal profile (e.g., age and years of fishing experience, favourite anecdotes) and fishing activity during the previous 12 months were asked. The questionnaire was completed with a final section where fishermen were asked to identify the main conservation priority action for effective management of the area. Given that fishermen use common names for species, and some names differ among communities, fish guides were used to clarify species identifications during the interviews.

3 QUESTIONNAIRE STRUCTURE

To make a customized collection of information aimed at a holistic approach to the problem, three questionnaires were prepared, one distributed to professional fishers, one to recreational fishers, and one to stakeholders of the fisheries sector. The questionnaire for stakeholders was focused, apart from the demographic information of the respondent, on: (a) the general knowledge on the structure and importance of the Marine Protected Area of Cape Greco, (b) identification on the fishing intensity in the area, and (c) determination of the illegal fishery. The questionnaires for the recreational and professional fishers were focused on issues related to (a) demographic features and characteristic of the fishing vessels, (b) general knowledge on the structure and importance of the Marine Protected Area of Cape Greco, (c) fishing operation, métier/typology (species composition per area, target and non-target species), and (d) features and identification of the illegal fishery. The questionnaires were designed to be compatible with those used in socio-economic surveys conducted in other Eastern Mediterranean coastal waters (small-scale fishery in Greek waters: Tzanatos 2006, Gonzalvo *et al.*, 2015), to facilitate comparisons. Official Fisheries data from professional fishery were derived by the fishing monitoring programs (European Data Collection Framework), including data such as fishing vessels per area and season, vessel length, vessel power, days at sea, catches/landings/biomass/sizes etc. With respect to data relating with the patrolling frequency (per month or season), surveillance in the study area is carried out almost whenever there is a marine patrolling and additionally, surveillance of the MPAs is also carried by land on a weekly basis. In addition, no offense was recorded for Cape Greco since the year of its establishment as an MPA (2018). The main reason was the fact that this was a new MPA and authorities dedicated the first year of its establishment to inform and increase awareness of the sea users.

3.1. Interview surveys

Descriptive statistics were applied, providing percentage contribution, mean and standard deviation (SD) values of several resulting parameters and frequency of occurrence (%) was applied to all statements. Comparisons were performed using the Kruskal-Walis non-parametric test. Whenever a significant difference was detected ($P < 0.05$), a Tukey post-hoc pairwise comparison test was used to detect the responsible factors (Zar, 2010). The non-parametric chi-square test ($\chi 2$-test) was used to examine whether there is a possible association and if so the degree of association between several key questions that were set in the three different fisher categories; stakeholders, recreationals and professionals. This test was used, among others (logit relation), because we aimed to describe the strength of a relationship between a categorical variable and demographic features and not to model the determinants of and predict the likelihood of an outcome (Zar, 2010). All statistical analyses were carried out using the statistical package IBM SPSS statistics v 24.0. For the spatial visualization of information, a GIS app was used (QGIS, 2020).

4
RESULTS

4.1. Demographic and generic information

The full structure of the questionnaires is shown in the Appendix. Tables 1 to 3 show the basic profiles of the stakeholders in Cyprus organizations, and the recreational and professional fishers participating to the survey. In total, 40 stakeholders working in fisheries sector, 34 recreational fishers, and 20 professional licensed fishers that operated in Cape Greco were interviewed. Overall, 78 professional fishermen were licensed in four ports around Cape Greco (i.e., Agia Triada, Paralimni, Agia Napa and Potamos Liopetriou) with 11, 18, 24 and 25 licensed active professionals, respectively. Interviews took place in the different fishing ports of Cape Greco (Figure 1). Therefore, more than one quarter (25.6%) of the licensed professional small-scale fishermen were interviewed in the area of Cape Greco, a ratio consistent with similar studies (Tzanatos *et al.*, 2005; Maynou *et al.*, 2011). With respect to the number of licensed recreational fishers across Cyprus they reached 2492 in 2019 for those fishing with vessels and 2343 for those using a speargun.

Apart from stakeholders, in which a small percentage of women participated to the survey, all recreational and professional fishery participants were males. Most of the participants (around 80%) originated from the adjacent big villages (Paralimni and Agia Napa) and cities (Leukosia). The mean age was highest for the professional fishers (51.6 years with SD: 12.1) and lowest for the stakeholder (44.5 years with SD: 11.1) participants, with the age-class of 26-45 being the most abundant in the sample for the recreational fishers (41.2%). In contrast, the middle age-class of 46-65 was the most abundant in the sample both for stakeholders and professional fishers (47.5% and 60.0%, respectively). Although more than half of the stakeholder participants were well-educated (52% with university degree), the highest percentage of the recreational and professional fishers were of low-educational background (> 70% of the basic education level).

Table 1
Basic demographic stakeholder profile of Cape Greco

Details	Stakeholders
Female:Male	15%:85%
Location	Agia Napa (17.5%) Cape Pyla (2.5%) Derinia (7.5%) Green Bay (2.5%) Larnaca (15.0%) Leukosia (20.0%) Ormidia (5.0%) Paralimni (10.0%) Protaras (12.5%) Xylophagou (7.5%)
Average fishermen's age (SD) (years)	44.5 yr (11.5)
Number of fishermen by age categories	18-25 (5.0%) 26-45 (45.0%) 46-65 (47.5%) > 65 (2.5%)

Details	Stakeholders
Education level	Gymnasium (5.0%) Lyceum (40.0%) Student (2.5%) College/University (47.5%) MSc/PhD (5.0%)
Profession	Freelancer (15.0%) Public servant (17.5%) Private employee (65.0%) Student/Military (2.5%)
Occupation with the sea	Fisheries manager (5.0%) Scuba diver (65.0%) Control officer (12.5%) Owner of touristic activities (10.0%) Other (7.5%)

Table 2
Basic demographic profile of the recreational fishers operating in Cape Greco

Details	Recreational
Female/Male	0/100%
Location	Agia Napa (8.8%) Derinia (5.9%) Kakopetria (2.9%) Leukosia (14.7%) Paralimni (50.0%) Patsia (2.9%) Protaras (8.8%) Pseuda (2.9%) Xylophagou (2.9%)
Average fishermen's age (SD) (years)	49.9 yr (16.3)
Number of fishermen by age categories	18-25 (5.9%) 26-45 (41.2%) 46-65 (38.2%) > 65 (14.7%)
Education level	No education (2.9%) Elementary (26.5%) Gymnasium (17.6%) Lyceum (23.5%) College/University (26.5%) MSc/PhD (2.9%)
Profession	Freelancer (20.6%) Public servant (14.7%) Private employee (44.1%) Retirement (5.9%) Household (11.8%) Unemployment (2.9%)
Owner of recreational license	Yes (26.5%)/No (73.5%)

Details	Recreational
Owner of harpoon recreational license	Yes (17.6%)/No (82.4%)
Member of recreational association	Yes (5.9%)/No (94.1%)
Owner of recreational fishing vessel	Yes (26.5%) with mean size of 7.2m (SD=2.8m) and mean HP 93.1 (SD=82.9 HP)/No (73.5%)
Fishing experience (yr)	1-9 (29.4%) 10-19 (11.8%) 20-29 (38.2%) 30-39 (5.9%) 40-49 (8.8%) >50 (5.9%)

Table 3
Basic demographic profile of the professional fishers operating in Cape Greco.

Details	Professional
Female/Male	0/100%
Location	Agia Napa (35.0%) Agia Triada (10.0%) Green Bay (5.0%) Liopetri (20.0%) Protaras (30.0%)
Average fishermen's age (SD) (years)	51.6 yr (12.1)
Number of fishermen by age categories	18-25 (0.0%) 26-45 (25.0%) 46-65 (60.0%) > 65 (15.0%)
Education level	Elementary (45.0%) Gymnasium (15.0%) Lyceum (25.0%) College/University (15.0%)
Profession continuity	Yes (26.7%)/No (73.3%)
Other alternative occupation	Yes (44.4%), touristic activities in summer/No (55.6%)
Dependence on fisheries (% of annual income)	0-19% (23.6%) 20-49% (17.6%) 50-75% (5.9%) 100% (52.9%)
Crue (%)	Yes (70.0%), mostly with 1 to 2 persons (73.3%)/No (30.0%)
Degree of personel relative	Yes (80.0%)/No (20.0%)
Vessel characteristics	Mean size of 9.4m (SD=2.8m) and mean HP 95.1 (SD=94.7 HP)

Details	Professional
Owner of professional license (License Type)	Yes (100.0.%) Type A (70.0%) Type B (10.0%) Type C (5.0%) License for pelagic fisheries (15.0%)
Fishing experience (yr)	1-9 (15.0%) 10-19 (15.0%) 20-29 (35.0%) 30-39 (15.0%) 40-49 (20.0%) >50 (0.0%)

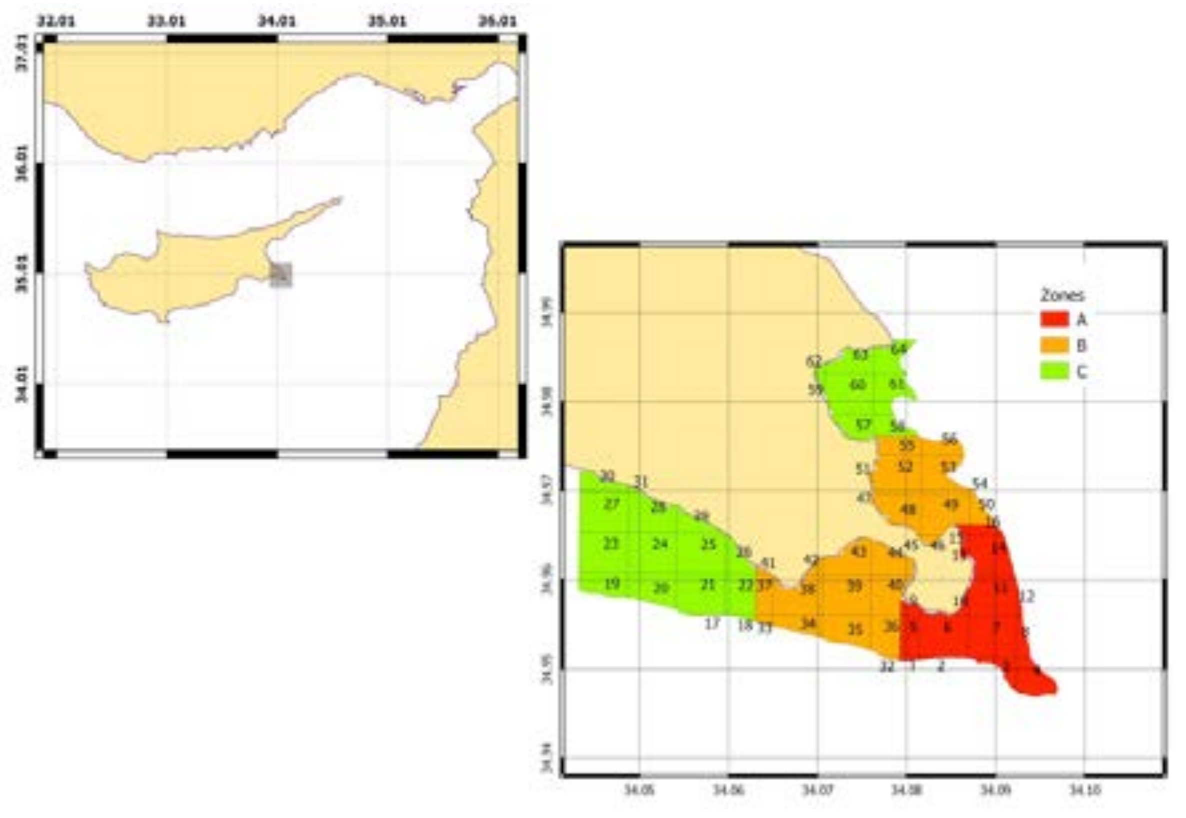

Figure 1

Study area and zones of the Marine Protected Area of Cape Greco. Zone A is prohibited for all fishers, zone B is prohibited only for recreational fishers, and zone C is allowed for all.

The highest percentage of stakeholder visits occurred during the summer according to the statements of the stakeholders (Figure 2). Specifically, 21.3% of the stakeholders reported that they visit the MPA in high frequency (>50%) during the summer, but less intensively during winter.

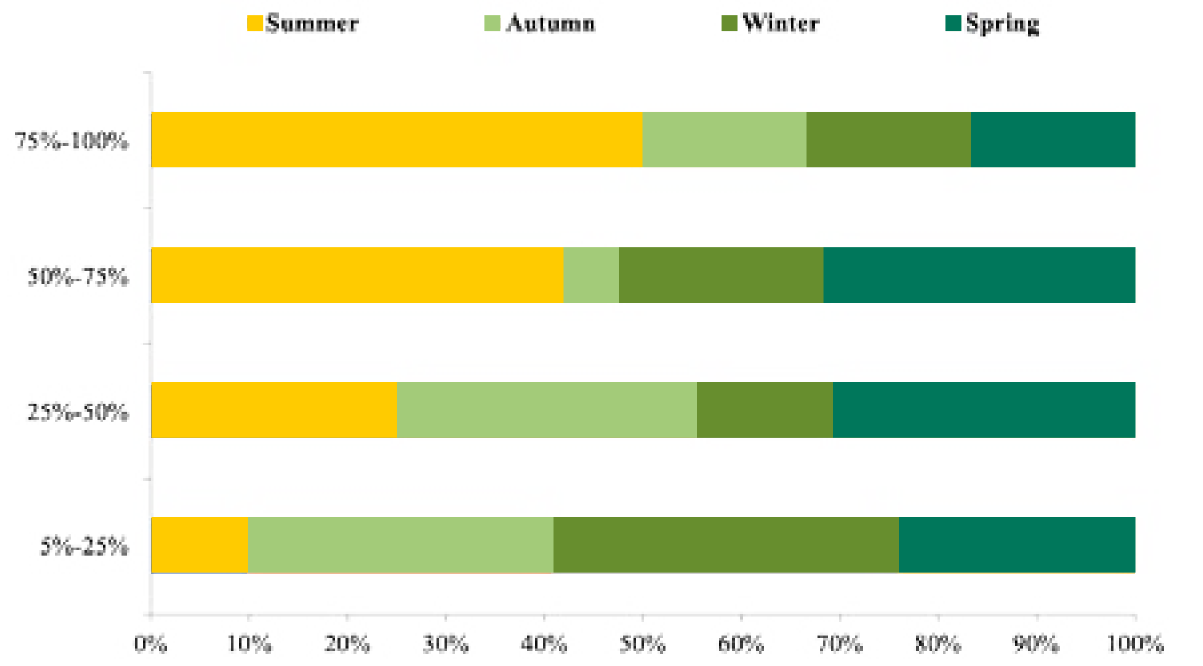

Figure 2

Percentage contribution of the frequency of stakeholder visits in the MPA of Cape Greco.

A high percentage of recreational fishers (> 70%) did not own a recreational license or a fishing vessel. In contrast, 100% of the professional fishers participating to the survey owned a professional fishing license. Specifically, 70% of them owned a Type A license, 10% a Type B, 5% a Type C and 15% owned polyvalent license which usually targets large pelagic fish using surface longline. Half of the recreational and professional fishers had fishing experience between 10 and 29 years and between 20 and 39 years, respectively. More than half of the professional fishers were fully dependent on fisheries with their annual income highly derived from fisheries (more than 50%), whereas the others were mostly occupied in touristic activities, especially during summer.

The characteristics of the fishing vessels of the professional fishers participating to the survey (mean length of 9.4 m, ranging from 6 m to 17 m and with mean engine horsepower of 95.1 HP, ranging from 16 to 380 HP) laid within the values of the corresponding characteristics of the fleet in the adjacent ports (i.e., Agia Triada, Paralimni, Agia Napa and Potamos Liopetriou). According to the data provided from the European Data Collection Framework, professional small-scale fleet in the study area has a mean vessel length of 8.4 m with engine horsepower of 70.3 HP

4.2. Views and perceptions on MPA

The pattern of views of the stakeholders, and recreational and professional fishers on issues related to the structure of the Marine Protected Area in Cape Greco, showed that most of the participants were aware on the presence of the MPA, but most were not aware about the presence of three zones as well as about the differences among these zones in the Cape Greco MPA (Figure 3). It is worth noting that although the highest percentage of the stakeholders and recreational fishers agreed with the establishment of an MPA in the area of Cape Greco, a similar high percentage of the professional fishers was opposed to this statement (Figure 3).

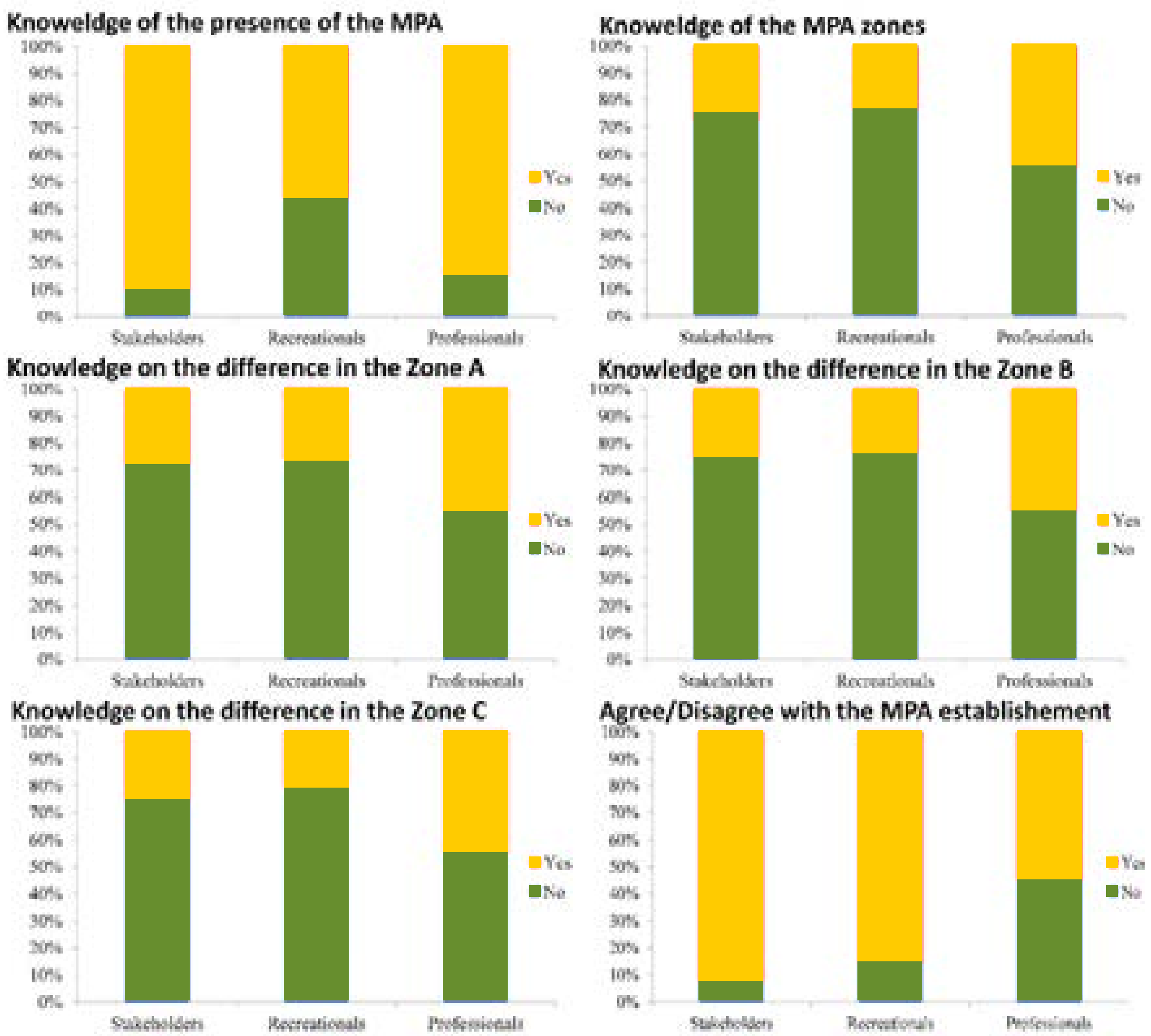

Figure 3

Percentage contribution of the knowledge of stakeholders on the structure and function of the Marine Protected Area in Cape Greco. Zone A = No Take, Zone B = Buffer, Zone C = Wider Area.

A high percentage of stakeholders declared an increase in the number of recreational fishers operating within the MPA after its establishment, but not the same increase of professional fishers (Figure 4). According to the stakeholders, spearfishing, rod line and traps were the fishing gears that have been gradually increasing within the MPA from recreational fishers, whereas the most frequent fishing gears used by the professional fishers within the MPA were the demersal longliners and the netter (gillnet / trammel nets). Despite the low number of stakeholders' responses about the reason for the increasing fishing incidents, some of them stated that probably a higher abundance of fish inhabits the MPA zones and that there is absence in fishing controls. Whereas the fishers declared a decrease in the number of fishers operating within the MPA, but few declared that this is due to Covid-19 incidents.

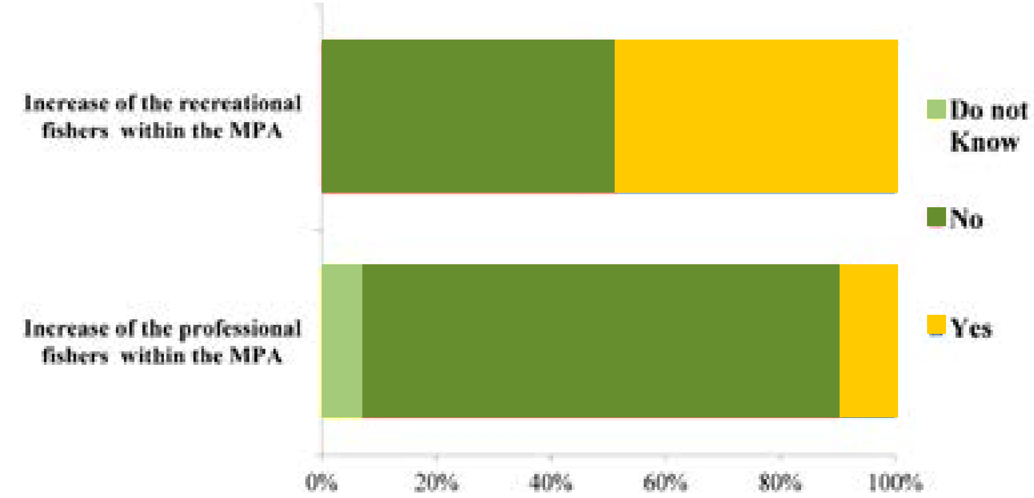

Figure 4

Percentage contribution of stakeholder view on the potential increase on the number of recreational and professional fishers operating within the MPA of Cape Greco.

With respect to general knowledge on the structure and function of the MPA in Cape Greco (Figure 5), the majority of professional fishers (more than 50%; χ^2-test; $P<0.05$) declared their positive view on hypothetic temporal closures or generic prohibition of fishing activities, fishing allowance in specific zones, or allowance to coastal fisheries and/or local resident fishing allowance. Professional fishers were also positive to co-operate with the local port patrol authorities against illegal fishery (Figure 5). Recreational fishers were clearly positive to temporal closures and the co-operation with the port patrol authorities, whereas a low percentage of them were positive to the general prohibition of fisheries, as well as the allowances in the local residents and coastal population (Figure 5). It should be noted that more than half of the professional fishers declared that they have changed their tactics after the establishment of the MPA in Cape Greco, whereas 75% of the recreational fishers stated that they have not changed their fishing tactics (Figure 5).

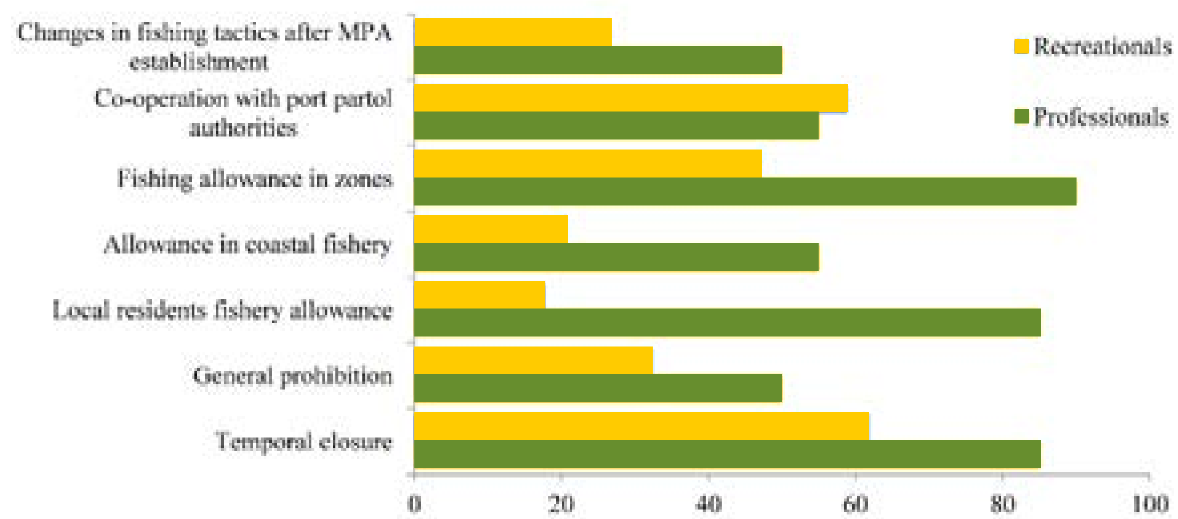

Figure 5

Percentage contribution of the positive responses (YES) on the type of fisheries management measures that were most acceptable from the professional and recreational fishers in Cape Greco.

4.3 Regulated fishery within Cape Greco

Taking into account the data from European Data Collection Framework derived from the fisheries monitoring of the active professional small-scale fishery in 2018 from ports adjacent to the study area (i.e., Agia Triada, Paralimni, Agia Napa, and Potamos Liopetriou), the highest fishing intensity of the professional small-scale fishery was marked in May and August and the lowest during November to December (Figure 6). In contrast, fisheries catches and catch per unit of effort was highest in May and in July (Figure 6), laying around 15000 kg, whereas the lowest values were three times lower and marked during November-December (less than 6000 kg).

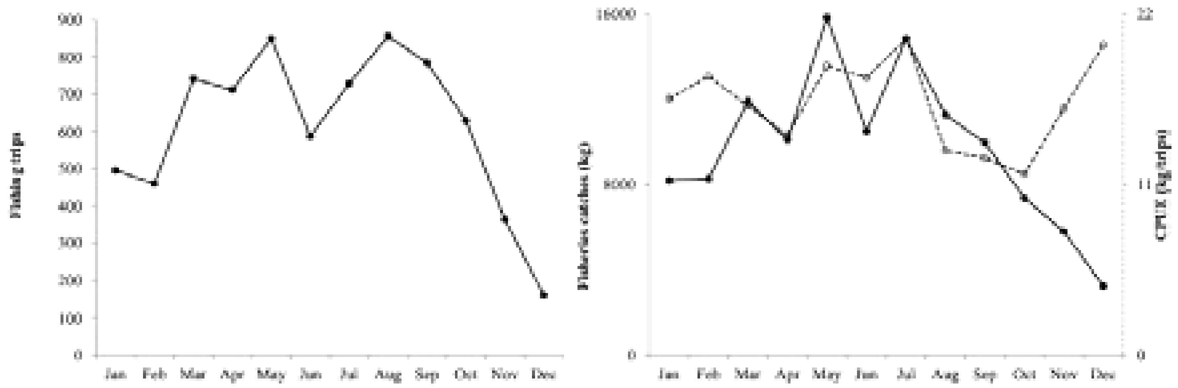

Figure 6

Number of fishing trips (left) and fisheries catches and Catch per Unit of Effort (right) (CPUE: kg/fishing trips) from the 78 professional small-scale vessels originated from ports in close distance to Cape Greco, Agia Triada, Paralimni, Agia Napa, and Potamos Liopetriou. Data taken from European Data Collection Framework for 2018.

According to the DFMR landing data from fishers and market distributors, there was an increase in the mean landings weight from 2017-2019 for all four fishing shelters (32.50% for Agia Napa, 10.39% for Agia Triada, 18.84% for Paralimni, and 38.26% for Potamos Liopetriou). According to the same data, the most widely used technique was trammel nets (69.81%) followed by set gillnets (27.30%), set longlines (2.77), and by minor quantities pots and traps (0.06%) and trolling lines (0.06%). Landings were composed at 75% of the total landings, by low commercial value species (less than 5 euros per kg). Seven taxa contributed more than 75% of the total landings caught in the four fishing shelters; specifically *Lagocephalus* spp. (16.03%), *Spicara maena* (13.16%), Holocentridae (11.70%) and *Sargocentron rubrum* (10.85%), *Boops boops* (9.96%), *Serranus cabrilla* (8.53%), Tetraodontidae (5.42%) and other 91 species (24.34%).

The description and quantification of recreational fishery was based on their statements, because no official authority has monitored this fishery. Species composition with the highest frequency of occurrence of recreational fishers at Cape Greco (Table 4) according to their statements, were *Siganus* spp. (from 32.1% to 53.8%, depending from season) and to a lesser extent *Dicentrarchus labrax* (from 6.3% to 11.4%), *Dentex dentex* and *Seriola dumerili* (each from 5.1% to 8.6%) and *Sparus aurata* (from 3.6% to 9.4%). These five species made up more than 60.7% of the total species catches depending on season according to recreational fishers' statements (Table 4).

Table 4

Seasonal species composition (%) of recreational fishery in Cape Greco. Bold values indicated the two most frequently species stated by the recreational fishers.

Species	Spring	Summer	Autumn	Winter
Coryphaena hippurus	3.1	2.6	2.9	
Dentex spp.	6.3	5.1	8.6	7.1
Dicentrarchus labrax	6.3	**7.7**	**11.4**	**10.7**
Diplodus sargus				3.6
Epinephelus marginatus				3.6
Lagocephalus scelleratus	3.1			
Lithognathus mormyrus	3.1		2.9	
Loligo sp.	3.1	2.6	8.6	7.1
Mugil spp.	6.3			3.6
Pagellus spp.	3.1	2.6	5.7	3.6
Pterois miles	3.1	2.6	2.9	3.6
Sargocentrum rubrum				3.6
Sarpa salpa		2.6		
Sepiotethys lessoniana	3.1			3.6
Seriola dumerili	6.3	5.1	8.6	7.1
***Siganus* spp.**	**34.4**	**53.8**	**40.0**	**32.1**
Sparisoma cretensis	3.1	5.1	2.9	7.1
Sparus aurata	**9.4**	5.1	5.7	3.6
Sphyraena sphyraena	3.1			
Tunids	3.1	5.1		

The quantification of intensity of the recreational fishery revealed that the mean number of fishing days exhibited a significant (Kruskal-Wallis, $P<0.05$) seasonal pattern, with the highest number of fishing days marked during summer (33.3 days with SD: 23.5) and the lowest fluctuated between remaining seasons from 18.5 to 23.5 fishing days (Figure 7). In contrast, fishing hours spent by recreational fishers did not show any significant (Kruskal-Wallis, $P>0.05$) seasonal pattern, and the mean number of fishing hours fluctuated around 3.0 and 4.3 hours per day for all seasons (Figure 7).

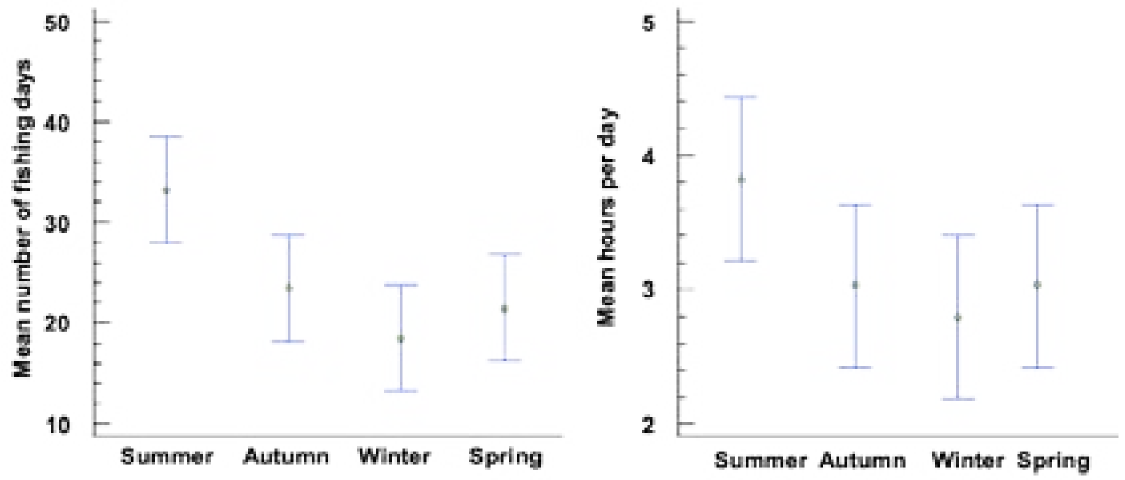

Figure 7

Mean number of fishing days (left) and hours of fishing according to statements of the recreational fishers (right) in the Cape Greco.

Figure 8 visualised the spatial distribution of fishing effort (fishing hour / fisher) per fishing gear from all recreational fishers who participated in the survey and operating in Cape Greco. From the maps we depicted that the majority of gears used (58%) were exclusively set either in the north eastern (Apiko, Bolognese, Egging, Trolling, and Surf casting) or in the south western (Kalamariera and Traps) part of the MPA (Figure 8). In contrast, more than a third of the recreational gears used were set in the entire MPA (Line, Longline, Rod, Spearfishing and Spinning). Figure 9 showed the aggregated, for all gears combined, fishing effort of recreational fishery in Cape Greco. Figure 10 depicted the movements of recreational fishers departed from their home mooring port and arrival to the fishing grounds of Cape Greco.

Figure 8

Annual fishing effort (fishing hour / fisher) of recreational fishers per fishing gear used in Cape Greco.

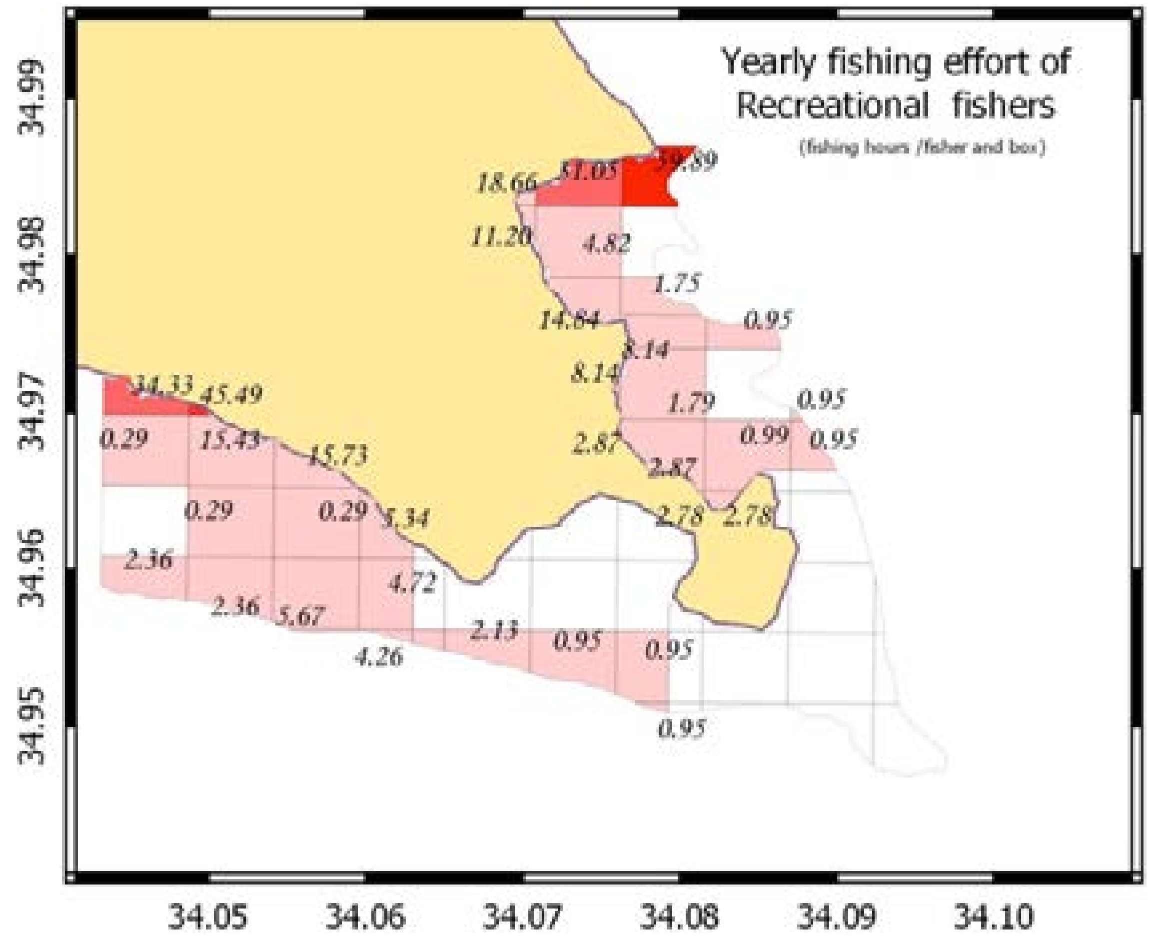

Figure 9

Annual fishing effort (fishing hour / fisher) of the recreational fishery in Cape Greco.

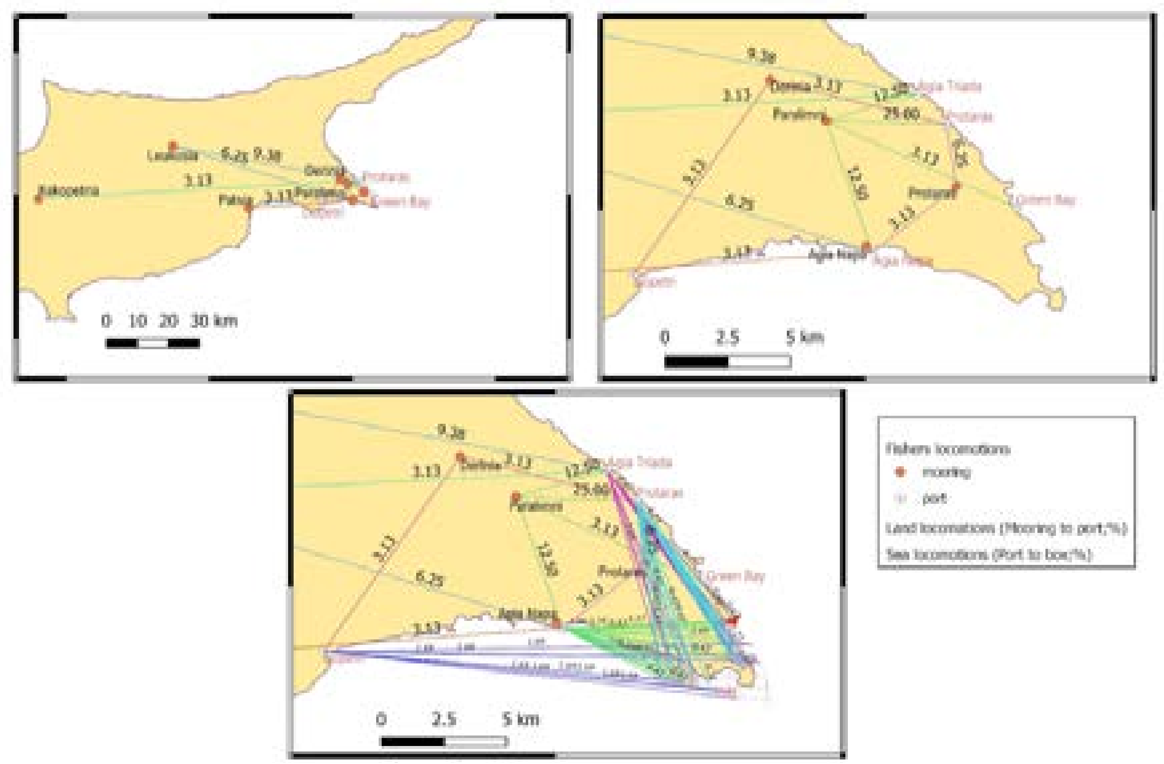

Figure 10

Movements of the recreational fishers from their mooring port to the fishing ground (Cape Greco).

Analysis of the fishing effort of recreational fishery operating in Cape Greco showed that each recreational fisher was fishing an average of 96.6 days per year spending an average 3.2 hours per day. Based on the responses, it seemed that a high percentage of the recreational fishers (70%) operate at least 119 days annually (Figure 11); from rare to three days per week. In contrast, the remaining recreational fishers (less than 30%) responded that they were fishing from three to every day on an annual basis (Figure 11). The most frequently used fishing gears by the majority of the recreational fishers (more than 80%) were boat road, kalamariera, line, rod, spearfishing, egging, traps, and trolling.

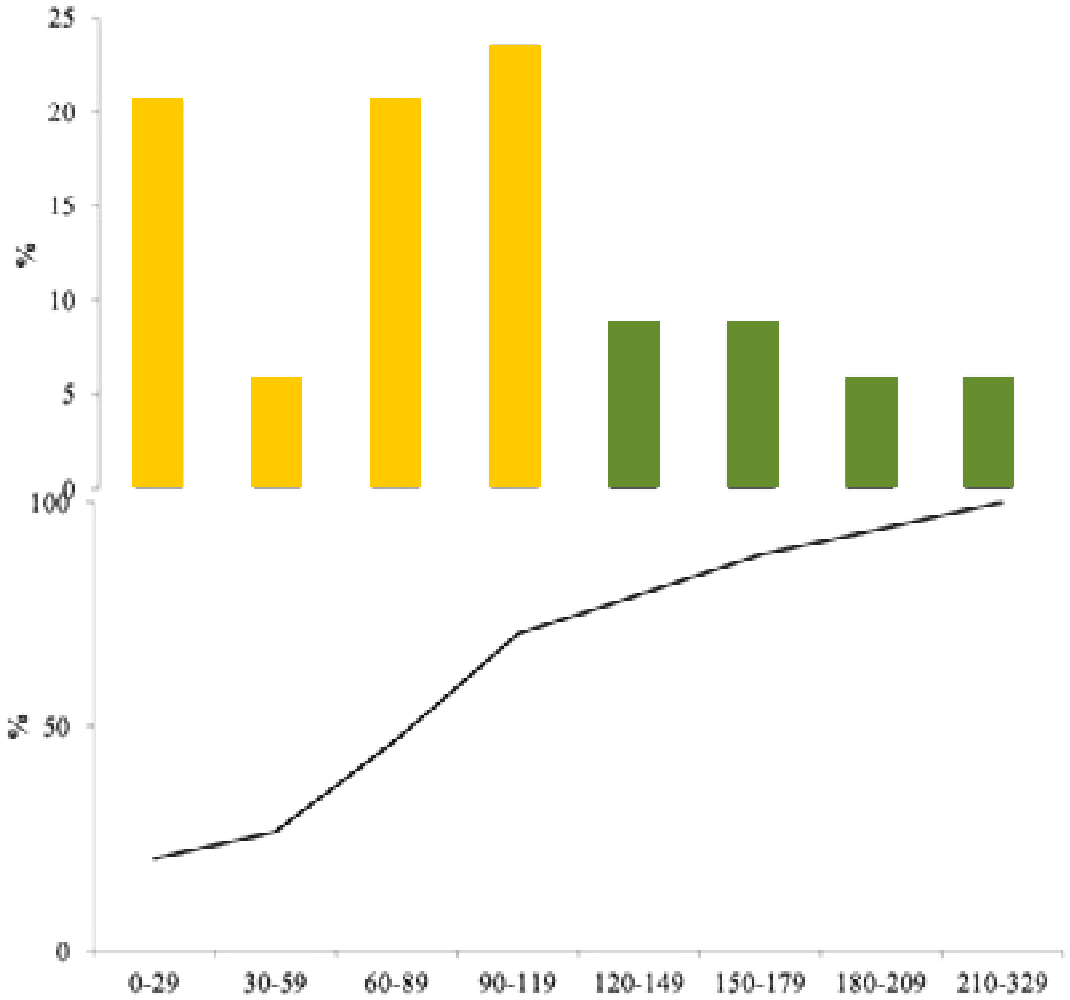

Figure 11

Percentage and cumulatively percentage contribution of the number of fishing days for the recreational fishers.

With regards to the professional fishery in Cape Greco, the visualization of the spatial distribution of the professional fishing effort according to their statements exhibited a high spatial overlap of the different small-scale fisheries in Zone C (Wider area) on both sides of Cape Greco (Figure 12). Netters and more specifically trammel nets were operating in the shallow waters of Zone B, whereas demersal longliners were operating in the offshore waters of the same zone. It is worth noting the absence of professional fishing activity in Zone A (No take zone) (Figure 12).

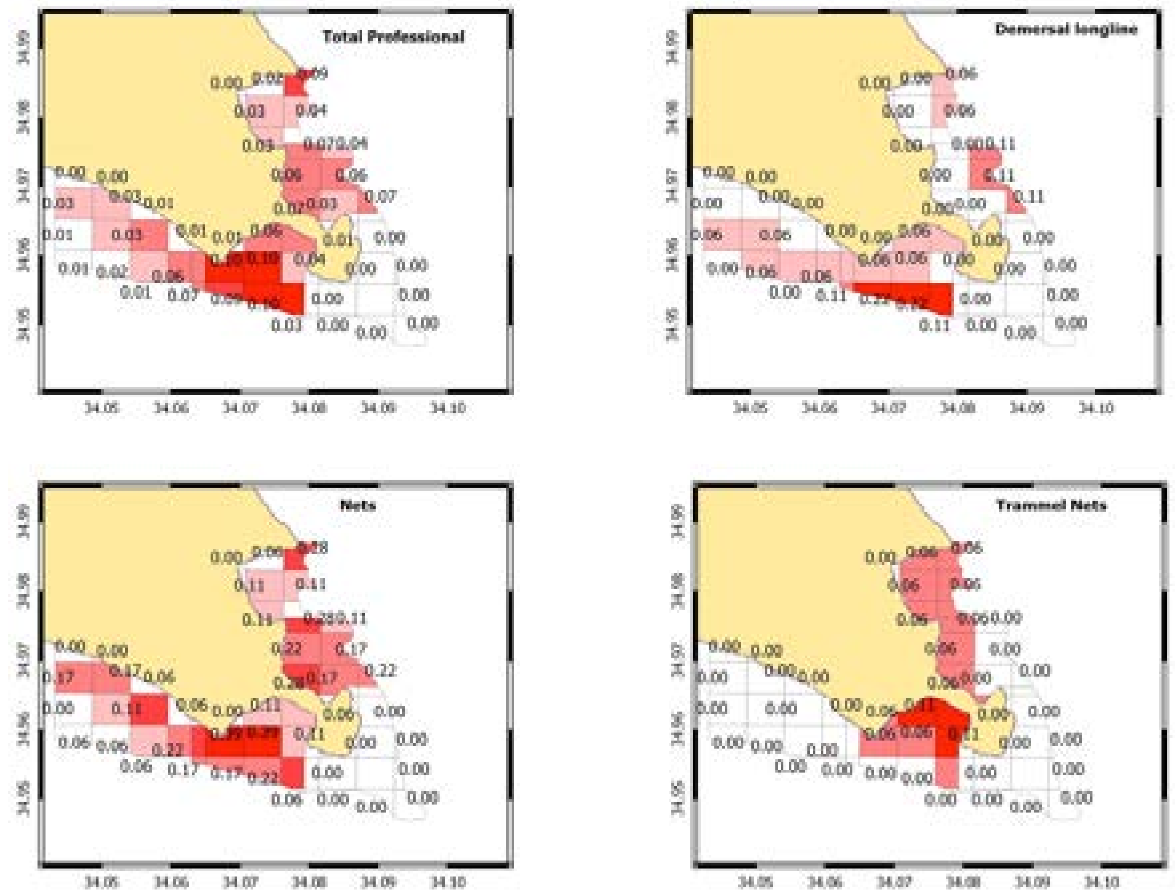

Figure 12

Professional small-scale fishery: Spatial distribution of total fishing effort and separated by gear in Cape Greco. The numbers are the proportion of box-declaration of the fishers indicated the preference of fishers in each box of the area.

The fishing areas of the professional fishery do not seem to be correlated with port origin (Figure 13), which were located from 3 to 15 km away from Cape Greco. It also seemed that the fishery exploitation of the professional fishery has a local character mostly expanded around an area of 2-3 km2 (at 85% of the total participants) (Figure 13). Figure 14 visualised the spatial distribution for each professional small-scale vessel and fishing gear operating in Cape Greco according to their statements. It seemed that this spatial distribution was not related to the minimum distance from the mooring port (Figure 13) of each professional fisher.

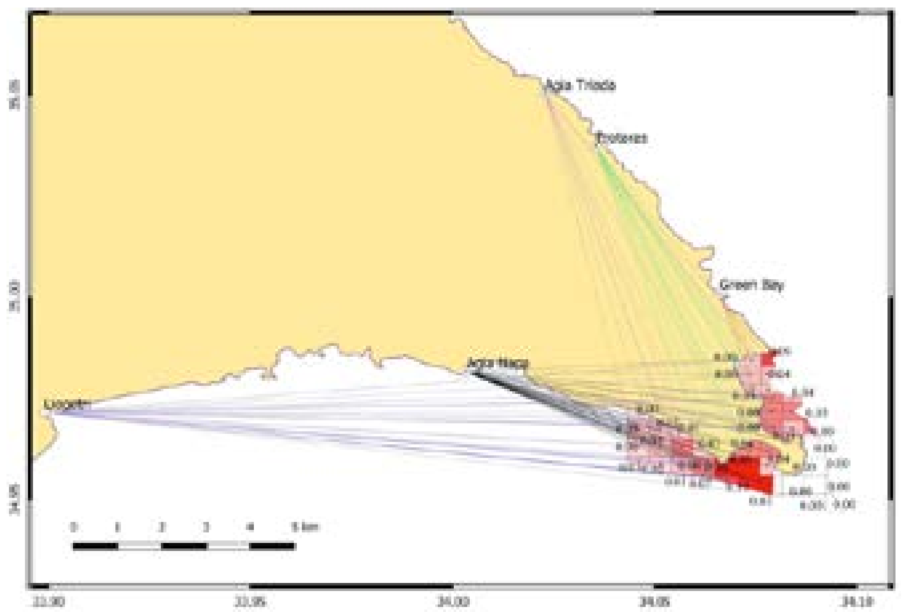

Figure 13

Fishing areas of the professional fishery according to fisher's port of origin.

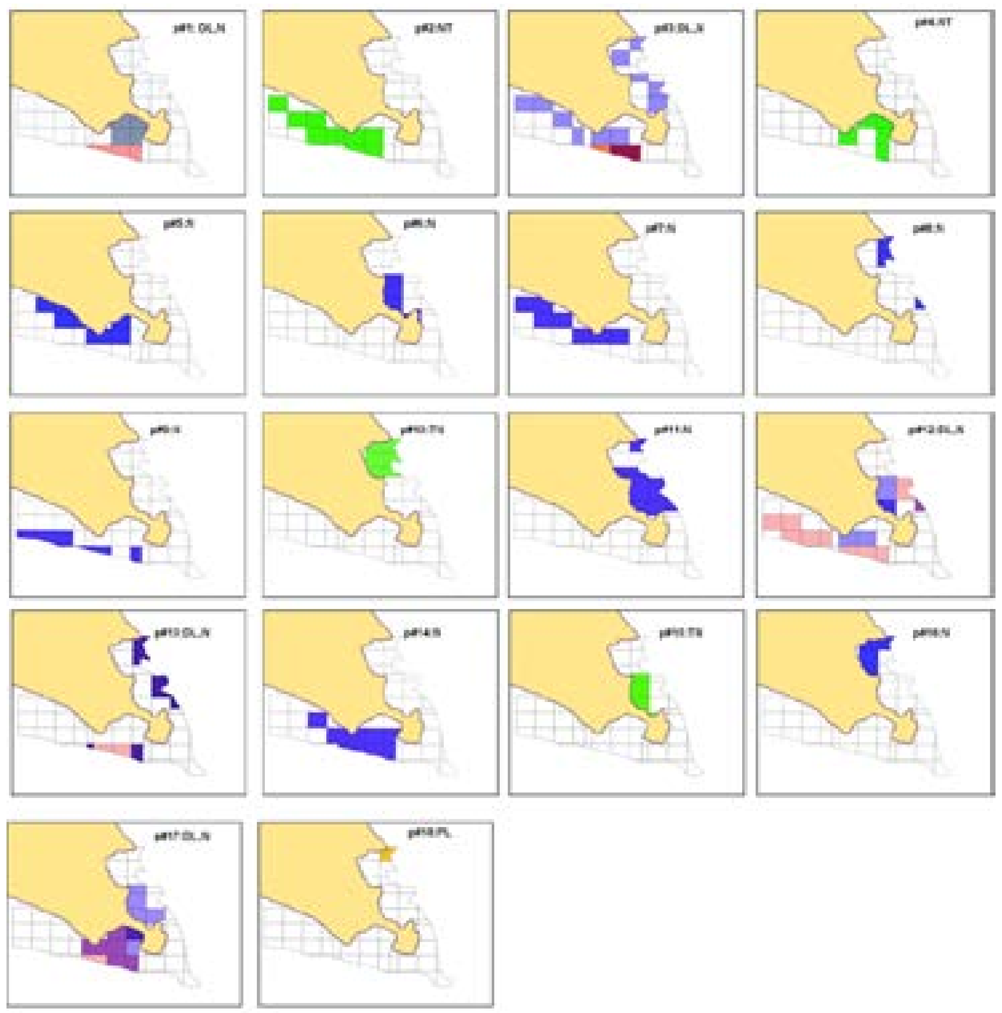

Figure 14

Spatial distribution for each professional (p#) small-scale vessel and fishing gear operating in Cape Greco (Blue: Nets (N), Red: Demersal longline (DL), Green: Trammel nets (TN), Orange: Pelagic longline (PL)).

4.4. Unregulated fishery within Cape Greco

The identification of illegal fishery in Cape Greco was clearly evident from any person working/activating in the fisheries sector (Figure 15). In particular, professional fishers significantly (χ^2-test; $P<0.05$) stated in more than 80%, compared with the stakeholders (68%) and recreational fishers (41%), that they have noticed illegal fishing activities within the zones of the MPA in Cape Greco (Figure 15).

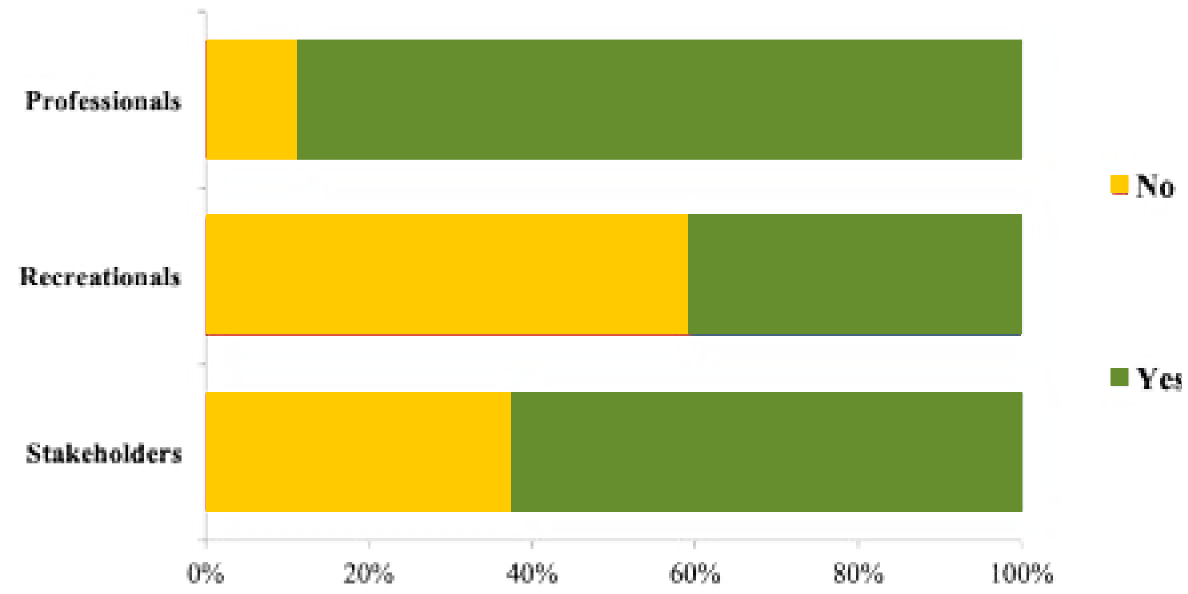

Figure 15

Percentage contribution of the illegal fishing activity as identified from the statements of stakeholders, recreational and professional fishers in Cape Greco.

An indirect quantification of the illegal fishing incidents was conducted using the frequency of fishing operations within the MPA and the cases that the fishers were inspected by the authorities. Despite the fact that all the participants, stakeholders, recreational and professional fishers, stated that they have noticed illegal activities within the Cape Greco MPA (50% in almost daily frequency), no participating person, both from recreationals and professionals, had been accused for illegal fishery and only in almost half of them (55.6%) an inspection was conducted by the authorities during the last three years and for one third (33.3%) an inspection was conducted 6 years ago. For the recreational fishers, a very limited portion of them (6.5%) stated that they have been checked once by guard authorities during the last 2 years, whereas more than 90% of the respondents declared that they have not been checked so far. Interesting is also the fact that both recreational and professional fishers declared that none of them have been accused for illegal activities within the limits of the MPA in Cape Greco. In addition, most of recreational fishers (more than 58.3%) stated that the main causes for the illegal incidents within the MPA were culture and attitude for illegal fishing and the inadequacy of fishing controls. In lower percentages (from 30% to 44%) recreationals also declared that the absence of information, higher abundance of fish inside the MPA and the low amount of fines imposed for the illegal fishery were the main causes for the illegal fishing incidents.

There was a variation on the reported type of illegal fishery between each participants category. In particular, stakeholders stated that illegal fishery was mostly conducted with the following fishing gears: "scuba spearfishing, night spearfishing with light", "rod", "spearfishing", "rod" and "dynamite fishing". Recreational fishers stated that illegal fishery was mostly conducted with the following fishing gears: "traps, scuba spearfishing, night spearfishing with light" and "rod". Professional fishers stated that illegal fishery was mostly conducted with the following fishing gears: "scuba spearfishing, night spearfishing with light", "gyrovolies (handheld trammel net that they use to encircle the catches), night spearfishing with light" and "nets withing the MPA". There was a consensus that scuba spearfishing and rod, followed by netters were among the most commonly fishing gears used for illegal fishery within the zones of the MPA.

Temporal patterns of the illegal fishery, according to the statements extracted from the professional fishers revealed that more than half of them considered that the illegal fishery intensity is almost stable across the last years, whereas only few stakeholders and the recreational fishers expressed the view that there is an increasing trend on this type of fishery. The visualisation of the spatial distribution of the illegal fishery as extracted by the statements taken from the professionals and recreational fishers showed that illegal fishery was highly concentrated around the Zone A (No Take Zone) of the MPA, whereas a moderate illegal fishing activity were also marked in both sides of the Zone B (Buffer Zone) of the MPA (Figure 16).

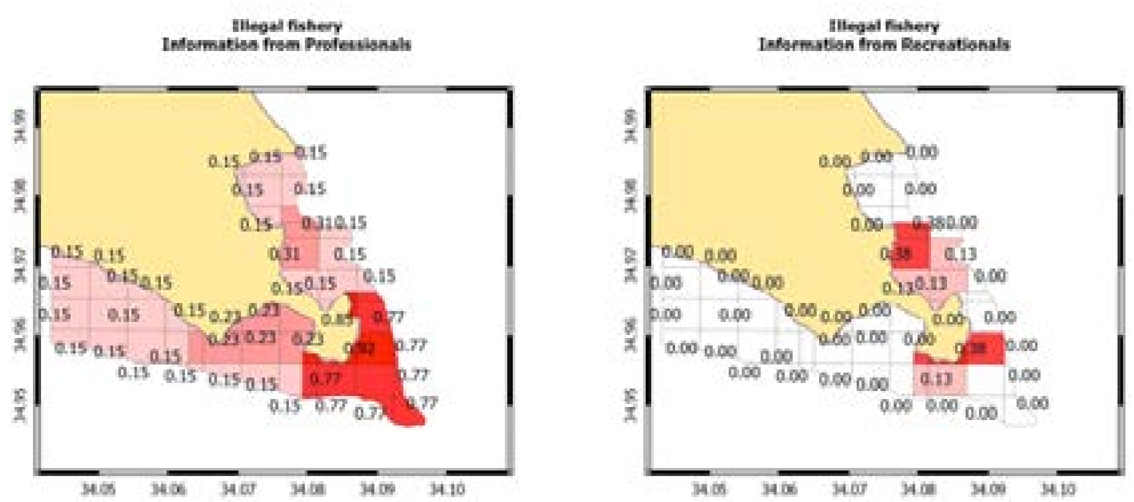

Figure 16

Spatial distribution of the illegal professional and recreational fishery according to their statements. Bold colours indicated the highest percentage of fishing intensity (frequency of occurrence of the spots indicated by the participants).

5 DISCUSSION

The integration of information derived from fishers' and stakeholders' ecological knowledge and fisheries data from the official fisheries authority sheds light on the role of a local professional and recreational fishery in a data-deficient system and leads to better evaluation of management policies. Such a bottom-up approach revealed a wealth of information on the operational fisheries issues and of human impacts on marine ecosystems and exploitable resources.

An aggravating factor of the local fishery is the gradual aging of the professional fishers' population that has also been observed in other Greek coastal marine fisheries (Tzanatos *et al.* 2006; Roditi *et al.*, 2020). Coastal communities in other Mediterranean areas also involved in traditional fisheries have also gradually 'decomposed' since 1990s, because of the decrease in their incomes through fishing due to a decline in catchments (Tzanatos *et al.*, 2005; Gonzalvo *et al.*, 2015). Small-scale fishery has not been linked to the recruitment of young fishers, because the young are not willing to be engaged in the fishers' profession, a situation that is also faced in other Greek (Amvrakikos Gulf, Ionian Sea: Gonzalvo *et al.*, 2015) and Eastern Mediterranean (Matić-Skoko and Stagličić, 2020) coastal areas. Changes in local socio-economic status in relation to fishery exploitation showed that the raising of living standard and changes in the living conditions have resulted in the abandonment of the fishers' profession by the new generations. The uncertain future of the fisheries is also aggravated by the low education level of the fishers, which is likely enhancing the lack of stakeholder participation in the decision-making policies and the reluctance of fishers to participate in subsidy programs (Matić-Skoko and Stagličić, 2020; Tzanatos *et al.*, 2020). These reasons may explain the chronic shortage of young people in Europe's fishing industry (Eurofish Magazine, 2018) which is also reported in other Mediterranean coastal areas with similar socio-ecological status/activities (Galicia: Frangoudes *et al.*, 2008; Greek waters: Tzanatos *et al.*, 2006). The observed situation in the professional fishery in the study area is also consistent with the situation in many European countries that are driven by other socioeconomic factors, such as the shift in service activities such as tourism (Lloret *et al.*, 2018).

Professional fishery in Cape Greco exhibits a seasonal pattern that is in line with small-scale fisheries in other Mediterranean countries (Greece: Tzanatos *et al.*, 2005, Adriatic coastal waters: Grati *et al.*, 2018), where during summer small size vessel encountered optimum weather conditions and high demand for fish due to touristic activities. Thus, both fishing intensity and catches were peaked in May and to a lesser extend in August (in terms of the number of fishing trips) and in July (in terms of the catches). However, this summer peak is not evident during all summer months, where the number of fishing trips were severely declined in June when compared with spring and summer months (Figure 7). This is in contrast with what occurred in the other Mediterranean countries (Greece: Tzanatos *et al.*, 2005; Adriatic: Grati *et al.*, 2018, southern European countries: Lloret *et al.*, 2018) and was most likely the effect of the COVID-19 pandemic since a curfew was imposed for recreational fishers on April-May while professionals had the option to receive a government fund (1000 EU for small scale fishers and 1500 EU for each polyvalent fisher per month) and cease their fishing activities in May-June.

The above-described fishery pattern, peak in summer, is also in line with what was observed for the recreational fishery, according to the statements of the recreational fishers. A similar pattern is also observed for the shore-based recreational fishing activity in several areas of the Greek waters (Moutopoulos *et al.*, 2013). Differences were observed in terms of fishing intensity and species composition estimations. Given that more than 80% of the recreational fishers participating in the current survey conducted a shore-based fishery, thus, the frequency of the studied recreational fishing per year (96.6 days of fishing) was higher than the values reported for other Mediterranean areas (75.5 days in Marmara strait: Ünal *et al.*, 2010; 67 days in Majorca island: Morales-Nin *et al.*, 2005), but much lower with the corresponding ones estimated for several Greek areas (around 190 days per year: Moutopoulos *et al.*, 2013).

The outputs of the shore-based recreational fishery conducted in Cape Greco can be considered valid and comparable, with that from other Cypriot waters, because based on a recent study conducted on the recreational fishery across all Cypriot waters (Michailidis *et al.*, 2020), a quarter of the participants (26.5%) owned a recreational fishing vessel, a value that is close to the estimated percentage found from the entire country (10% of vessel used for fishing and 8.5% used for spearfishing) (Michailidis *et al.*, 2020). Also, there is an agreement regarding the target species caught by the recreational fishers; especially the invasive rabbitfishes (Michailidis *et al.*, 2020). In contrast, species composition of the shore-based recreational fishery in Cape Greco also differentiated with that from other European countries. In particular, in the study area recreational fishers stated that *Siganus* spp. are the most representative species all year round, followed to a lesser extent by high commercial species such as *Dicentrarchus labrax, Dentex dentex, Seriola dumerili* and *Sparus aurata*. Sparidae is the most commonly species caught by the shore-based recreational fishery in other Mediterranean countries (approximately 25% in Marmara Strait: Ünal *et al.*, 2010; more than 50% in Southern Portuguese waters: Veiga *et al.*, 2010 and Greece: Moutopoulos *et al.*, 2013), because these species are of high economic price, a fact that creates a personal motivation for fishers and therefore affects the frequency and intensity of fishing (Moutopoulos *et al.*, 2013). In a recent study on the recreational fishery in Cypriot waters the contribution of the number of shore-based recreational fishers reaches 85%, almost comparable with the 73.5% exhibited from the present study.

Recreational fishers also stated about 20 species targeted, mostly on shore, in Cape Greco. Given that a high number of species, ranging from 11 to 48 species depending on the area, made up an important part of the shore-based recreational catch in other Mediterranean countries (Moutopoulos *et al*., 2013). This shows the multispecies nature of the recreational fisheries in the southern European waters. The diversification of the species composition in the study area mostly attributed to the invasive species *Siganus* sp., a fact that is also indicative of the presence of this category of fish species in the Cypriot waters.

What is also important from the presently reported study is the categorisation of the recreational fishers into two categories of fishing activity; the systematic operating (those fishing from 10 days per month to almost each day in an annual basis) and the opportunistic (from one day per month to 10 days per month) operating ones. By aggregating the number of fishing days of recreational fishery it seemed that a high percentage of the recreational fishers participating in the survey (70%) operate up to 119 days on an annual basis (Figure 8); approximately from rare to three days per week. In contrast, the remaining recreational fishers participating to the survey (less than 30%) seemed that they are fishing from three days per week to each day on an annual basis (Figure 8). The implementation of management actions that are based on the fisher's profile would facilitate the synthesis of the different activities developed by fishers and would define the evaluation of the fleet dynamics. In this context, fishing effort control measurements implemented through the license control systems would have a negligible effect on the ecosystem sustainability, because the reduction of fishing effort regardless of the level of dependence of the fishers can lead to the reduction of nominal fishing effort (abandoning fishing by irregularly operating professionals) (Tzanatos *et al.* 2006).

Considering the complete lack of knowledge regarding the catch of the recreational and illegal fisheries conducted in the Cape Greco, it can be assumed that the actual catches are much higher and thus the officially reported data could be very misleading. Thus, the actual impact of fisheries is hard to be evaluated due to misreporting estimates and serious limitations in the official landing statistics. Practically, in the present study the anonymity of the interviews, and thus protecting the fishers from being traced for tax purposes, professional fishers might provide more accurate catch per species estimates.

Most of recreational fishers stated that the main causes for the illegal incidents within the MPA were notion of the illegal fishers, the inadequacy of fishing controls, absence of information and knowledge and the low amount of fines imposed for the reported illegal fishery cases. There is a paradox regarding the high percentage of illegal professional fishery in Zone A (no Take Zone) according the statements of the recreational fishers. This may be due to the absence of information on the benefits of the present MPA a fact that was also revealed by the high percentage of fishers not being aware on the different degree of prohibitions among the zones of the MPA. This phenomenon might also be the result either of the lack of an essential control on the professional and recreational fisher or due to the lack of fisher's compliance with the rules (Moutopoulos *et al*., 2016, 2017), issues that enlarge the conflicts between recreationals and professionals, control agencies, fisheries departments and the Ministry (Gonzalvo *et al*., 2015). The mooring ports for the professional and recreational fishing vessels also makes the access easy to the illegal fishing. However, in our study and based on the spatial distribution for each professional small-scale vessel and fishing gear operating in Cape Greco according to the statements of the fishers, is that this spatial distribution was not related to the minimum distance from the mooring port (Figure 10) of each professional fisher. Despite the low number of observations in each port (18 in four ports), it is clear that (Figure 12) for all mooring ports, the "departures" of the fishing trips ended up on north and south part of the Cape Greco. This is in contrast of what someone expects in case that the fishers follow the minimum distance (and thus the minimum cost of gas) from the mooring ports. This is because the fishers having as mooring ports Liopetri and Agia Napa will finally end up to the south part of Cape Greco, whereas for those that started their fishing trips from Protara or Agia Triada will end up in the north part. This suggests that the distances from mooring port are laid within the limits of the economical tolerance of its fishery exploitation.

The bipolar of "easy access of fisheries-high illegal fishing activities" that has been confirmed from the recorded illegal fishing activities in the Greek waters (Moutopoulos *et al.*, 2016) is also confirmed regarding the illegal recreational and professional fishery in Cape Greco. Interviews also revealed that the fishery exploitation of the professional fishery has a local character around an area of 2-3 km2 that might be attributed to the easy and quick access of the fishermen, which were located in close distance from Cape Greco (i.e., Agia Napa, Potamos Liopetriou, Protaras). This might be also due to the share of the space among the fishers (both recreational and professionals).

It is important to note in support to the illegal fishing activities reported by the interviewees and despite the fact that we are not presenting this data, that our team also observed several incidences of illegal activities during our field work for this project. We recorded 33 incidences of illegal fishing (25 in the northern Buffer Zone and 8 in the No Take Zone) during only the first two-week period of intensive field work in the area. Halting the illegal fishing could be accomplished if fisheries legislation is modified (Moutopoulos *et al.*, 2016), taking into account the number of the most active fishers and enforcing fisheries control based upon social participation (Arlinghaus *et al.* 2015, Giovos *et al.* 2018). This would trigger professional fishers to establish self-control (Zaucha *et al.* 2016) by contributing with their professional knowledge and experience to effective management measures acting as guardians of traditional fisheries. Also, most of the professional fishers stated that the fines of the illegal fishery were not harmonized with the type of the illegal fishery. Fines/penalties should be proportionate and dissuasive.

In conclusion, traditional ecological knowledge of local fisheries communities is particularly important in the absence of conventional datasets, especially for a poor-data area, such that of the Cyprus waters in order to promote conservation measures and to enhance legislation and policy. Outputs highlight the need to integrate up-to-date scientific knowledge with the experience of professional experts who have long-term multi-species knowledge of changing fisheries. Fisheries management should be up to date by enlarging the transparency in the decision-making process. In this target the re-orientation of the activities and services of the professional fishermen in a Marine Protected Area such as Cape Greco could contribute to the sustainable management and use of marine resources. This is the case of the participation of fishermen in advisory roles in management issues and/or through delegation and sharing power. The results presented here should also optimize the status of the fisheries exploitation in the MPA of Cape Greco and could be incorporated in the decision-making process towards the improvement of the implementation of the revisited Common Fisheries Policy;

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PART 2

An **inventory**
of the **active fishing gear types**
and **practices**
at **Cape Greco MPA**

Fishing gear types and Practices in Cape Greco

Table 1
Active fishing gear types and practices of professional and recreational fishers in Cape Greko.

Fishers	Fishing gear and practices	Map
Professional	Demersal longline	Deliverable 1.2iii Map_3_Professional fishery
	Gillnets	
	Trammel Nets	
Recreational	Apiko	Deliverable 1.2ii Map_2_Recreational fishery by type
	Bolognese	
	Egging	
	Trolling	
	Kalamariera	
	Line	
	Longline	
	Rod	
	Spearfishing	
	Spinning	
	Surf casting	
	Traps	

PART 3

Evaluation
of the **socio-economic impact**
of **invasive fish species** in **Evaluation**
of the **socio-economic impact**
of **invasive fish species**
in **Cape Greco MPA**

PART 3

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PART 3

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1 INTRODUCTION

The health of the Mediterranean ecosystems are at risk from an increasing host of human activities and pressures (Coll *et al.* 2010). Non-Indigenous Species (NIS) invasions have been widely acknowledged as among the most serious threats that the Mediterranean basin is facing (Edelist *et al.* 2013; Katsanevakis *et al.* 2014). The NIS number has been accelerating without saturation signs in the last decades and is now far greater than in any other world region; reaching 821 recorded and over 600 established multicellular species in 2017 (Zenetos *et al.* 2017). Some of the major pathways for NIS in the basin include the shipping (transfer via ballast waters or as biofouling), Suez Canal, aquaculture, and aquarium releases. In the eastern Mediterranean, Suez Canal is the dominant pathway responsible for the majority of the introductions (Galil *et al.* 2015). The recent enlargements of the Canal together with climate change are driving more Indo-Pacific thermophilic species into the basin while other large sized native populations are diminished (Galil *et al.* 2017a; Moullec *et al.* 2019).

A fraction of the introduced NIS — termed as 'invasive alien species (IAS)' — is causing adverse impacts on the recipient ecosystems; affecting native species richness and abundance, increasing the risk of native species extinction, affecting the genetic composition of local populations, changing native animal behaviour, alter ecological processes and ecosystem services (Chaffin *et al.* 2016; de Castro *et al.* 2017; Geburzi and McCarthy 2018; Pyšek *et al.* 2009). However, other NIS might be able to introduce novelty, replace ecological functions and provide ecosystem services (Chaffin *et al.* 2016).

The socioeconomic consequences of NIS have been largely neglected compared to their ecological impacts. Some NIS that have been introduced are poisonous or venomous ones causing important implications for coastal or marine industries such as tourism and fisheries (Galil 2018). Nuisance species such as the various pufferfishes (Family: Tetraodontidae), the striped eel catfish *Plotosus lineatus*, and the nomad jellyfish *Rhopilema nomadica* strongly interfere with or alter fishery activities by damaging gears and fishery catches (EastMed 2010; Galanidi *et al.* 2018; Kalogirou 2013). *Rhopilema nomadica* outbreaks also cause significant costs to power plants by clogging intake pipes and to the tourism industry as they can release venomous stinging cells (Galil 2007; Ghermandi *et al.* 2015). It was estimated that the pufferfish *Lagocephalus sceleratus* damages to the artisanal gear of small-scale fishers, of Turkey alone, are around € 2 million per year (Ünal *et al.* 2015), while an outbreak of jellyfish *Rhopilema nomadica* in Israel can cost an annual monetary loss of €1.8–6.2 million (Ghermandi *et al.* 2015).

On the other hand, some NIS have become targets for local fisheries of the eastern Mediterranean region, often helping to stabilize local fisheries catch and provide an important source of income for the local communities (Michailidis *et al.* 2019; van Rijn *et al.* 2019; Saygu *et al.* 2020).

Most socioeconomic studies that have been carried out so far focused to identify priority NIS that have the potential to cause the most important negative impacts on the recipient ecosystems, and guide policy interventions (Galanidi *et al.* 2018; Peyton *et al.* 2019). The potential positive contribution of other species has been largely neglected. Furthermore, studies exploring the social aspects of NIS have been limited in the Mediterranean. To our knowledge, no studies have been carried out exploring the socioeconomic aspects of marine NIS in Cyprus to date. This study aimed to shed light on the socioeconomic aspects of important established NIS in the island, and particularly off the Cavo Greco MPA.

2
METHODOLOGY

2.1. Selected non-indigenous speciesSelected non-indigenous species

The survey was focused on 12 species, namely *Lagocephalus sceleratus, Torquigener flavimaculosus, Parupeneus forsskali, Pterois miles, Fistularia commersonii, Sepioteuthis lessoniana, Sargocentron rubrum, Siganus luridus, Siganus rivulatus, Sphyraena chrysotaenia/flavicauda, Pempheris sp., and Saurida lessepsianus*. The selection of the species was based on experts' knowledge for the densities and interactions of the selected NIS in the area, and by taking into account the coastal priority species identified through the Joint GFCM-UN Environment/MAP subregional pilot study for the Eastern Mediterranean on non-indigenous species in relation to fisheries (GFCM-UNEP/MAP 2018).

2.2. Fishery composition and value

To understand the contribution of NIS in the fishery of the Cavo Greco area, official fisheries landing data collected as part of Data Collection Framework (DCF) were requested by the Cyprus Department of Fisheries and Marine Research (DFMR). Information about the description and quantification of the recreational fishery are not monitored by any official authority, and data were acquired from the results of this project (Activity 1 - Identification, quantification, spatial and temporal distribution of commercial and recreational fishing activities and unauthorised fishing in Cavo Greco MPA)

2.3. Questionnaires

2.3.1. Questionnaire structure

To understand the social and economic implications of NIS, interview surveys were conducted between June and July 2019 targeting the local professional and recreational fishers operating at Cavo Greco. To make a customized collection of information aimed and a holistic approach to the problem, the questionnaires were conducted to the same people that were interviewed as part of Activity 1 - Identification, quantification, spatial and temporal distribution of commercial and recreational fishing activities and unauthorised fishing in Cavo Greco MPA. Therefore, some information were already known such as the demographic information, knowledge of interviewers about the MPA, and their fishing operation. Detailed information can be found at the Deliverable 1.

The full questionnaire that has been used to understand the NIS social and economic interactions is shown in Appendix 1.

2.3.2. Questionnaire surveys

Interviews took place around fishers' mooring/landing sites, frequently on board of their own vessels while they were mending their nets or doing vessel maintenance before/after going out at sea to minimize disruption to their routines (Figure 1). To stimulate fishers' perceptions and minimize potential bias, all interviews were carried out by the same person, ensuring that questions were presented in an identical manner and freely answered with no prompt or influence. Respondents were approached informally and asked if they were willing to answer a few questions about their fishing, and interviews were held privately, on one-to-one sessions, to prevent influence or interference by other people (Figure 1). To avoid pseudoreplication, the professional fishers' respondents were exclusively owners of fishing vessels or captains, and no more than one questionnaire per fishing vessel took place. Given that fishers use common names for species, and some names stand for many species or differ among communities, fish guides were used to clarify species identifications during the interviews.

Figure 1
Annual fishing effort (fishing hour / fisher) of the recreational fishery in Cape Greco.

2.3.3. Questionnaire surveys

To enable comparisons among responses and better understanding of the interactions, fishers were separated into two categories (professional fishers and recreational fishers), and six sub-categories based on the fishery activities in the area: Small scale fishing (licenced A-C by the Cyprus government) and polyvalent fishers for the professional fishers category, and boat fishers using demersal techniques, boat fishers using pelagic techniques, shore fishers, and spearfishers for the recreational fishers category.

Descriptive statistics were applied, providing percentage contribution, mean and standard deviation (SD) and standard error (SE) values of several resulting parameters and frequency of occurrence (%) was applied to all statements. The non-parametric chi-square test (χ2-test) was used to examine whether there is a possible association and if so the degree of association between several key questions that were set in the two different fisher categories; recreationals and professionals. All statistical analyses were carried out using the statistical package IBM SPSS statistics v 24.0.

3 RESULTS

3.1. Fishery composition and value

Overall, 78 professional fishermen were licensed in the four ports around Cavo Greco for 2019 (DFMR data). Taking into account the data from European Data Collection Framework derived from the fisheries monitoring of the active professional small-scale fishery in 2018 from ports adjacent to the study area (i.e., Agia Triada, Paralimni, Agia Napa, and Potamos Liopetriou), the highest fishing intensity of the professional small-scale fishery was marked in May and in August and the lowest during November-December (more information can be found at the Deliverable 1). There were landing data available only for a number of the selected species or taxa. *Torquigener flavimaculosus* and *Lagocephalus sceleratus* were both sold as *Lagocephalus* spp., *Sphyraena chrysotaenia/flavicauda* data were sold as *Sphyraena* spp. and couldn't be separated from other native species (e.g. *Sphyraena sphyraena*), no data were available for *Saurida lessepsianus*, *Pempheris* sp., and *Sepioteuthis lessoniana*.

According to the reported data for the period 2017-2019, the contribution of the selected NIS (for those with available data) to the total landings of all species was relatively low with the exception of May-July. Overall, the six non-indigenous taxa (*Fistularia commersonii, Lagocephalus spp., Parupeneus forsskali, Pterois miles, Sargocentron rubrum, Siganus* spp.) contributed for 28.55% (97,292 kg) of the total landing weight and for 27.55% (340,802 Euros) of the landings value for the three year period 2017-2019; equal to an annual income of 1456 Euros for each fisher.

During the summer period, the contribution of the selected species was usually more than 50% for both total landings and value (Figure 2). Total landings and catch per unit effort (kg per trip) followed a similar pattern over the months for all species (Figure 3 and 4). The contribution was particularly large for some NIS; for example, *Lagocephalus* spp. contributed for 16.03% of the landings for the period 2017-2019, and *Sargocentron rubrum* contributed for 10.85%. The rabbitfish *Siganus* spp. contributed for 4.1% of the total weight but represented 16.9% of the total value of the landings from the four fishing shelters (2017-2019). From the data, a peak of NIS landings was apparent during the summer period for NIS (Figure 3). Landings exponentially grew for *Parupeneus forsskali* since 2019, and also the first reports of *Pterois miles* were reported in 2019. There were little changes in the value price of each species over a three-year period; with *Siganus* spp. and *Parupeneus forsskali* being the most valued species (Figure 5).

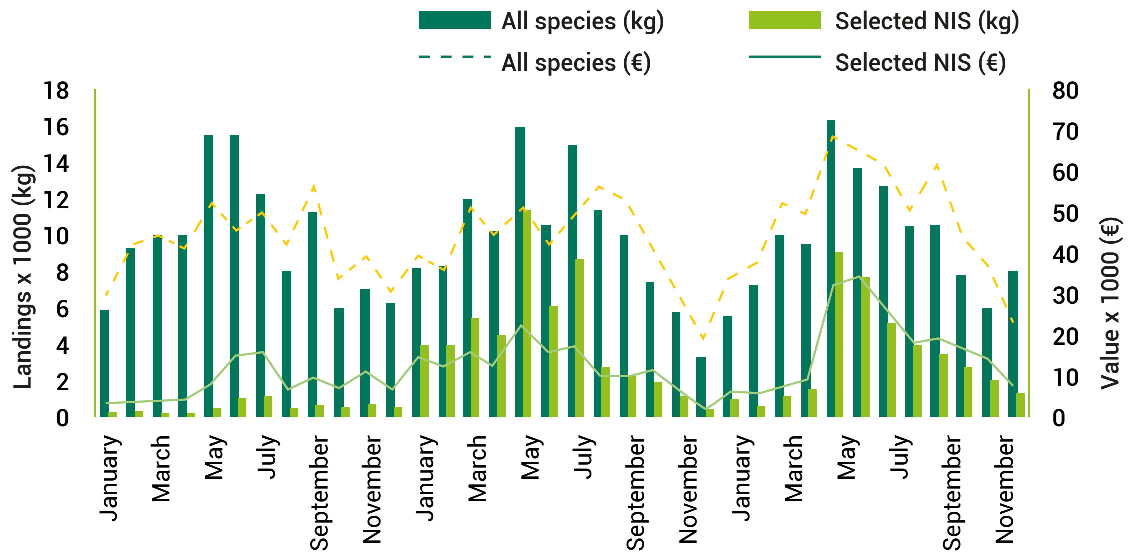

Figure 2
Monthly landings (kg) and value (Euros) of all species and for the selected NIS (Lagocephalus spp., Sargocentron rubrum, Siganus spp., Fistularia commersonii, Parupeneus forsskali, and Pterois miles) from the fishing shelters Agia Triada, Paralimni, Agia Napa, and Potamos Liopetriou for the period 2017-2019.

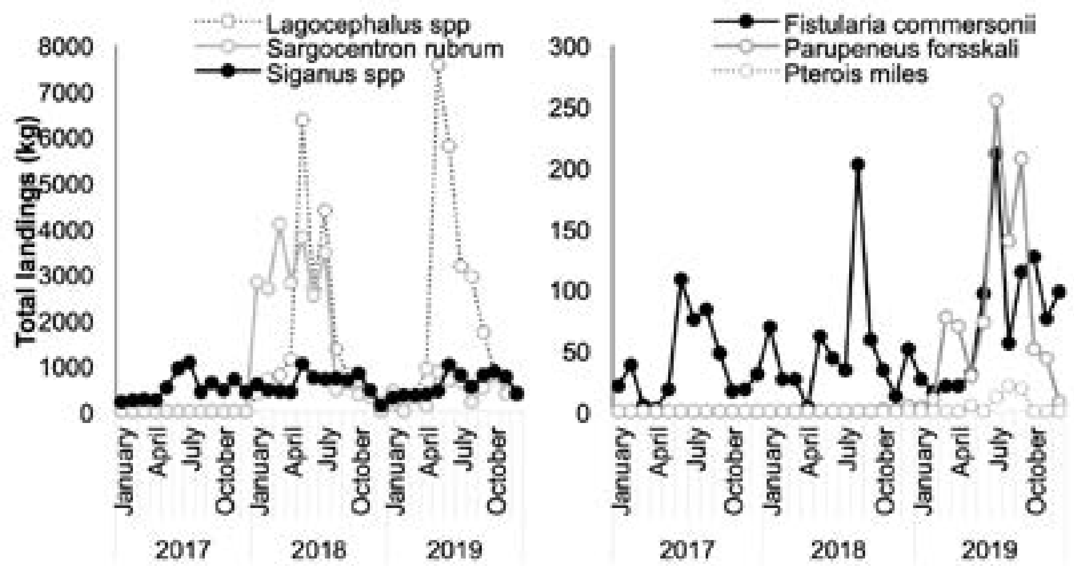

Figure 3
Monthly landings of the selected non-indigenous species for the period 2017-2019

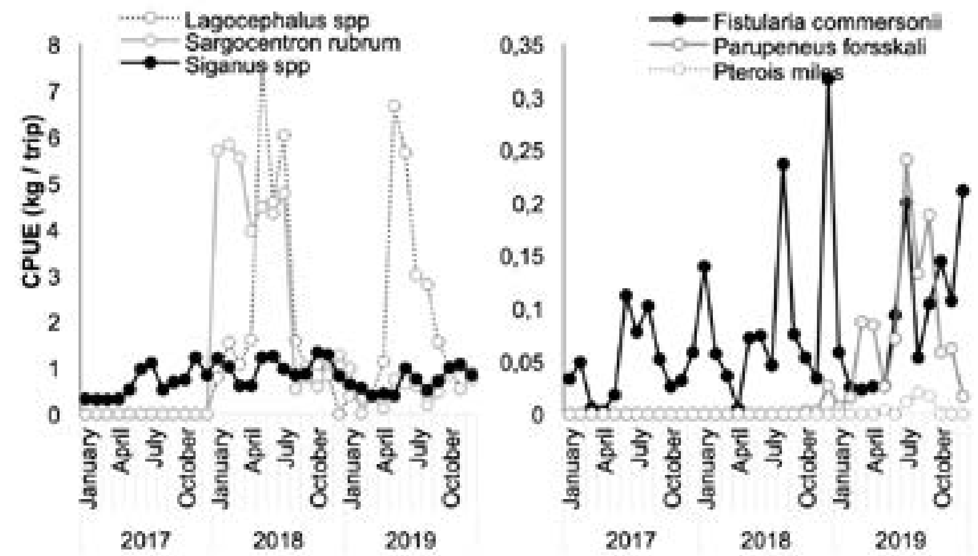

Figure 4
Monthly catch per unit effort of the selected non-indigenous species for the period 2017-2019.

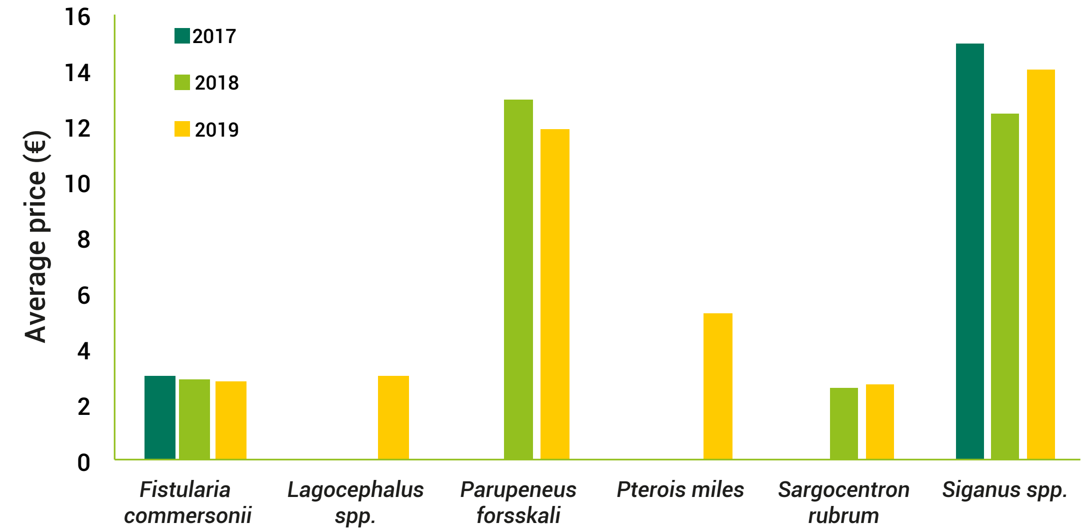

Figure 5
Average price of the selected non-indigenous species sold by fishers for the period 2017-2019. Error bars indicate monthly standard error.

The description and quantification of the recreational fishery were based on analyses and results of the Deliverable 1 since no official data are available for this fishery. According to the statements of fishers, catches were largely represented by the rabbitfish *Siganus* spp. (from 32.1% to 53.8%, depending on season); indicating the importance of the species in the area. Seasonal catches (as found through the Deliverable 1) of other selected NIS is shown in Table 1.

Table 1

Seasonal species composition (%) of the non-indigenous species for the recreational fishery of Cavo Greco. Source: “Deliverable 1 Identification, quantification, spatial and temporal distribution of commercial and recreational fishing activities and unauthorised fishing in Cape Greco MPA.”

Species	Spring	Summer	Autumn	Winter
Lagocephalus scelleratus	3.1			
Pterois miles	3.1	2.6	2.9	3.6
Sargocentrum rubrum				3.6
Sepioteuthys lessoniana	3.1			3.6
Siganus spp.	34.4	53.8	40.0	32.1

3.2. Questionnaire results

In total 55 respondents were interviewed. From them, 20 were professional fishers; of whom 17 small scale fishers (SSF), and 3 polyvalent fishers (PV). A total of 35 recreational fishers were interviewed with small overlap since few fishers used more than one technique (sub category), specifically 5 of them were fishing for demersal species with a boat (BFD), 5 were fishing for pelagic species with a boat (BFP), 28 were fishing from the shore (SF), and 4 were fishing with speargun (SP).

The vast majority (more than 90%) of both recreational and professional fishers who participated in the survey supported that they were aware of what is a non-indigenous (or alien) species. Likewise, a very high percentage of participants from both two fishery compartments reported that NIS have a very negative (more than 80%) and negative (around 15%) impact to the fishery resources and the ecosystem structure (Figure 6), whereas only a very small portion of the professional fisher (5%) stated that the NIS have a positive impact to the corresponding issues (Figure 6).

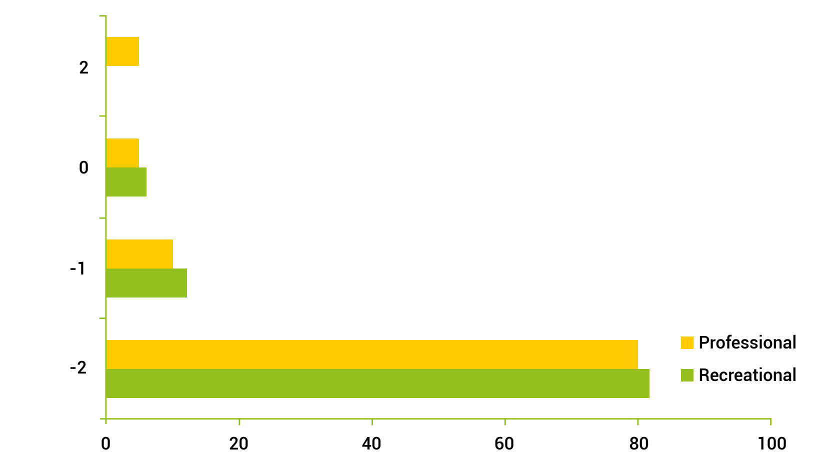

Figure 6

Percentage contribution of the impact of alien species to fisheries resources and ecosystem of Cavo Greco (-2 corresponded to strongly negative, -1 to negative, 0 to neutral, +1 to positive, and +2 to strongly positive.

Fishers were aware about the origin of some of the selected NIS but not for all. Specifically, the vast majority of both professional and recreational fishers were confident that *Lagocephalus sceleratus*, *Torquigener flavimaculosus*, *Parupeneus forsskali* and *Pterois miles* are NIS, whereas only professionals identified *Sepioteuthis lessoniana* as a NIS (Figure 7). For the rest of alien species listed in the present survey, both professionals and recreational fishers wrongly responded in significant (χ^2-test; $P<0.05$) higher percentages that these species were not NIS.

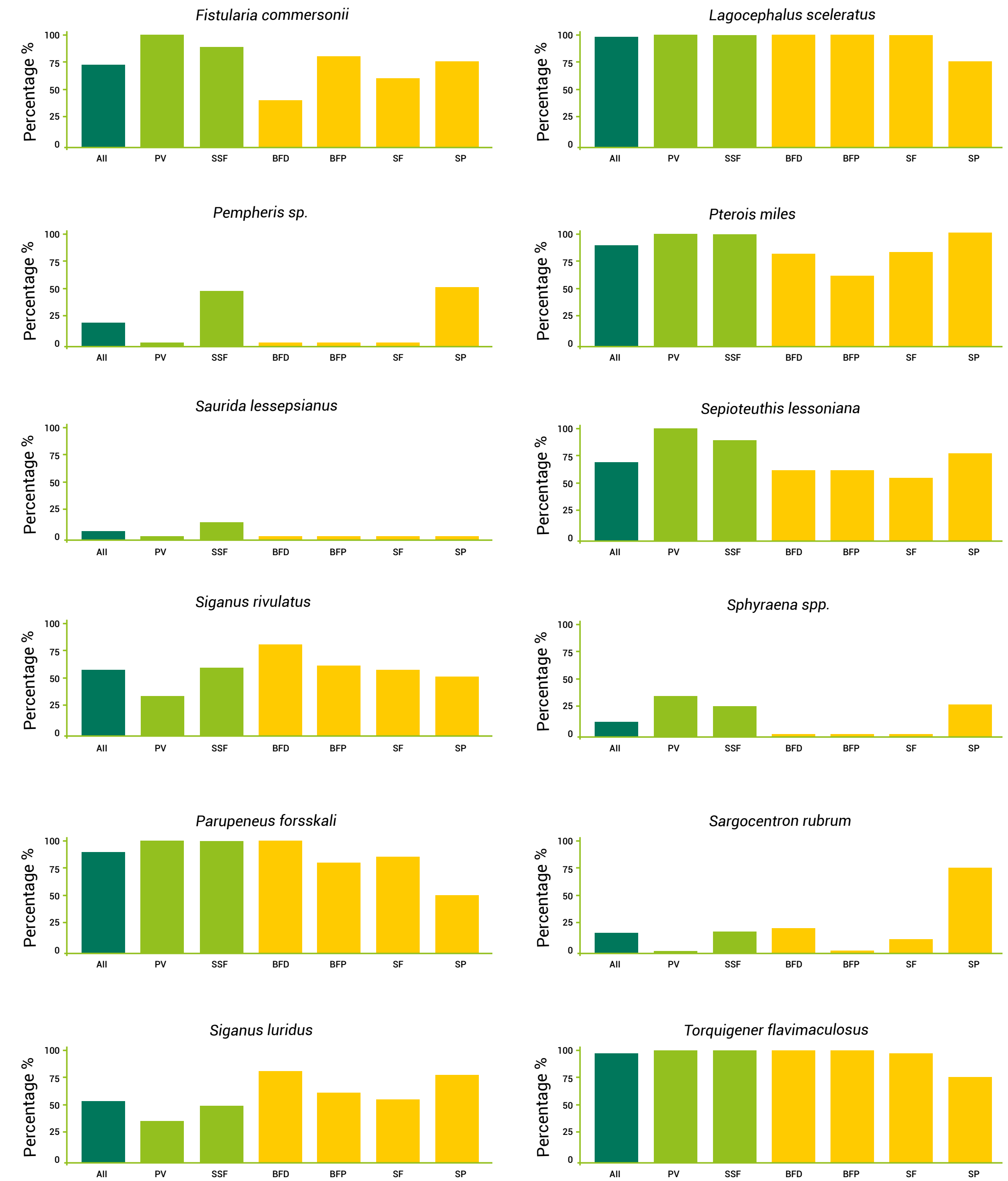

Figure 7

Knowledge of fishers about the origin of each NIS. SSF: Small scale fishers, PV: Polyvalent, BFD: Boat fishing demersal, BFP. Boat fishing pelagic, SF. Shore fishing, SP. Spearfishing. Grey colour shows all responses, blue colour indicates professional fishers, and yellow colour indicates recreational fishers.

The opinions regarding the impacts varied for each species. Species that are highly commercial and valued were perceived as positive with the most positive responses; including *Siganus* spp. *Parupeneus forsskali* and *Sphyraena* spp. On the other hand, the poisonous *Lagocephalus sceleratus* and *Torquigener flavimaculosus* were perceived as negative with most negative scores, followed by the venomous *Pterois miles*. Professionals generally responded in significantly (χ2-test; P<0.05) higher percentages with clear way (either positive or negative) on the impact of alien species to the ecosystem compared with the recreationals (Figure 8).

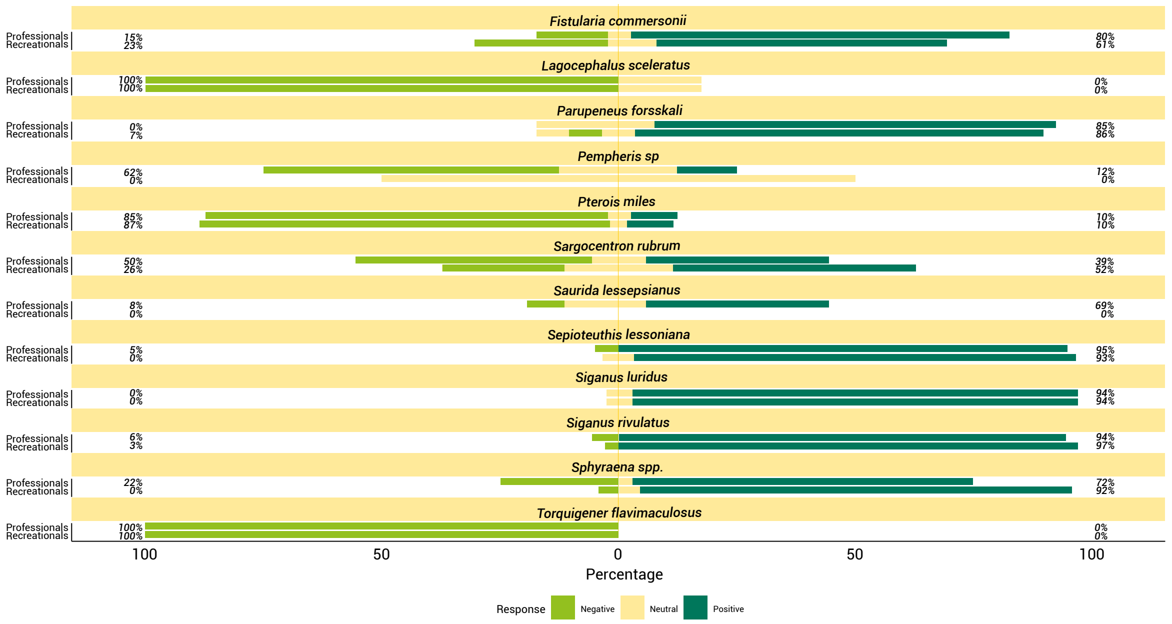

Figure 8

Perceptions about the impacts (positive, negative or neutral) of the selected NIS from professional and recreational fishers.

A heterogeneous pattern was revealed regarding the responses about the discarded status of the studied species. Species with the highest discard rates were *Torquigener flavimaculosus*, *Lagocephalus sceleratus*, and *Pempheris* sp., followed by *Pterois miles* and *Sargogentron rubrum* (Figure 9). For eight out of 12 listed species (i.e., *Parupeneus forsskali*, *Fistularia commersonii*, *Sepioteuthis lessoniana*, *Siganus luridus*, *Siganus rivulatus*, *Sphyraena chrysotaenia/flavicauda*, *Pempheris* sp. and *Saurida lessepsianus*) responses between recreationals and professionals were similar (χ2-test, P<0.05). (Figure 9).

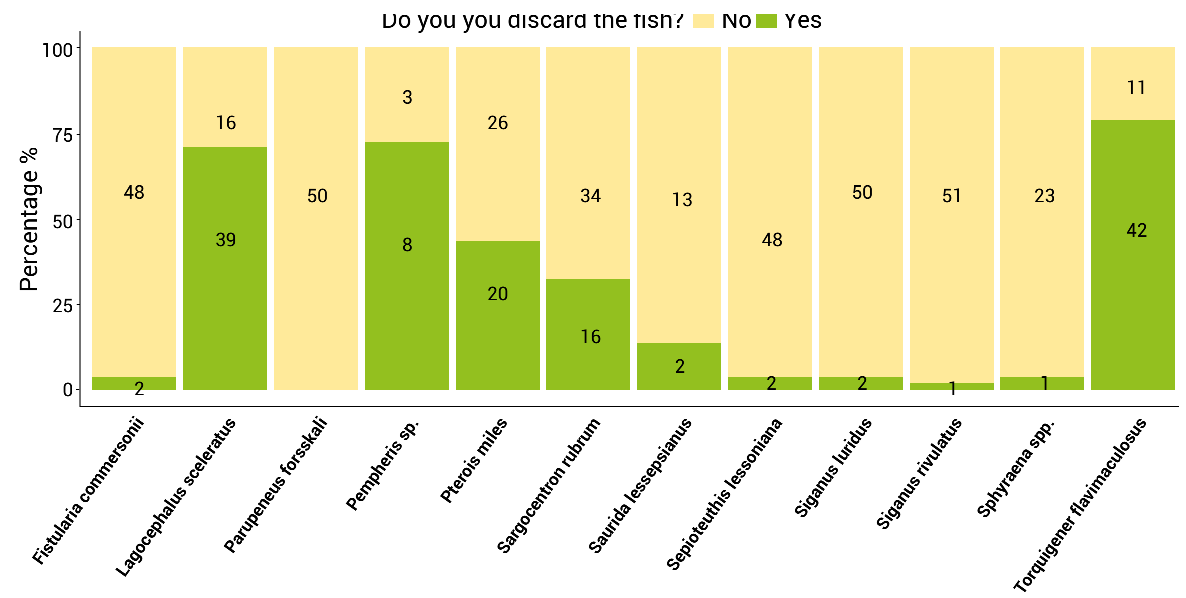

Figure 9

Discard rates of each non-indigenous species according to the fishers' responses.

A significant (χ^2-test; P<0.05) heterogeneous pattern was observed regarding the responses about the frequency of fishing of NIS between recreationals and professionals. In particular, professionals stated significantly (χ^2-test; P<0.05) higher fishing frequencies (>50% of their fishing effort) targeting *Fistularia commersonii, Sargocentron rubrum, Siganus luridus* and *Siganus rivulatus*. In contrast, recreationals stated significantly (χ^2-test; P<0.05) higher percentages (>50% of their fishing effort) for *Lagocephalus sceleratus, Torquigener flavimaculosus* and *Sepioteuthis lessoniana*. For the remaining species (i.e., *Parupeneus forsskali, Pterois miles, Sphyraena chrysotaenia/flavicauda, Pempheris* sp. and *Saurida lessepsianus*) both the majority of recreationals and professionals fishers responded low fishing effort (< 20%) on these species.

Similar with the fishing intensity, the species contribution to the total catch also exhibited a heterogeneous pattern between the recreationals and professionals. In particular, both recreationals and professionals agreed (χ^2-test; P>0.05) about the high contribution (>20%) of *Siganus luridus and Siganus rivulatus* and the low contribution (<20%) of *Fistularia commersonii*, *Sphyraena chrysotaenia/flavicauda, Pempheris* sp. and *Saurida lessepsianus* on their catches. For the remaining species, professionals exhibited significantly (χ^2-test; P<0.05) higher frequency of catches compared to the recreationals for *Lagocephalus sceleratus, Torquigener flavimaculosus, Parupeneus forsskali, Pterois miles* and *Sargocentron rubrum*), while recreationals reported higher proportion of catches for *Sepioteuthis lessoniana*. Information for each type of fishery and the catches of each species are displayed in Appendix 2.

Regarding the direct damages of each NIS (due to depredation or fish gear damages), fishers reported no direct damages for all of the species except pufferfish (*Lagocephalus sceleratus* and *Torquigener flavimaculosus*). For them, there was a great variation in responses and a bigger sample is needed to reliably estimate the potential damages (*Figure 10*). About 30% of the fishers reported that they changed their fishing location (e.g. moving deeper), tools (e.g. larger mesh size), or fishing duration due to the presence of pufferfish in an area (Figure 11).

Fishers did not report any injury incident from the NIS apart from one fisher who reported three stings by lionfish over the past year (Figure 12). Finally, professional fishers stated that non-indigenous by-catches/damages increase the time of their fishing for almost one to one and a half hour per fishing (55% of the professional fishers in the survey).

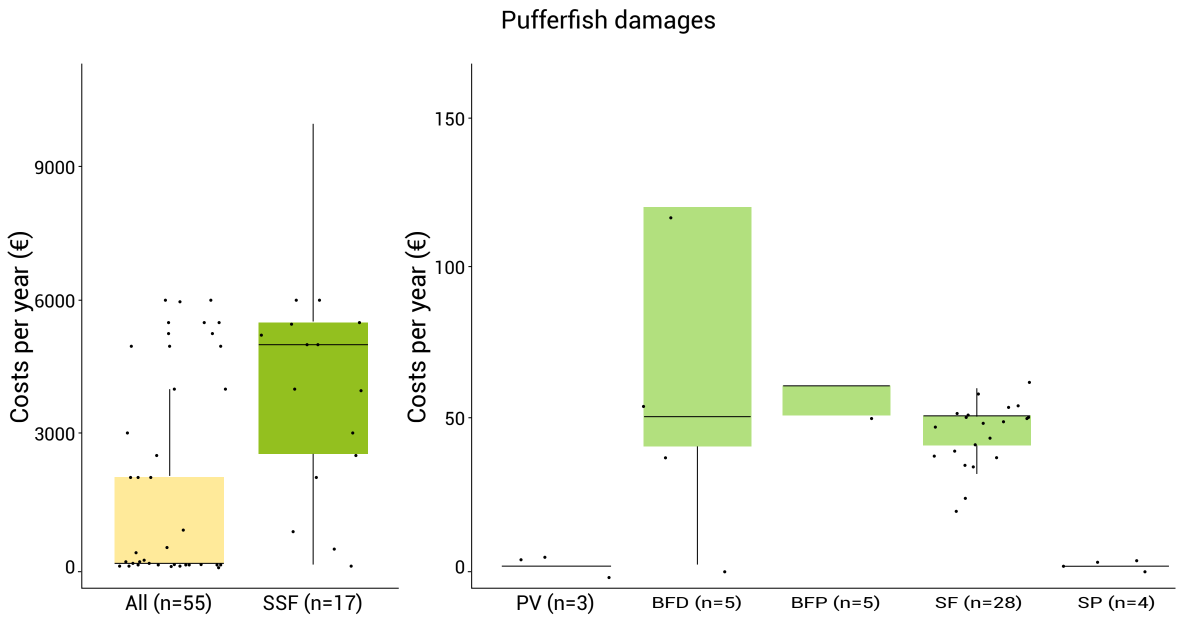

Figure 10

Costs (Euros) per year caused by direct damages of pufferfish according to the fishers' responses. SSF: Small scale fishers, PV: Polyvalent, BFD: Boat fishing demersal, BFP. Boat fishing pelagic, SF: Shore fishing, SP. Spearfishing. Grey colour shows all responses, blue colour indicates professional fishers, and yellow colour indicates recreational fishers.

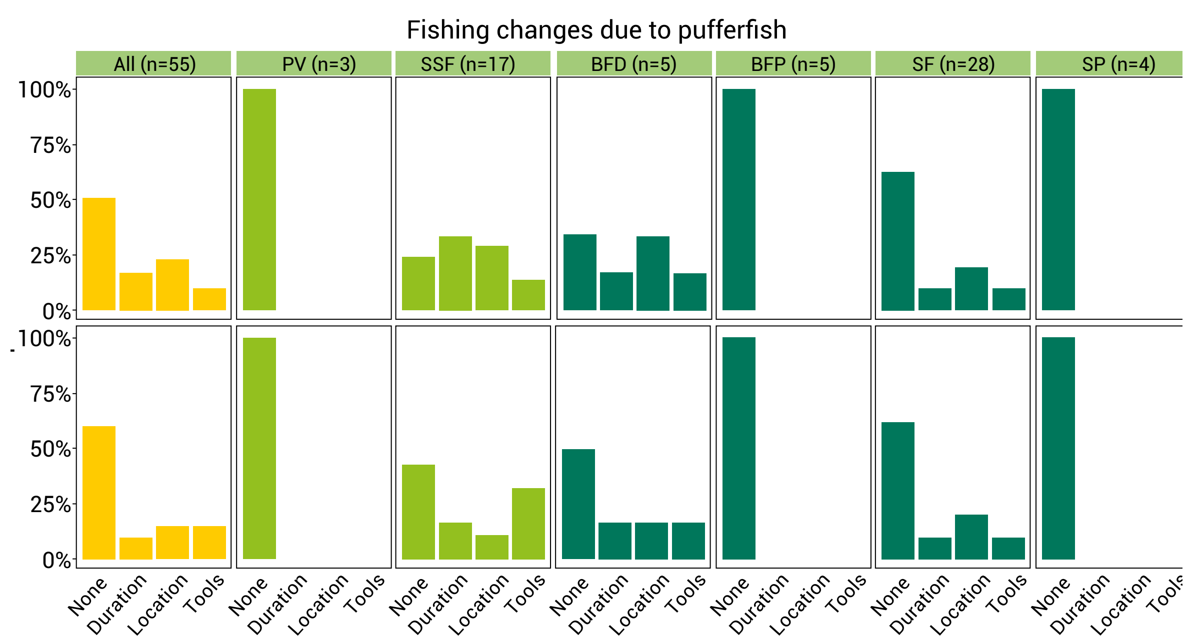

Figure 11

Reported fishing changes due to the presence pufferfish (Lagocephalus sceleratus and Torquigener flavimaculosus) in an area. SSF: Small scale fishers, PV: Polyvalent, BFD: Boat fishing demersal, BFP. Boat fishing pelagic, SF: Shore fishing, SP. Spearfishing. Grey colour shows all responses, blue colour indicates professional fishers, and yellow colour indicates recreational fishers.

4
DISCUSSION

Invasions are complex and often cause immense long-term direct and indirect impacts but these might become apparent or problematic only when invaders are well established and have large ranges; thus making their management highly challenging (Pyšek *et al.* 2020). It seems apparent that NIS now play important role in the fishing community within the Cavo Greco MPA.

According to the results of this study, non-indigenous species are contributing over a quarter of the total value of catches, and they play a particular role in the fishery industry especially in the summer period. The most popular and highly priced fish was rabbitfish (*Siganus* spp.), which was remarkably targeted by recreational fishers – especially in the summer period when they represented over half of recreational fishers catches. These results agree with Michailidis *et al.* (2020) who found that *Siganus* spp. were the most important species (in terms of weight and value) in marine recreational fishery of Cyprus.

The knowledge whether a species is non-indigenous was found to vary among species. Poisonous pufferfish were unanimously recognised as NIS, followed by the venomous lionfish, and recently (after year 2000) introduced species such as *Fistularia commerosnii, Parupeneus forsskali,* and *Sepioteuthis lessoniana* which, were recognised by the majority of respondents as NIS. Results were more contradictory for *Siganus* spp., while few fishers knew about the origin of *Pempheris* sp., *Sargocentrun rubrum, Saurida lessepsianus* and *Sphyraena* spp. The knowledge might have been affected by the year of introduction (species introduced decades ago were considered native by many fishers), interaction with fishery and human health, and exotic appearance of species.

Most negative perceptions were reported for *Lagocephalus sceleratus, Torquigener flavimaculosus,* and *Pterois miles.* On the other hand, highly priced species such as *Parupeneus forsskali, Siganus* spp.*, and Sepioteuthis lessoniana* were perceived as positive by over 90% of the respondents. The last species are among the most common in the area, therefore fishers did not perceive a species as a negative disturbance based on their high abundance as reported in other studies (e.g. Cerri *et al.* 2020) but likely affected by the price and commercial status of the species. Perceptions for *Siganus* spp. are not in agreement with studies that have shown that the presence and expansion of *Siganus* spp. has caused profound impacts on the native communities in the Mediterranean infralittoral zone through overgrazing of important algae (Giakoumi 2014; Vergés *et al.* 2014). *Siganus* spp. was also included in the 100 worst invasive species for the Mediterranean (Streftaris and Zenetos 2006). Therefore, fishers' perceptions were not in agreement with ecological research studies; highlighting the importance of acknowledging all aspects of invasions in policy making.

High discard rates were reported for lionfish (about 45%) which indicates the lack of awareness about the commercial potential and taste of the species. Lionfish market campaigns are anticipated in the LIFE RELIONMED project (www.relionmed.eu) following the examples of the USA and Caribbean to motivate public and stakeholders hunting and consumption of lionfish (Chapman *et al.* 2016); given its high nutritional value (Morris Jr *et al.* 2011). It is expected that market promotion of lionfish will increase its value, decrease its discard rates, and likely turn the perceptions towards positive. It is worth to note that in a previous study, stakeholders unanimously supported that lionfish presence is negative (Kleitou *et al.* 2019), while some fishers reported lionfish as positive in our study indicating a potential changing trend. From all NIS, it was evident that pufferfish (*Lagocephalus sceleratus* and *Torquigener flavimaculosus*) had the worst negative interactions with fishery gears, techniques, catches and operations. However, estimates were characterized by high variability indicating the importance of further studies to accurately and more reliably estimate the damages caused to each industry and type of gear.

The threat of biological invasions in MPAs and Natura 2000 sites has been largely neglected to date (Mazaris and Katsanevakis 2018). These uncertainties have inevitable consequences at decision-making and management level (Mazaris and Katsanevakis 2018). The present study highlights the discrepancy that can exist between the perceived effects of NIS for stakeholders and research studies, and the complexity of NIS management. Apparently, past damage and introductions to Mediterranean ecosystems are impossible to be reversed and may take decades to restore ecosystems even with concerted efforts. In this context, adaptation becomes highly important.

The current management strategy against Non-Indigenous Species (NIS) of the Mediterranean is based on the traditional narrative approach of NIS as only negative perturbations. An ecosystem-based fishery management approach is therefore needed which will consider both the socioeconomic and ecological trade-offs in an integrative framework. To this end, stationary monitoring stations are needed to understand ecological implications before and after invasions, while socioeconomic studies can provide some concrete results about the impacts of each species. An ecosystem based management approach and a concerted action at a Mediterranean level (e.g. through the Barcelona Convention) against each species is needed; acknowledging the transboundary character of marine invasions as well as the importance of some species that have been established for decades and form an integral part of the ecosystem and socioeconomic systems. Research, citizen science and market campaigns, and monitoring are urgently needed to improve socioeconomic profits by NIS and decisively inform management policy.

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PART 4

Marine sensitivity assessment:
Assessing the **sensitivity**
and **risk** of **degradation**
on **natural habitats**
and **species** of **community**
interest by **fishing activities**

PART 4

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1 INTRODUCTION

The fishing industry and generally the effects of fishing activities on benthic marine ecosystems is of growing concern for the past few decades among fisheries scientists, conservationists and managers (Turner *et al.* 1999). Mobile fishing gear, such as dredges and trawlers, can greatly alter the seafloor, destroying the complexity of three dimensional physical (rocky reefs) and biological habitats (e.g. seagrasses, coral reefs). These types of fishing gear as well as many others, further contribute to the phenomenon of ghost fishing (Brown and Macfadyen 2007), which continuously impacts marine life, by passively catching commercially important fish, traps animals, entangles and potentially kills marine organisms, smothers habitats, and acts as a hazard to navigation (Kaiser *et al.* 1996; Brown and Macfadyen 2007; Stelfox *et al.* 2016).

Undoubtedly the Mediterranean Sea is a hotspot of artisanal and semi-industrial fishing activities, surrounded by fishing nations all of which benefited by its resources for centuries (Hughes 2013; Goffredo and Dubinsky 2014). The amount of fishing intensity superimposed in the marine ecosystems of the Mediterranean Sea has severely reduced the fish stocks as well as the integrity of numerous habitats including seagrasses (i.e. *Posidonia oceanica,* and *Cymodocea nodosa*), reefs (biogenic concretions or of geogenic origin), and sea caves. Such habitats play a critical role in ecosystem functioning, structuring, and they are identified as habitat types for conservation under the EU's Habitats Directive (Dir 92/43/CEE) i.e. 1110 - Sandbanks which are slightly covered by sea water all the time, 1120 - *Posidonia* beds, 1170 – Reefs, and 8330 – Submerged and Partially Submerged Sea caves.

Despite the EU's legal environmental framework, which is revolved around the Natura 2000 Network, economic activities are still allowed within Natura 2000 sites. Although not obligatory, for each of these sites a management plan should be implemented, which will be based on a legal management framework, consisting of regulatory decrees, sustainable development, conservation and monitoring actions (Kati *et al.* 2015). These will ensure the compatibility of socio-economic activities with safeguarding the valuable species and habitats, since many of such activities interact with the priority habitats or species that have justified the designation of the site (Evans 2012; Kati *et al.* 2015); in some cases they can inflict a great deal of damage and cause negative impacts when these are characterised as harmful, illegal and intense human activities (Kati *et al.* 2015).

When it comes to the marine environment, fishing is among the most prominent activities, and because of its variable nature in fishing techniques and fishing gears used, the impact on marine benthic habitats will greatly vary. To ensure that fishing activities can co-exist with sensitive species, a sensitivity assessment and risk of degradation is a critical step prior to the finalization of any management plan.

The Specially Protected Areas Regional Activity Centre (SPA/RAC) commissioned this project to generate an improved understanding of the sensitivities of seagrass beds to pressures associated with fishing activities in the marine environment of Cape Greco peninsula, Cyprus. Cape Greco is a Natura 2000 area, which was recently designated as a Marine Protected Area that revolves three major zones: the No Take Zone, Buffer Zone and the Wider Zone. Specifically, the aim of this work is to conduct a sensitivity assessment and risk of degradation on benthic habitats of the MPA by various fishing activities. This work will provide an evidence base that will facilitate and support management advice for Natura 2000 sites as well as Marine Protected Areas, the development of Cyprus marine monitoring and assessment, and conservation advice to the fishing industry.

2 METHODS

The study adopted the methods of Rivière *et al.* (2016), a similar approach to that of the Marine Evidence based Sensitivity Assessment (MarESA) (Tyler and Tillin, 2018) developed in the United Kingdom, to assess the sensitivity of seagrass *P. oceanica* beds, Reefs and Sandbanks in the MPA of Cape Greco to the fishing activities. The methodology aims to be (i) pragmatic (ii) applicable to all benthic habitats and relevant human pressures (iii) consistent (insofar as possible) with other equivalent European methodologies, iv) able to produce standardised results at a national level, v) adaptable to both site-scale and regional scale marine management (under the HD, MSFD, OSPAR, etc.), and (vi) based on best available knowledge. The evaluation of benthic habitat sensitivity is based principally on expert judgement (drawing on available scientific literature wherever possible), following recommendations from Mcbride *et al*. (2012) and Barnard and Boyes (2013)

2.1. Definition of sensitivity, resistance and resilience

The 'concept' of sensitivity has been applied for many decades in coastal and marine habitats. Numerous approaches have been developed, applied at a range of spatial scales, and to a variety of management questions (Roberts *et al.* 2010). The most common approaches define 'sensitivity' as a product of the combination of two separate parameters: resistance (the ability of a habitat to tolerate a pressure without a significant change in its biotic and abiotic characteristics.) and resilience (the time needed for a habitat to recover, once the pressure in question has been alleviated). These were first described by Holling (1973) and are used to assess sensitivity under the OSPAR convention (Texel-Faial criteria) and under French MSFD legislation (MEDDE, 2012).

Resistance is an estimate of an individual's, a species population, and/or a habitat's, ability to resist damage or change as a result of an external pressure. It is assessed in either quantitative or qualitative terms, against a clearly defined scale. While the principle is consistent between approaches, the terms and scales vary. Resistance and tolerance are often used for the same concept, although other approaches assess 'intolerance', the scale which is the reverse of resistance, i.e. a species that is highly intolerant has low resistance and a species with low intolerance has high resistance.

Resilience is an estimate of an individuals' species population, and/or a habitat's, ability to return to its prior condition, or recover, after the pressure has passed, been mitigated or removed. The term resilience and recovery are often used for the same concept and are effectively synonymous.

Sensitivity can, therefore, be understood as a measure of the likelihood of change when a pressure is applied to a feature (receptor) and is a function of the ability of the feature to tolerate or resist change (resistance) and its ability to recover from impact (resilience). The concepts of resistance and resilience are widely used in this way to assess sensitivity. Therefore, sensitivity is assessed as a combination of these two parameters, with a final score for each habitat derived from its resistance and resilience scores to each pressure. A species with high sensitivity is one that has low resistance to human pressures and recovery is not achieved or if it is achieved it happens over a prolonged period (OSPAR, 2008).

Sensitivity is an inherent characteristic determined by the biology/ecology of the feature (habitat or key species) in question. But it is a 'relative' concept as it depends on the degree (expressed as magnitude, extent, frequency or duration) of the effect on the feature (habitat or key species). Therefore, sensitivity assessment uses a variety of standardized thresholds, categories and ranks to ensure that the assessments of 'relative' sensitivity are comparable. These are:

- standard categories of human activities and natural events, and their resultant 'pressures' on the environment
- descriptors of the nature of the pressure (i.e. type of pressure, e.g. temperature change, physical disturbance or oxygen depletion)
- descriptors of the pressure (e.g. magnitude, extent, duration and frequency of the effect) termed the pressure benchmark
- descriptors of resultant change/damage (intolerance/resistance) (i.e. proportion of species population lost, area of habitat lost/damaged)
- categories or ranks of recovery (recoverability/resilience) thought to be significant; and
- final ranks of sensitivity and/or vulnerability

A range of factors determine how species react to pressures in the marine environment. These are broadly determined by species' characteristics. Biological traits and habitat preferences of a species dictate resistance and resilience and ultimately sensitivity.

As such, the crucial aspects of these traits must be understood. The definitions of sensitivity, resistance and resilience can be seen in Table 1.

Table 1
Definition of sensitivity and associated terms (Rivière et al. 2016).

Term	Definition	Additional Sources
Sensitivity	The combination of a habitat's capacity to tolerate a pressure (resistance) and the time needed to recover after an impact (resilience)	Tyler-Walters et al. (2001)
Resistance (Intolerance / tolerance)	The ability of a habitat to tolerate a pressure without significantly changing its biotic or abiotic characteristics.	Holling (1973)
Resilience (Recoverability)	The time a habitat needs to recover from the effect of a pressure, once that pressure has been alleviated.	Holling (1973)
Anthropogenic Pressure	The mechanism through which a human activity can have an effect on a habitat. Pressures can be physical, chemical or biological. The same pressure can be caused by a number of different activities.	Robinson et al. (2008)
Exposure	The presence of a pressure in/on a habitat. Levels of exposure to a pressure can vary temporally (according the pressure's frequency and duration) and spatially (according to the pressure's distribution).	
Habitat:	Terrestrial or aquatic areas distinguished by geographic, abiotic and biotic features, whether entirely natural or semi-natural (Directive 92/43/EEC).	
Impact (= Effect)	The consequences of a pressure on a habitat where a change in its biotic and/or abiotic characteristics occurs	
Intensity	The combination of magnitude, frequency and duration of a pressure	
Risk of impact (=Vulnerability)	The combination of the likelihood that a feature is exposed to a pressure to which it is sensitive and its sensitivity to that pressure	

2.2. Sensitivity Assessment Methodology

Evidence based sensitivity assessment involves a detailed literature review and compilation of the evidences on the effect of a given pressure on the feature (species or habitat) in question, at the pressure benchmark or predicted level of effect, on a pressure by pressure basis (Figure 1; Table 2). The sensitivity assessment process identifies 'elements' of the feature that are important for the structure and functioning of the community or characteristic (dominant) in the habitat, based on the literature review.

Habitat sensitivity assessment assumes that the sensitivity of a habitat is dependent on the physical nature of the habitat, and the sensitivity of the species that make up the community present. In practice, communities can be composed of many tens or hundreds of species. Therefore, the species identified as important for the structure and functioning of the community or characteristic of the habitat are used to focus the assessment.

In this case the habitat sensitivity is assessed at the "biocenosis" level (which takes into account biotic and abiotic components), under the following habitat classification systems:

- *The French Mediterranean benthic habitat classification (Michez et al., 2014)*

Relationships between the French classification and other classifications/habitat lists (EUNIS, OSPAR, HD Annex I, etc.) are available through the INPN (HABREF register).

To facilitate the assessment of features, pressure definitions were established. from existing lists of pressures under the MSFD (Annex III Table 2) and OSPAR (ICG-C pressures list, OSPAR 2011).

The sensitivity assessment involves the following stages.

i) Identifying the key biotic and abiotic elements affecting habitat sensitivity

ii) Assessing the habitat's resistance to the pressure in question

iii) Assessing the habitat's resilience to the pressure in question

iv) Combining resistance and resilience scores to generate an overall sensitivity score

v) Assess confidence of the scores

vi) Supporting evidence provision through bibliographic review

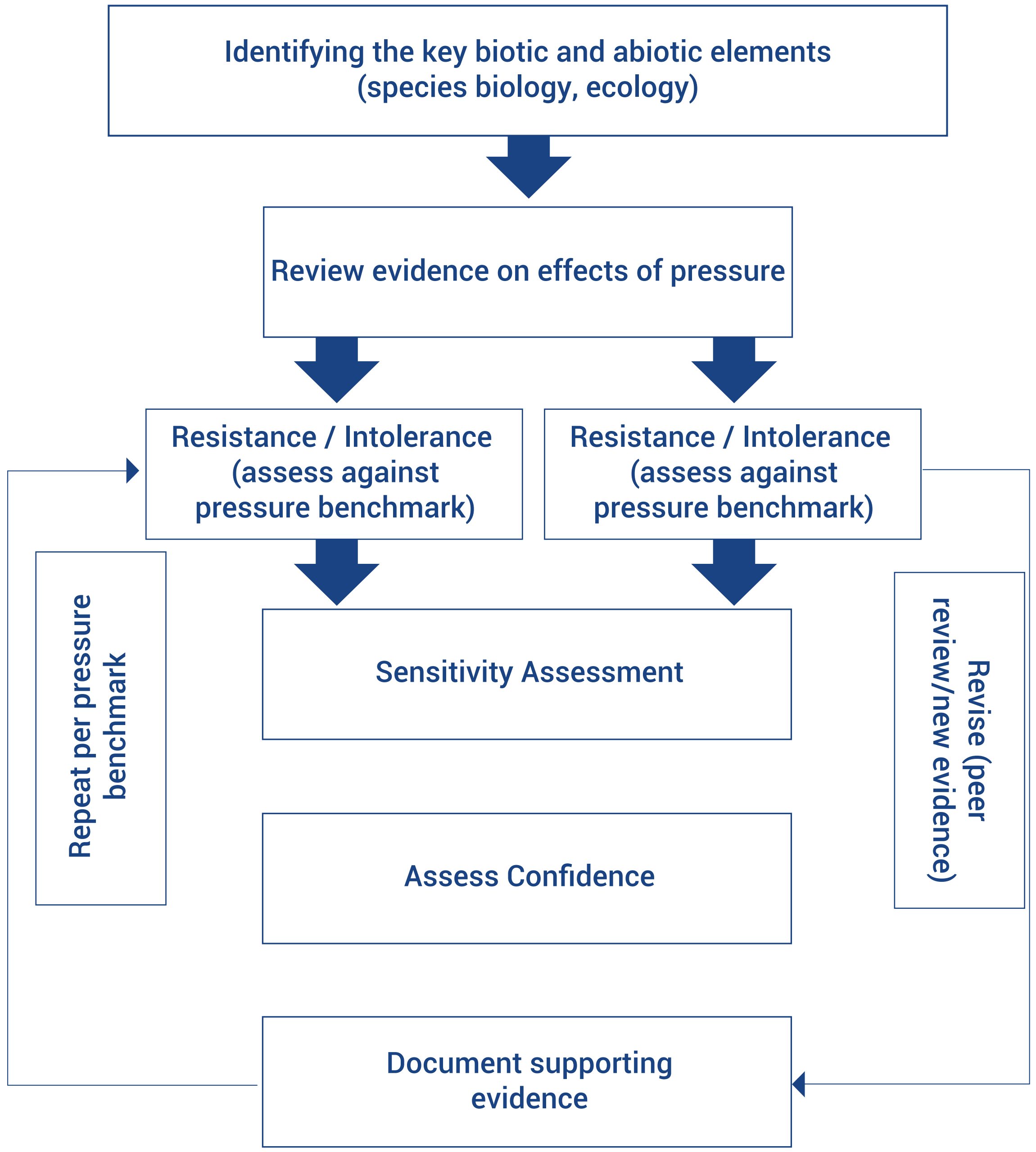

Figure 1
Overview of the sensitivity assessment process.

2.2.1. Defining the key biotic and abiotic elements

In order to assess sensitivity, elements of the habitats/biotopes must be selected as the basis of the assessment. The assessment of sensitivity should be guided by certain criteria including:

Characteristic, structuring and/or engineer species' life traits (Box 1; Table 2)

Substratum type

Hydrodynamic conditions

Bathymetric range

In this study, the key focusing species is *Posidonia oceanica* and is addressed as an engineer species (Table 2).

Box 1. Factors affecting benthic species' sensitivity

The following factors may affect the resistance and/or resilience (and thus sensitivity) of benthic species:

i) Size and shape (growth form)
ii) Substratum position (e.g. epibenthic, infaunal, free-living)
iii) Depth in substratum (e.g. shallowly or deeply burrowed)
iv) Mobility/ability to move freely (e.g. permanently/temporarily attached, burrower, crawler, swimmer etc.);
v) Flexibility and fragility;
vi) Dependence on type of substratum
vii) Dependence on hydrodynamic conditions
viii) Lifespan, growth rate, regeneration rate, age at sexual maturity
ix) Reproduction mode and rate, larval dispersion capacity, recruitment rate, vegetative propagation, propagules.

Table 2
Types of species identified for assessment. Definitions adapted from Rivière *et al.*, (2016).

Category	Description
Characteristic species	A species that is exclusive or preferential for the biotope considered, whether it is represented widely or not, sporadic or not (PNUE-PAM-CAR/ASP, 2002).
Structuring species:	A species that provides a distinct habitat which supports an associated biological community. Degradation or loss of this species would result in degradation or loss of the associated community but not necessarily the habitat (Tyler-Walters *et al.*, 2001) (e.g. gorgonians in a Mediterranean coralligenous habitat)
Engineer species	A species that creates, modifies or maintains a habitat by causing physical state changes in biotic and abiotic materials, that directly or indirectly, modulate the availability of resources to other species (Jones et al., 1994). Degradation or loss of this species would result in degradation or loss of the habitats it creates (e.g. calcareous algae of the coralligenous habitat). An engineer species is a structuring species, but the inverse is not true.

2.2.2. Resistance (tolerance) and Resilience to a defined intensity of pressure

The resistance and resilience of the key elements are assessed against the predicted level of each pressure (magnitude, extent, duration, and/or frequency) using the available evidence. Four assessment scales were defined for **resistance** (**Table 3**).

Table 3
Assessment scale for resistance (tolerance) (Rivière *et al.* 2016).

Resistance	Description
None	Habitat destruction, corresponding to a total loss of biotic characteristics (e.g. disappearance of characteristic, structuring and/or engineer species) and abiotic characteristics (e.g. loss of the substratum) potentially causing a change of habitat type.
Low	Severe degradation of a habitat, corresponding to a major loss of its biotic characteristics (e.g. major decline in characteristic, structuring and/or engineer species) and abiotic characteristics (e.g. severe degradation of the substratum) potentially causing a change of habitat type.
Medium	Some modification of the habitat's biotic characteristics (e.g. decline in characteristic, structuring and/or engineer species) or abiotic characteristics (e.g. substratum degradation) without changing the habitat type.
High	No notable modification of the biotic or abiotic characteristics of the habitat. Some biological processes, like feeding, respiration and reproduction rates may be affected, but no effect on population viability of characteristic, structuring and/or engineer species.

Five assessment scales were defined for **resilience** (**Table 4**). Resilience assumes that the pressure has been alleviated or reduced. Full recovery is a return to the state of the habitat prior to impact, i.e. to a structurally and functionally recognisable habitat and its associated biological community. This does not necessarily means a return to prior condition, exact community composition, abundance or extent, nor to a hypothetical original ("reference") state. A habitat's recovery is determined by its capacity for regeneration or recolonization (by adults, larvae, spores or propagules of its associated species).

Table 4
Assessment scale for resilience (recovery) of benthic habitats.

Resilience	Description
None	Negligible or prolonged recovery possible; at least 25 years to recover structure and function
Low	Full recovery within 10-25 years
Medium	Full recovery within 2-10 years
High	Full recovery within 2 years
Very High	Full recovery within 1 year

2.2.3. Resistance and resilience combined to derive an overall sensitivity score

The resistance and resilience scores can be combined, to give an overall sensitivity score as shown in **Table 5** for benthic habitats and key species. The following option can also be used for pressures where an assessment is not possible or not felt to be applicable (this is documented and justified in each instance):

Not applicable (NA) – is recorded where the evidence base suggests that there is no direct interaction between the pressure and the habitat or species of interest.

Table 5
The combination of resistance and resilience scores

	Resistance			
Resilience	None	Low	Medium	High
None	Very High	High	High	Medium
Low	High	High	Medium	Medium
Medium	High	Medium	Medium	Low
High	Medium	Medium	Low	Low
Very High	Low	Low	Low	Very Low

2.2.4. Confidence Assessments

A confidence index is assigned to each assessment (resistance, resilience, sensitivity) as an indication of the quality of supporting evidence. Wherever possible, assessments are based on empirical data demonstrating the resistance and/or resilience of benthic habitats. Where such information is lacking, assessments are based on expert judgment (informed by recommendations set out by Mcbride *et al.* (2012) and Barnard and Boyes (2013).

Confidence scores are derived from the combination of three aspects for each resistance and resilience assessment (**Tables 6** and **7**):

- Quality of information sources: expert judgement, peer-reviewed papers, grey literature, etc.
- Applicability of evidence: the same habitat/area/pressure is evaluated
- Degree of concordance of evidence and quantity of evidence available.

These three aspects are weighted according to their relative importance in order to derive an overall confidence score. Quality and Concordance are considered the most discriminating factors (weighting scale from 0 to 2), while more flexibility is ascribed to Applicability (weighting scale from 1 to 3).

Resilience and resistance confidence scores are then combined to derive the sensitivity assessment's confidence score (**Table 8**).

Table 6
Confidence assessment categories for the evidence found.

Confidence Level	Quality of Information Sources	Applicability of evidence	Degree of Concordance
High	Based on peer reviewed papers (experiments and. observational studies) on the habitat	Assessment based on the same pressure acting on the same habitat in the same geographical area (Mediterranean Sea, Atlantic, English Channel-North Sea)	Many studies at multiple sites with high concordance of resistance and resilience assessments
Medium	Based on some peer reviewed papers, mostly on grey literature reports or expert judgment on the habitat or similar habitats	Assessment based on the same pressure acting on the same/equivalent habitat in a different geographical area	Few studies, or studies on a single site, or discrepancies in resistance or resilience assessments
Low	Based on expert judgement in the absence of sufficient or reliable published evidence	Assessment based on proxies for pressures (e.g. natural disturbance events) or on a similar habitat	Discrepancies in resistance and resilience assessments

Table 7
Combining the three confidence assessment category scores to derive a resistance or resilience confidence score.

Quality	Applicability	Concordance Low - 0	 Medium - 1	 High - 2
	Low - 1			
Low - 0	Medium - 2		0 -Low	0 -Low
	High - 3			
	Low - 1		1 -Low	2 -Medium
Medium - 1	Medium - 2	0 -Low	2 - Medium	4 -Medium
	High - 3		3 - Medium	6 -High
	Low - 1		2 - Medium	4 -Medium
High - 2	Medium - 2		4 - Medium	8 -High
	High - 3		6 - High	12- High

Table 8
Combining the resistance and resilience confidence indices (CI) to derive the sensitivity confidence score

		CI Resilience Low	 Medium	 High
CI Resistance	Low	Low	Low	Low
	Medium	Low	Medium	Medium
	High	Low	Medium	High

2.2.5. Documented evidence base

The evidence base and justification for the sensitivity assessments is presented to enable transparency and repeatability. Specifically, a complete account of the evidence that was used to make the assessments is presented for each sensitivity assessment in the form of the literature review and a summary of the assessment, the sensitivity scores, and the confidence levels.

2.3. Human activities and pressures

A pressure is defined as 'the mechanism through which, an activity has an effect on any part of the ecosystem' (Robinson *et al*. 2008). In this case, a pressure is considered as the mechanism by which an anthropogenic activity may influence a receptor (a population of an Ecological Group). Pressures can be physical (e.g. sub-surface abrasion or damage), chemical (e.g. organic enrichment) or biological (e.g. introduction of non-native species).

An activity may give rise to more than one pressure (**Figure 2**). For example, a number of pressures are linked to trawling, such as increased silting and smothering, increases in turbidity and the introduction of underwater noise and vibrations. It should be noted that the same pressure can also be caused by a number of different sources (**Figure 2**), for example, noise can be caused by the trawler while it dredges the seafloor, but also by the vessel that will be operating above the fishing area.

Rather than assessing the impact of activities as a single impact, the pressure-based approach supports clearer identification of the pathway(s) through which impacts on a feature may arise from the activity. If the pressures are not separated, then it could be difficult to identify the stage in the operation that gives rise to the impact. This approach is especially useful to assess the impacts of activities that involve a number of different stages that are carried out in different habitats. Adoption of the pressure-based approach means that a wide range of evidence, including information from different types of activities that produce the same pressures, field observations and experimental studies can be used to inform sensitivity assessments.

Nonetheless, it is important, in a management context, to retain information on sensitivity to all pressures associated with an activity in case changes in how that activity is practised (e.g. fishing gear modifications) leads to the reduction/elimination of certain pressures. Thus, here the sensitivity assessment was carried out based on the risk posed by each associated pressure individually and then the scores were aggregated by each fishing activity through a theoretical assessment, by which is weighted and refined by local expert's judgment and the use of scoring system adapted by MNHN (2012) (Appendix Table 1).

This study used pressure definitions from existing lists of pressures under the MSFD (Annex III Table 2) and OSPAR (ICG-C pressures list, OSPAR 2011) to ensure consistency at a European level. Similar pressure definitions ensure that i) habitat sensitivity is assessed with respect to equivalent thresholds or benchmarks and ii) the relative sensitivity of different habitats can be compared.

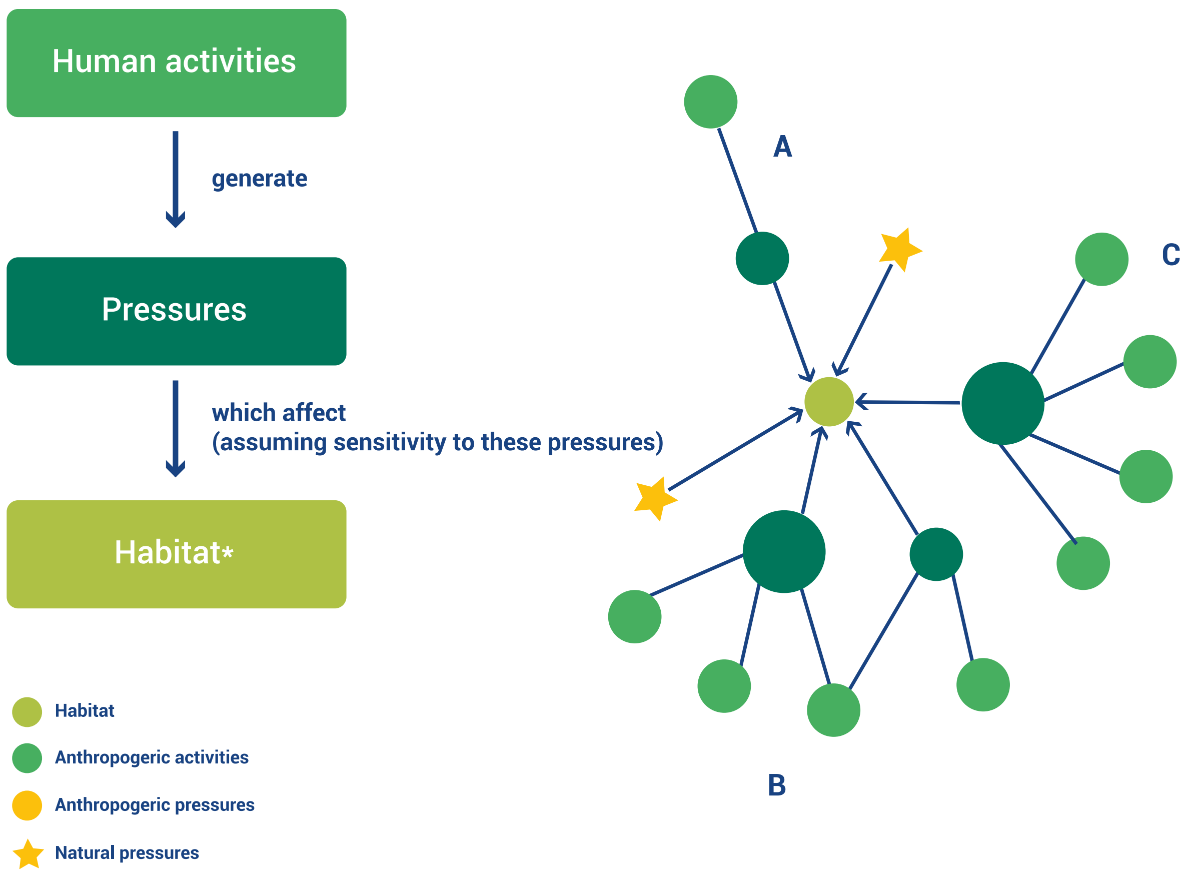

Figure 2

Overview of relationships between different sources of pressures affecting a habitat in three different scenarios. Adapted by Rivière *et al.*, (2016)

3

DESCRIPTION OF BENTHIC HABITATS OF CAPE GRECO

3.1. Ecological Services

Sandbanks are found in coastal and shelf areas, where currents act in conjunction with coastal or seabed topography to move and accumulate mobile sediments in a wide variety of forms (Kaiser *et al,* 2004) Sandbanks may hold their own distinct assemblage of flora (e.g. *Cymodocea nodosa* in the case of Mediterranean Sea) and fauna adapted to the conditions of this habitat (Ellis *et al*., 2011; Atalah *et al*., 2013; Markert *et al*., 2015). Sandbanks are of considerable importance in stabilising coastlines, preventing erosion, and may act as nursery grounds for a number of commercially exploited species of fish in Northern Europe (Dyer and Huntley, 1999; Atalah *et al*., 2013).

Mediterranean shallow rocky reefs are very productive and diverse ecosystems providing important provisioning, regulating and cultural ecosystem services (Salomidi *et al.* 2016). Rocky/biogenic reefs are enhanced in structure, complexity and ecosystem functioning by macroalgal communities, such as *Cystoseira* forests (Cheminée *et al.* 2013), rhodoliths, coralligenous assemblages (Fredericq *et al.* 2019) and sessile gastropods (i.e. vermetids) (Safriel 1975). The associated rocky reef fish assemblages are also of high ecological importance, since they play a fundamental role in the functioning of reef ecosystems by regulating food web dynamics and nutrient releases, thus securing ecosystem stability and resilience, and the flow of respective services to humans (Holmlund and Hammer, 1999). Overall rocky reefs, not only support a great variety of species including fishes, invertebrates and algae, but their importance also lies on the ecosystem services they provide such as food, coastal protection from storms, wave energy or sediment transportation, and also as the main source of income for local communities throughout fisheries or tourism (Sánchez-Rodríguez *et al.* 2015).

Seagrasses are among the most valuable ecosystem service providers (Unsworth *et al.* 2014) and one of the most productive ecosystems at global scale (Costanza *et al.* 2014). Overall, they support great biodiversity, provide refuges, nursery and reproduction grounds to ichthyofauna and invertebrate species, purifies water, protect the coastline from erosion and mitigate the effects of climate change by their exceptional carbon storing properties (Beer 2001; Larkum 2006; Mcleod *et al.* 2011). More specifically *P. oceanica* has been associated with many provisioning, regulating and cultural services (Table 9), all of which their estimated summed economic value contribution to human well-being ranges between 28,500 and 51,500 €/km^2/year, whereas the species itself is valued to a range between 21.2 million and 43.9 million €/year (Campagne *et al.* 2014).

Table 9
Ecological Services of *Posidonia oceanica* and the meadows it forms. Adapted by Campagne et al. (2014).

Type	Division	Description
Provisioning	Materials	Dead leaves used as bioindicator, roof isolation, industrial water waste absorbents
		Use as food for cuttle and compost
Regulation & Maintenance	Mediation of waste, toxics and other nuisances	Water Purification by filtration
		Sequestration of nutrients and contaminants
		Sequestration of nutrients and contaminants by organisms living in and on the P. oceanica meadows and dead or alive organisms within the matte
		Sound wave reduction by the formed banquettes and the meadows near the coastline
	Mediation of flows	Coastline erosion protection by P. oceanica banquettes
		Decrease of wave power and currents in P. oceanica beds
	Maintenance of physical, chemical, biological conditions	Habitat for many species: living area, nursery, spawning ground, protection area from predators, hunting area, source of food
		Habitat for protected species
		Limitation of invasive species like Caulerpa taxifolia
		Stabilization/consolidation of seabed and/by sediments depositions: matte development
		Increase of fauna diversity and micro-organisms and thus, increase of physico-chemico processes in the soil
		Water Oxygenation
		Nutrient Cycling
		Carbon sinks and sequestration in the plants, the matte and the trapped sediments
Cultural	Physical and intellectual interactions	Visit of P. oceanica meadows: Snorkelling and glass bottom boats
		Fishing cuttlefish, angling in the P. oceanica meadows
		Research subject
		Education opportunities
		Cultural value and heritage
		Artistic inspiration: theatre, painting, sculpture
	Spiritual, symbolic other interactions	Emblematic species in the Mediterranean Sea
		Enjoyment of wild and charismatic existing species
		Willingness to preserve for future generation

3.2. Habitat distribution in Cape Greco

The MPA of Cape Greco is mostly dominated by sandy bottom (Figure 3A), where some areas are associated with the seagrass *C. nodosa* as well as with the alien *Halophila stipulacea* and *Caulerpa taxifolia* var. *distichophylla*. *Cymodocea nodosa*, is commonly found within enclosed and well protected bays on sand beds down to 10 m depth, whereas the two formers may extend to deeper waters down to > 30 m. Rocky reefs are also rather abundant along the shallow range of the coastline, although hard bottom extends to the deeper areas of the MPA (Figure 3B). *P. oceanica* beds are formed all around the MPA (Figure 3C) at depths ranging from 5 to approximately 40 m. Large and dense meadows are met at 10 to 25 m depth, with the healthiest observed at the tip of the peninsula.

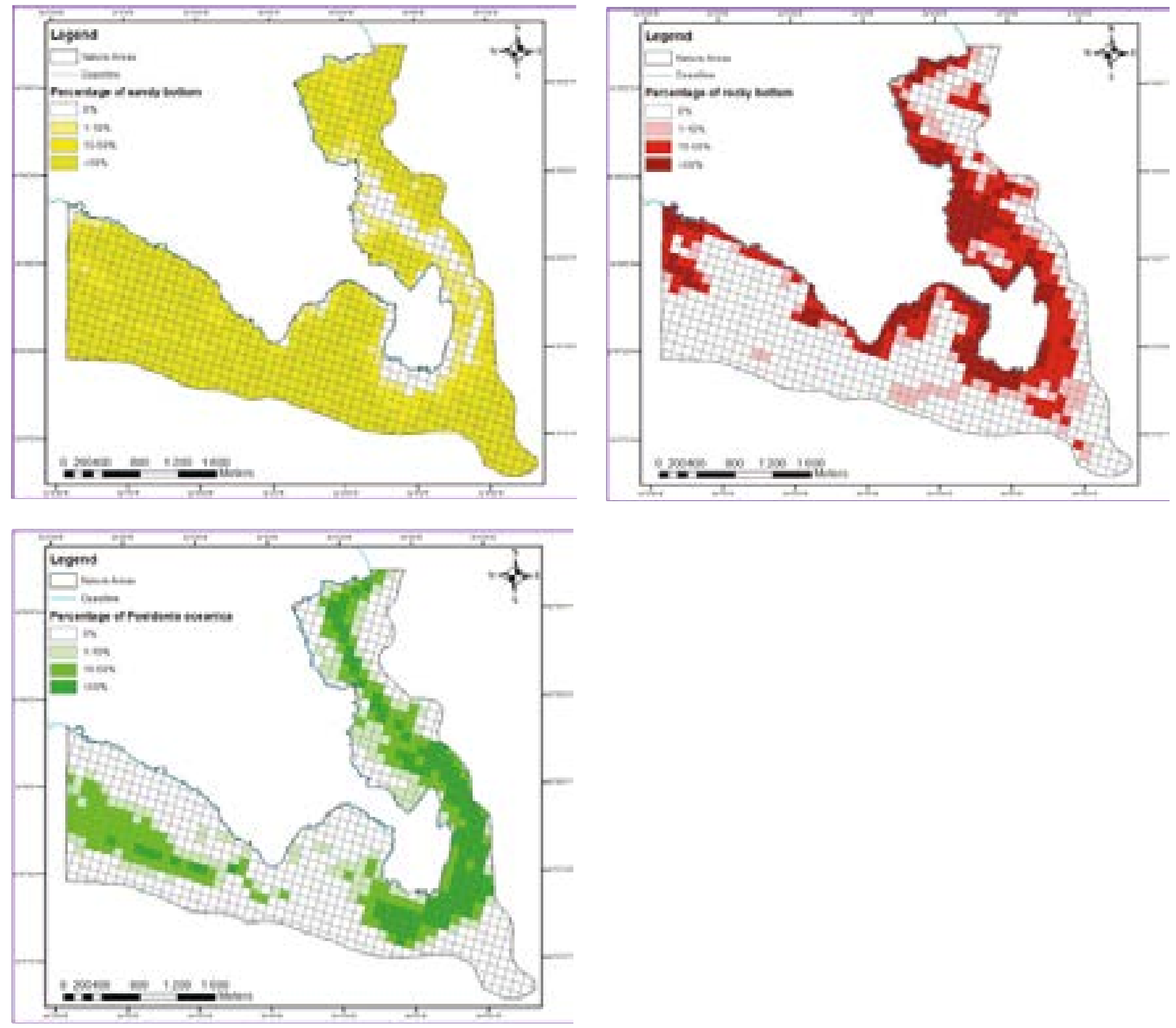

Figure 3
Percentage of cover of benthic habitats in the MPA of Cape Greco. Adapted by DFMR, 2013

3.3. Biology and Ecology

Sandbanks, as described by the Manual of European Habitats, is a habitat complex that can encompass a variety of soft bottoms. They consist mainly of sandy sediments, but larger grain sizes, including boulders and cobbles, or smaller grain sizes including mud may also be present. Water depth is seldom more than 20 m below surface waters. These can be in the form of non-vegetated sandbanks or sandbanks with vegetation belonging to the *Zostera* marina and *C. nodosa.* The latter is the key characteristic feature in this habitat in Cyprus. *C. nodosa* is a fast growing and tolerant, species which can withstand a variety of environmental conditions and as a consequence is widely distributed in Mediterranean coastal waters, including high-energy and degraded environments, whereas *P. oceanica* meadows are not able to thrive (Lardi *et al*., 2015). It can co-occur with other seagrasses in mixed meadows and has been observed to grow in association with opportunistic macroalgae (Lardi *et al*., 2015). Sandbanks are habitats that host epibenthic and infauna assemblages, including fish (e.g. *Xyrichtys novacula*, *Bothus podas*), crustacea (e.g. *Bathyporeia* sp.), mollusca (e.g. *Donax venustus*) and *polychaetes* (*Capitellidae* sp., *Orbiniidae* sp., *Paraonidae* sp., and *Spionidae* sp.) (Knittweis *et al*. 2017).

Eastern Mediterranean shallow reefs are characterised by both abiotic and biotic formations (rocky and biogenic nature). More specifically, at the intertidal level, reefs are mostly formed by the successional growth of rhodoliths and the gastropod vermetids (i.e. *Dendropoma* spp.), providing key ecosystem functions and services (Milazzo *et al*., 2017), by protecting the shoreline from wave erosion (Chemello and Silenzi 2011), acting as carbon sink and being nursery and refuge habitats from predators for many diverse species assemblages (Donnarumma *et al*., 2014). The growth of such biogenic reefs is extremely slow due to their peculiar reproduction characterized by low connectivity and dispersal range and the low recruitment via nearby reefs (Calvo *et al*., 1998). Both rocky and biogenic reefs harbour hundreds of species of algae and invertebrates, but they tend to be dominated in cover and biomass by macrophytes (Zabala and Ballesteros, 1989). In particular, the least impacted communities are often dominated by prominent canopies of *Fucales*, mostly *Cystoseira* spp. (Cheminée *et al*. 2013) that are in many ways analogous to the kelp forests of other temperate rocky coasts, adding an exceptional value to the reef system, and enhancing the fish and vertebrate diversity (Vergés *et al*. 2009). The growth of *Cystoseira* forests on reefs is variable depending on the hydrological regimes. For instance, the high hydrodynamism in *Cystoseira* forests of exposed shores allows species thriving in these environments to maintain a high nutrient uptake enhanced by turbulence, which results in high production values (Ballesteros 1989). In contrast, the growth of seaweeds in wave sheltered calm waters is more limited by nutrients because the low rate of water renewal results in rapid nutrient depletion in the boundary layer during intense photosynthesis (Gerard 1982). Additionally, herbivores are likely to exert a stronger pressure on sheltered algal communities because these habitats are slightly deeper and always available, whereas *Cystoseira* spp. that inhabit wave exposed habitats are only available to fish during unpredictable calm periods when turbulence does not hinder feeding.

Seagrass meadows can be highly dynamic, changing as a result of natural fluctuations (i.e. herbivory rates, temperature, nutrients, intraspecific competition, light) and anthropogenic influence (i.e. pollution, physical damage, siltation). The endemic *P. oceanica* is the most important of all the three found in Cape Greco. This is attributed to its suite biological traits, which allow it to provide a greater and stable habitat formation on the seafloor, hence greater biodiversity (Beer 2001). These include the development of large and thick leaves, large rhizome, characterised by high biomass production, patchy flowering, few larger seeds, rapid seed germination, and high longevity but slow turnover rates, able to hold space on the long-term (Beer 2001).

More specifically, *P. oceanica* forms persistent monospecific meadows with different types of coverage pattern (continuous to patchy with leopard-skin, in row distributions) (Borg *et al*., 2005) with shoot densities ranging from meadows where densities range between 150 and 300 shoots m^{-2} (very sparse bed) to more than 700 shoots m^{-2} (very dense bed) (Marbà *et al*. 1996). The shoots are borne by rhizomes growing either vertically (orthotropic rhizome), avoiding burial, or horizontally (plagiotropic rhizome), enabling colonization. The progressive silting and the two types of rhizome growth result in a typical terraced formation called 'matte' consisting of the intertwining of various strata of rhizomes, roots, and sediment. This matte formation indicates very high rates of carbon sequestration. In fact, compared to other seagrasses, *P. oceanica* is identified as the most efficient carbon sink from all seagrass species (Mateo *et al*. 2006), a crucial ecosystem service in regards to climate change mitigation (Mcleod *et al*. 2011). The horizontal growth (rhizome elongation) of a meadow is relatively slow, ranging from 1-7 cm rhiz^{-1} year^{-1} (Marbà *et al*. 1996; Marbà and Duarte 1998), a trait that makes it vulnerable to human disturbance (i.e. direct physical damage and deterioration of water quality), since meadow recovery rates are commonly outpaced by the anthropogenic regression rate within human-time scales (Duarte, 1995).

P. oceanica requires a rather stable substratum, preferring a coarse-grained sandy seafloor but ranging from soft substrata (from fine sand to pebbly, but not muddy sediments) to rock (Mazzella *et al*., 1993). Seasonality does not affect much the meadow per se but can induce shifts in shoot biometry and consequently on the overall biomass of the bed. For instance, seasonal variations reflect the annual cycle of leaves: appearance on the shoot, leaf fall, and growth rhythm (Bay, 1984). At 10 m depth, the turnover rates for the leaf canopy was shown to average for over an annual cycle as 1.1–1.8% day^{-1} (Bay, 1984; Gobert, 2002). The rhizome biomass shows low seasonal variability. The shoot density (number of shoots m^{-2}) in a meadow is relatively constant throughout the year (Pergent *et al*., 1995). Shoot growth is highest in February and lowest in August possibly related to nutrient availability (Romero *et al*., 2006).

3.4. Legal protection

Because of these unique functions and biological traits, *P. oceanica* is characterised as a valuable ecosystem in the Mediterranean Sea, due to the important services it provides. Its recognition has reached the European and EU environmental legislative framework and as a result to be currently protected by the Common Fisheries Policy of the European Union (EU) for the Mediterranean against trawling, is included in the reference list of priority habitats of the SPA/BIO Protocol of Barcelona Convention as well as in the Annex II of the Bern Convention as a strictly protected flora species. It is also considered as a priority habitat under the EU's Habitats Directive. Other countries protect *P. oceanica* at a national level and established its partial protection by designating hotspot areas (usually these are also designated as Natura 2000 areas) as Marine Protected Areas. Despite these legal protections, the species still remains vulnerable to anthropization as has been shown in protected and unprotected areas (Montefalcone *et al.* 2009).

Rocky/biogenic reefs and sandbanks are also protected from the EU's Habitats Directives. In respect to the former, some of its biological components are legally protected by different conventions and international initiatives. For instance, vermetid reefs are considered to be endangered habitats and have been listed in the Mediterranean Red Data Book (UNEP/IUCN/GIS POSIDONIE, 1990). They are also included in the reference list of priority habitats to guide selection of sites of conservation interest within the purview of the Barcelona Convention (UNEP-MAP-RAC/SPA, 2006). In addition, *Dendropoma petraeum* is listed in Annex II (Endangered or Threatened Species) of the Protocol for Specially Protected Areas (RAC/SPA), and the Biological Diversity in the Mediterranean Revised at the 17th COP meeting (UNEP/MAP, 2012). Lastly but not least, the vermetid reef is further included in Annex I of the European Habitats Directive under 'reefs' (code 1170), while the main builder species (calcareous red macroalgae and vermetids) are also included in the annexes of the Berne Convention. *Cystoseira* forests are also under protection. In fact, most of the species are legally protected under the Barcelona (Annex II, COM/2009/0585 FIN) and Bern (Annex I) Conventions.

3.5. Resilience and Recovery rates

Very little information is provided in the literature regarding the resistance and resilience of sandbanks, with the exception of a global review on the benthic communities recovery from the impacts of trawling (Hiddink *et al.* 2017). This study demonstrated that although benthic communities are not so resistant during the impact, they can be rather resilient. Otter trawls showed to eradicate 6% of the biota per pass and penetrating the seabed on average down to 2.4 cm, whereas hydraulic dredges caused the most degradation, removing 41% of biota and penetrating the seabed on average 16.1 cm. Recovery post-trawling ranged between 1.9 and 6.4 years, which largely depends on the availability of nearby recruits and/or maintaining local sources of recruits to repopulate impacted areas (Lambert *et al.* 2014). In sandy habitats, Collie *et al.* (2000) demonstrated that recovery can be achieved within 100 days, which implies that they could perhaps withstand 2-3 three incidents of physical disturbance per year without changing markedly in character (Kaiser *et al.* 2001).

Human disturbances on reef sources and processes are key to the resilience, conservation and recovery of reefs from natural disturbances. When the level of human stressors is low and a short-term natural disturbance affects the reef, these environments can have a condition far from their equilibrium for a period of time, but still recover. In contrast, when the human impacts are continuous or chronic (e.g., overfishing, permanent pollution, habitat destruction), the reefs commonly fail to recover from recurrent natural disturbances (Hughes *et al.* 2010). Not surprisingly, the associated assemblages have high diversity and many of the associated species are large-bodied and slow-growing. Hall-Spencer and Moore (2000) showed that four years after the occurrence of an initial scallop-dredging disturbance had occurred, certain fauna, such as the nest building bivalve *Limaria hians*, had still not re-colonized trawl tracks. Similarly, work by Sainsbury *et al*., (1987, 1999) suggests that recovery rates may exceed fifteen years for sponge and coral habitats off the western coast of Australia. Milazzo *et al.* (2017) further adds that recovery of vermetid reefs after a given mortality, is highly unlikely due to the very peculiar reproductive and developmental biology and an extremely low larval dispersal and population connectivity. Slow recovery was also shown for the perennial *Cystoseira* forests, which may take even up to more than 10 years (Thibaut *et al.* 2005).

The seagrass resilience is largely depended on the type of pressure (direct physical vs. abiotic changes) as well as the characteristics of the disturbance e.g. intensity, duration, spatial extent, timing and recurrence (O'Brien *et al.* 2018). Furthermore, resilient seagrass ecosystems may have some of the following features: high genetic diversity; high species diversity; continuous (not fragmented) habitat; energy reserves; and a robust seed bank or rapid clonal growth (Unsworth *et al.* 2015). Critical bio-physical features of a resilience seagrass ecosystem include moderate temperatures (lacking temperature anomalies or extremes) and good water quality (low turbidity and low-moderate nutrients). Water quality also affects the abundance of other primary producers such as macroalgae and epiphytes, which can reduce the resilience of seagrass at high abundances. (Unsworth *et al.* 2015).

Cymodocea nodosa meadows are subject to large natural fluctuations, and show a higher resilience compared to *P. oceanica*. In areas with signs of decline, the seagrass was able to recover within less than 3 years (Fernandez *et al*., 2006). Nonetheless, the species is also vulnerable to eradication in response to chronic disturbance (Boudouresque *et al.* 2009). For instance, in the Gulf of Tigullio (Ligurian Sea, Italy), *C. nodosa* meadows declined between 1991 and 2001, attributed to climate change (increase in rainfall) and human activity (harbour defences) (Barsanti *et al*. 2007). In heavily polluted sites, the decline and elimination of *C. nodosa* meadows have been reported, e.g., in Koper Bay (Slovenia, Adriatic Sea) and in the Gulf of Thermaikos (Greece) (Avčin *et al*. 1974, Haritonidis *et al*. 1990).

Considering the fact that *P. oceanica* meadows grow clonally (horizontal elongation) at a rate of 1-7 cm rhiz^{-1} year^{-1} (Marbà *et al.* 1996; Marbà and Duarte 1998) and vertically between 0.4 and 1.1 cm rhiz^{-1} year^{-1} (Boudouresque and Jeudy de Grissac, 1983), the species is without doubt deemed vulnerable and sensitive to pressures that cause substantial loss within a short amount of time. In fact, for this species, successful recovery is accomplished only by vegetative growth, rather than seed production and seedling establishment (Marba *et al*.,1996) despite its very slow pace. For instance, recovery after a disturbance event is possible once it's eliminated, but it occurs at an even slower pace with full recuperation to almost a century (González-Correa *et al.* 2005; González-Correa *et al.* 2008). For example, horizontal growth rate in trawling impacted areas was found slower by 30% than in intact *Posidonia* meadows (González-Correa *et al.* 2005), whereas new shoot generation was considerably lower in the impacted sites (1– 1.2 shoots/year m^2 vs. 19-27 shoots/year m^2). In many other cases, natural recovery is achieved on the perimeter of the meadow, while regression takes place on the inner part, particularly at the footprint area, a phenomenon possibly linked to the side-effects of the mechanical impact, such as increased turbidity, sedimentation, biogeochemical and currents alteration, the release of organic matter and the introduction of contaminants (Badalamenti *et al.* 2011). In terms of low level of damage, it is suggested that *P. oceanica* can recover only if all sources of disturbance are removed for at least 5 years.

4

DESCRIPTION OF FISHING ACTIVITIES AND ASSOCIATED PRESSURES

4.1. Fishing Activities in Cape Greco

Fishing practices in territorial waters of Cyprus are mostly limited to the artisanal level (1035 licensed vessels), with the exception of a small semi-industrial (i.e. 34 licensed polyvalent vessels) and industrial fleet (i.e. 2 purse seine and 2 trawler vessels). Small-scale artisanal fisheries target a high variety of species, including demersal fish, crustaceans and some small and large pelagic species. Production is of high economic value, as the catch is generally sold fresh in local markets or directly to private consumers or restaurants, and in some cases is directly exported. The small-scale fisheries of Cyprus are similar to those of the wider Mediterranean region and consist of a variety of fishing techniques and gear (Table 10). Despite the great variation in artisanal fishing techniques, the most common identified in Cape Greco are the traps, trammel nets, demersal longlines and gillnets, all of which are licensed to professional fishers. Cape Greco is targeted by many fishers of the Famagusta district, including from Ayia Napa, Protaras and Liopetri, forming a fleet of 326 vessels. Beyond professional fishing, there are also the recreational fishing practices which are mostly characterised by Hand/Pole lines via shore and spearfishing.

Table 10
Small-scale artisanal fishing techniques of Cyprus.

Passive/Static Gear	Mobile
Trammel nets	Egging
Gill Nets	Trolling lines
Traps / Pots	Octopus Hook and Line (Saglatzia)
Hand lines/ Pole and Line	
Demersal longlines	
Egging	
Hand-held trammel net (Gyrovolia)	
Surfcasting	
Apiko	
Bolognese	

Compared to the artisanal fishery fleet, which operates close to the coast, trawlers and purse seines are obliged to operate beyond 50 m depth to avoid contact with *Posidonia* beds. In the case of the Cape Greco MPA, no such fishing practices are allowed, but in this assessment, the sensitivity of *Posidonia* beds will be assessed on these type of fishing practices in case future guidelines and legislations change.

4.2. Fishing Pressures

Any fishing gear will affect the flora and fauna of a given location to some degree, but the magnitude and duration of the effect depends on several factors, including gear configuration, towing speed, water depth, and the substrate over which the tow occurs. Variations in substrate include differences in sediment type, bed form (sand waves and ripples, flat mud), and biologic structure (shell, macroalgae, vascular plants, sponges, corals, burrows) (Auster and Langton, 1999).

Specifically, demersal fishing activities are well known to cause ample physical damage on the benthic environment, including the trawlers and dredges (Turner *et al.* 1999), causing complete habitat loss and reducing the benthos' physical integrity. Other smaller-scale artisanal fishing activities, such as clam digging and use of push nets over intertidal and shallow areas and, in extreme cases, dynamite fishing may also severely damage *Posidonia* meadows (Duarte *et al.* 2004). Although not directly operated by fishers, ghost fishing is also now evident at global scale (Richardson *et al.* 2019), causing damage on the seafloor when drifted via bottom currents. This is also the case in the MPA of Cape Greco (Figure 4 & 5), a threat that should be taken seriously by the local authorities. Recreational activities such as pole fishing do not interact with the benthic habitats, but when practiced on a boat, *Posidonia* beds and rocky/biogenic reefs are at risk of mechanical damage by anchoring (including the anchoring chains), and moorings (Hastings *et al*., 1995; Francour *et al*., 1999; Milazzo *et al.* 2004; Montefalcone *et al.* 2006; Ceccherelli *et al.* 2007).

The fishing activities and techniques identified within the Cypriot fishing community can generate 6 physical, 1 chemical and 2 hydrological pressures (Table 11) that are considered a hazard on the coastal benthic habitats. These range from physical disturbance via direct physical impact of the fishing gear on the seafloor, smothering, and habitat modification/ desertification to changes in the hydrological patterns, release of organic and chemical pollutants from sediments and water clarity. Benthic habitat sensitivities and their risk of impact to these activities were only assessed on single pressures, whereas interaction or cumulative effects of impacts were not considered in this sensitivity assessment. Furthermore, some of the pressures identified in MSFD Annex 2 may also have an impact, but here are excluded, as these are either very localised with negligible consequences (e.g. noise pollution).

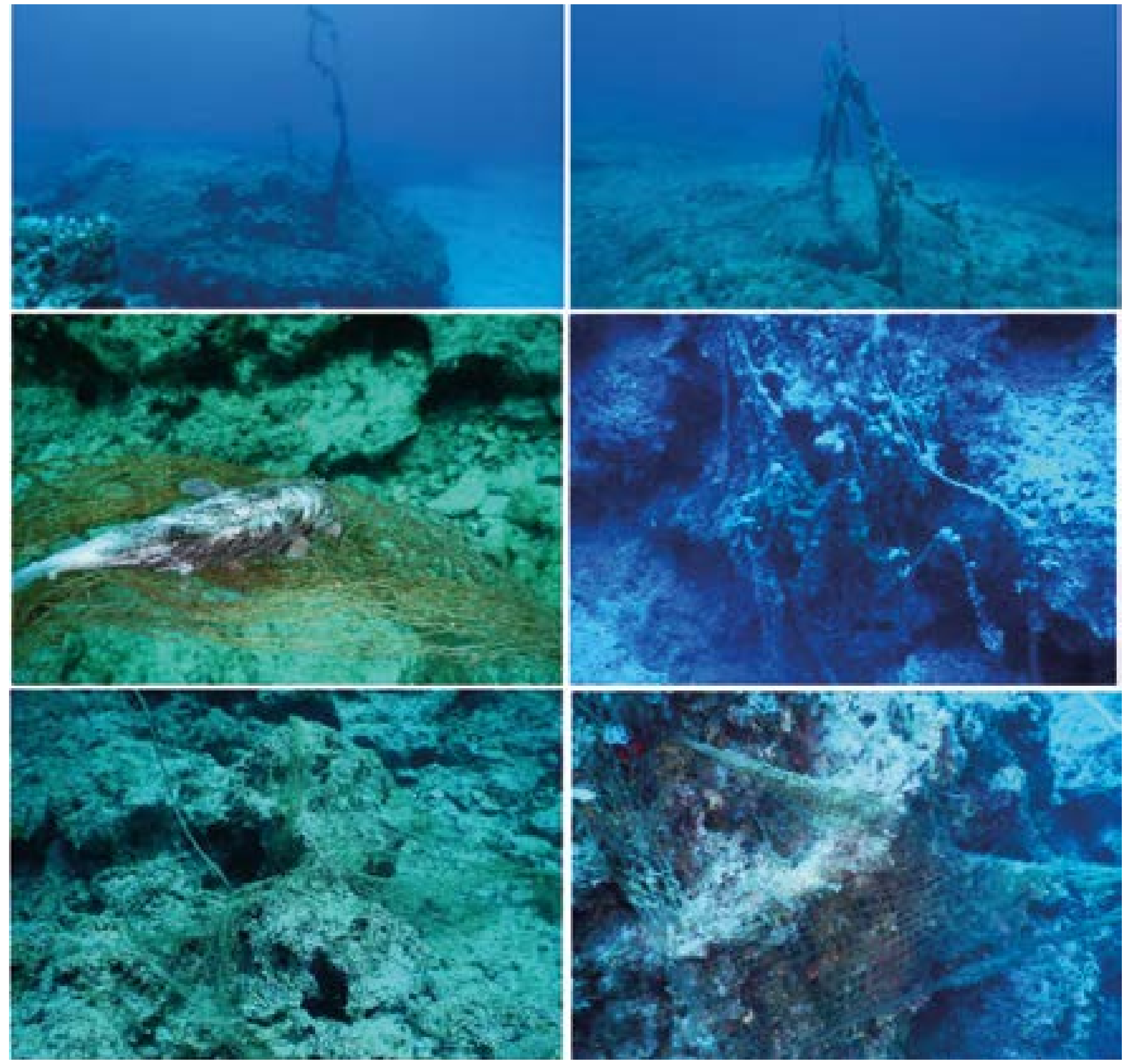

Figure 4
Examples of ghost gear found at the MPA of Cape Greco.

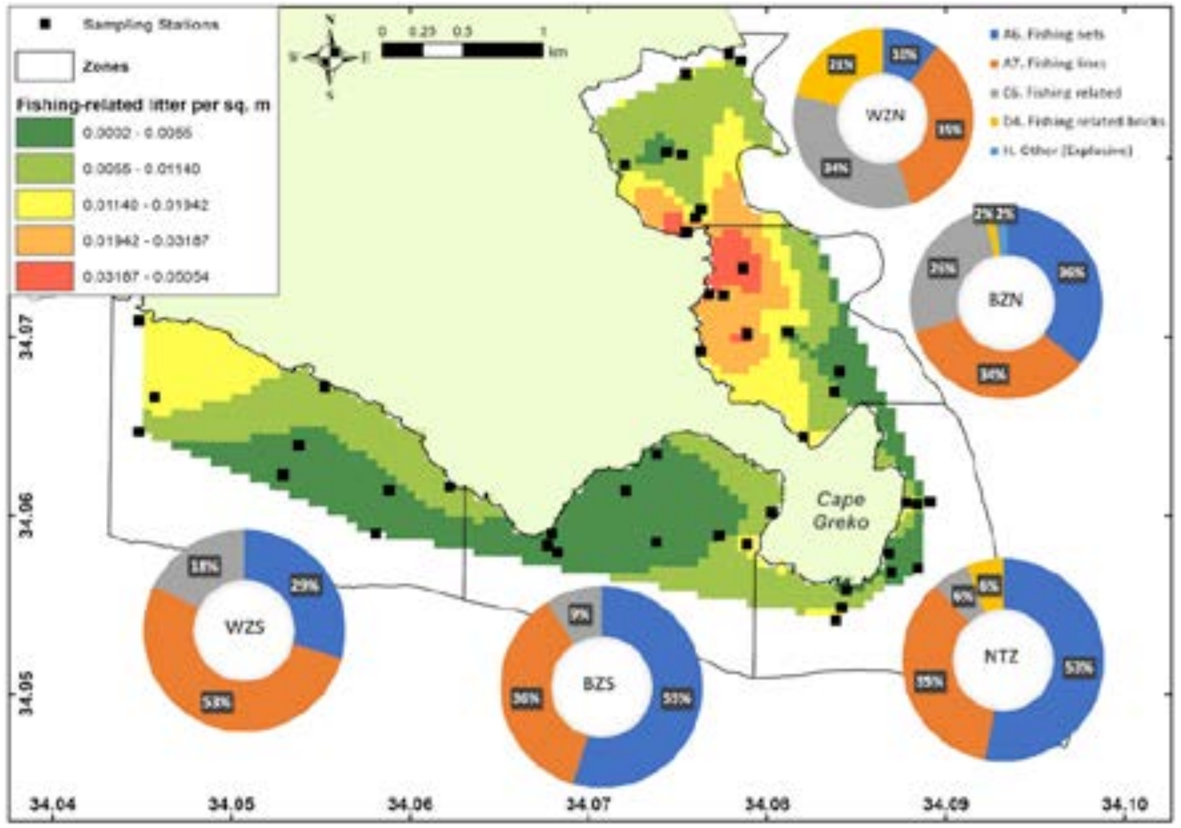

Figure 5
Fishing-related seafloor litter density per m². Densities were acquired via marine litter visual censuses across 45 sampling stations of 4 x 25 m transects. Categories were adapted by Directive (2013).

Table 11
Identified pressures and their definition

Pressure category	Pressure	Definition
Physical loss (permanent change)	Habitat change (to another type)	The permanent replacement of one marine habitat by another marine habitat, through a change in substratum and/or a change in biological zone (depth band). This can be caused by i) the addition of a new substratum or ii) the extraction of existing substratum permanently exposing a different seabed type. For soft sediment habitats, a change in substratum is defined here as a change in 1 class of the modified Folk classification. This includes change to artificial substratum. NB: This pressure can arise from other physical pressures (physical disturbance or hydrological changes) where the magnitude, frequency or duration of exposure leads to a permanent change in habitat type.
Physical disturbance or damage (temporary and/or reversible change)	Substratum extraction	Substratum removal (including of biogenic habitats) which i) exposes substratum of the same type, or ii) temporarily exposes substratum of another type. NB: This pressure becomes « habitat change» if: - The removal exposes substratum of a different type and environmental/ hydrodynamic conditions do not allow the newly exposed seabed to return to its original substratum type - The depth of extraction leads to a change in bathymetry.
	Trampling	The vertical compression of the seabed and its associated species.
	Abrasion	Mechanical action resulting in disturbance of the seabed and associated species (epifauna and epiflora) with or no loss of substratum.
	Reworking of the sediment	The displacement and rearrangement of seabed sediment without any net loss of substratum. This pressure does not apply to hard substrata.
	Deposition/ Smothering	The addition of material on the seabed. This pressure concerns the addition i) of material of the same type as the original substratum, or ii) of a different type but where hydrodynamic conditions allow its rapid removal. NB: This pressure becomes « habitat change » if the original biological communities are not able to recolonize the deposited substratum.
Chemicals and other pollutants	Changes in chemistry	The release of organic and other chemical pollutants from the sediments as a cause of high degree of abrasion and reworking of the sediments.
Hydrological changes	Hydrodynamic changes	Changes in water movement associated with tidal streams, currents, or wave exposure for less than 1 year. NB: This pressure becomes « habitat change » where new hydrodynamic conditions provoke a change in biological composition by changing the immersion/emersion rate, or by changing the nature of the seabed.
	Change in suspended solids	An increase in sediment or organic matter (particulate or dissolved) concentrations in the water column that leads to a change in water clarity and/or affects filter-feeding organisms, for less than 1 year. NB: This pressure becomes « habitat change » if an increase in suspended matter permanently changes biological community composition.

4.3. Physical Loss (Permanent Change)

4.3.1. Physical change (to another sediment type and seafloor modification)

4.3.1.1. Pressure description

Physical loss refers to the permanent change of one marine habitat type to another marine habitat type, through a change in seabed structure, substratum type. This, therefore, involves the permanent loss of one marine habitat type but with an equal creation of a different marine habitat type. Associated activities include the installation of infrastructure (e.g. surface of platforms or wind farm foundations, marinas, coastal defences, pipelines and cables), the placement of scour protection where soft sediment habitats are replaced by hard/coarse substratum habitats, removal of biological substrata (e.g. coral beds and seagrass meadows) or removal of coarse substrata (marine mineral extraction) in those instances where surficial finer sediments are lost, capital dredging where the residual sedimentary habitat differs structurally from the pre-dredge state, creation of artificial reefs, mariculture i.e. mussel beds. Protection of pipes and cables using rock dumping and mattressing techniques. Placement of cuttings piles from oil and gas activities could fit this pressure type, however, there may be additional pressures, e.g. "pollution and other chemical changes". This pressure excludes navigation dredging where the depth of sediment is changed locally but the sediment typology is not changed.

4.3.1.2. Bibliographic review

Significant habitat loss by fishing activities is directly linked with considerable intensity on a large spatial scale, to a point where the habitat is completely eradicated. Excessive habitat loss is possible by bottom mobile fishing gear, including, trawlers and dredges (e.g. Erftemeijer and Lewis 2006). The direct effects of trawling and dredging include loss of erect and sessile epifauna, smoothing of sediment bedforms and reduction of bottom roughness, or removal of taxa that produce structure (Table 12). Trawl gear can crush, bury, or expose marine flora and fauna and substantially simplifying the structural diversity (Table 12) (Auster and Langton, 1999; Rossi 2013). When the recovery time is longer than the interval between the trawls, the original benthic structure and species populations do not have the opportunity to recuperate to pre-trawl conditions (Watling and Norse, 1998). Current knowledge indicates that variable environments inhabited by short-lived species show a more rapid recovery than stable communities composed of sessile, long-lived species (e.g. *P. oceanica* and coral reefs), which sustain longer-term damage.

Repeated trawling and dredging result in detectable changes in benthic communities. Dynamite fishing still occurs in some Mediterranean waters and it can severely affect *Posidonia* beds and rocky reefs. Poacher fishermen target salema (*Sarpa salpa*) shoals and cause extensive damage to rocky bottoms and coastal seagrass beds. Juveniles of many demersal fish species are known to aggregate near seabed structure. In trawled areas of the North Sea, the abundance of larger bodied, long-lived benthic species was depleted more than that of smaller, short-lived species, and there was an overall reduction in benthic production (Jennings *et al.*, 2001).

Table 12

Summarised pressures on seafloor habitats by various bottom fishing techniques. Adapted by Steele *et al.*, (2002).

Gear	Submerged Aquatic Vegetation (SAV)	Sand	Hardbottom/ Biogenic	Muddy Sand	Gravel
Scallop dredge	Increased dredging resulted in significant reductions in biomass and number of shoots	Smoothed bedforms; reduction of epifaunal coverage; shell aggregate dispersal	1) Single passage can kill 70% of the living maerl in the dredge path. Flora and megafauna to a depth of 10 cm are damaged; 2) Dredge tracks remain visible for 2.5 years in maerl habitats; Maerl is a living sediment that is slow to recover from, disturbance due to extremely low growth rates	A gradient of increasing large epifaunal cover correlated with decreasing effort	1) Undredged sites had higher numbers of organisms, biomass, species richness, and species diversity than dredged sites. Undredged sites had bushy epifauna, dredged sites were dominated by hard-shelled molluscs, crabs, and echinoderms; 2) Suspended fine sediment and buried gravel below the sediment water interface; 3) Smoothed bedforms; 4) hydrozoan cover removed
Oyster dredge	1) Gear modified for clam harvest -reduction in smothering of SAV coverage; 2) extended recovery time; sediment suspension; 3) loss of rhizomes;		Reduction in height of oyster reefs, increased susceptibility to hypoxia		

Gear	Submerged Aquatic Vegetation (SAV)	Sand	Hardbottom/ Biogenic	Muddy Sand	Gravel
Otter trawl	1) Reduction in coverage; 2) loss of rhizomes; 3) smothering of SAV sediment suspension	1) Reduction of epifaunal coverage; smoothed bedforms; compression of sediments; sediment suspension (fines); reduction in depth of oxygenated sediments. 2) roller gear produced depressions; chain gear caused damage or loss of epifaunal coverage; 3) Well buried boulders removed and displaced from sediment; penetrated seabed 0–40 mm	1) Reduced density and size of bryozoan colonies in trawled areas vs. closed areas; 2) Trawled areas showed mussel beds of lower structural complexity and less attached epibenthos compared with untrawled areas	1) Reduction of epifaunal coverage; 2) smoothed bedforms; 3) compression of sediments; 4) sediment suspension (fines); 5) reduction in depth of oxygenated sediments	
Beam trawl		Trawl removed high number of the hydroid Tubularia.			50% reduction in density of epifauna such as hydroids and soft coral
Roller-rigged trawl			Damage or loss of coral and coral cover		1) Significant reductions in density of structural components of habitat; 2) No differences in densities of small sponges; 3) 20% of boulders moved or dragged
Roller frame bait shrimp trawl	Minimal SAV degradation; mostly from propeller scars		1) Damage, loss of sponge and coral cover; 2) 30-80% damage to coral		

Several documented cases demonstrated that *P. oceanica* and its associated biotic communities have been greatly impacted by otter trawlers, mostly as result of illegal act (Sánchez Lizaso *et al*., 1990; Jones, 1992; Sánchez-Jerez and Ramos 1996; Kiparissis *et al*., 2011). Trawling is the main agent causing the degradation of deep seagrasses off Murcia, Spain, where up to 40% of the total *Posidonia* surface is highly damaged (Sánchez Lizaso *et al*., 1990; Jones, 1992; Sánchez-Jerez and Ramos 1996).

The loss of complex habitats such as seagrasses and hardbottom rocky/biogenic reefs can have a significant negative impact on the trophic webs and therefore on the ecosystem structure, services and functions they provide, such as productivity (Jennings *et al*., 2001), even at shallower depths, where the benthic system is more exposed and adapted to natural disturbances. The loss of seagrass habitat, and the subsequence flattening of the area can ultimately lead to immediate changes in the fish and macroinvertebrate communities

(Sánchez Lizaso *et al*., 1990; Sánchez-Jerez and Ramos 1996), as they become exposed to other stressors, such as predation, and hypoxia. Comparison between fished and protected *Posidonia* beds in France and Italy, showed a decrease in apex predators, mainly Scorpaenidae and Serranidae feeding on fish and large crustaceans, and to a parallel increase in mesocarnivores (Labridae), due to the lower predation pressure of the former, more susceptible to fishing (Harmelin-Vivien, 2000). The decrease in the mean weight, density and biomass of fish in the exploited seagrass, as well as the higher indices of animal diversity found in the reserves have been reported in several studies (Buia *et al*., 1999; Harmelin-Vivien, 2000; Francour, 1999).

Sandy banks, do not necessarily shift to another habitat by intense fishing activities, but trawling and dredges can ultimately cause dramatic changes in the structure of both the physical support system and the related biological assemblages (e.g. *C. nodosa* or other macrophytic vegetation). Specifically, bottom towed gear can scrape or plough the seabed, resuspend sediment, change grain size and sediment texture, destroy bedforms, and remove or scatter non-target species. Sandy seafloor though, may not be modified or altered in the long-term, since sandy environments exposed to waves and currents can have the trawler and dredging tracks filled within a few hours (Krost *et al*. 1989). Much of the damage documented so far within the Mediterranean Sea is found in the shelf areas and deep muddy slopes; areas that will not be assessed here.

The impacts of fishing activities can extent also to hard substratum, such as biogenic and rocky reefs, and are not necessary linked with large-scale fishing gear. Off the Apulian coast (southeastern Italy), an area with a large surface of carbonate rocks, macrophytic coverage (e.g. *Cystoseira* spp.) and associated communities, was severely damaged and desertified by intensive fishing harvesting practices, targeting the date mussel *Lithophaga lithophaga* (Guidetti and Boero 2004). Rocky/biogenic reefs, are vulnerable to destruction by dynamite fishing but also by standard otter trawling, which is able to harm rocky bottoms without getting damaged, attributed to its special rolling devices (Board, 2002).

4.3.1.3. Sensitivity assessment

Seafloor modification and loss of habitat by fishing activities concerns mostly the use of bottom trawling gears, namely trawlers (beam and/or otter) and dredges, together with some aggressive practices affecting rocky bottoms such as dynamite fishing. The intensity and the magnitude of these disturbances will determine the recovery of the seafloor habitats. The sensitivity of assessed habitats on this pressure is provided on Table 13.

Table 13
Sensitivity Assessment table for Habitat Loss – Physical Change (to another sediment type and seafloor modification.

Habitat code	Resistance	CI Resistance	Resilience	CI resilience	Sensitivity	CI Sensitivity	Evidence Base	Evidence type
1110 - Sandbanks	Medium	Medium	Medium	High	Medium	Medium	The marine habitat is considered to have medium resistance with high turnover rates and therefore higher resilience (Hiddink *et al*. 2017).	Expert judgment, literature review on multiple locations; studies on empirical data and application of mathematical modelling.
1170 - Reefs	Low	Medium	None	Medium	High	Medium	The marine habitat is considered to have a low resistance but unable to recover from a permanent loss of habitat, although no specific evidence is described.	Expert judgement. Confidence index is Medium due to the lack of scientific literature providing information on habitat loss by fishing activities, but not from other disturbances.
1120 - Posidonia beds	Low	High	None	High	High	High	The marine habitat is considered to have a low resistance and unable to recover from a permanent loss of habitat, or at least on a human-time scales; Enough evidence on peer-reviewed literature were found.	Expert judgment, literature review on various locations in the Mediterranean Sea.

4.4. Physical disturbance or damage (temporary and/or reversible change)

4.4.1. Substratum extraction

4.4.1.1. Pressure description

Unlike the "physical change" pressure type where there is a permanent change in sea bed type (e.g. sand to gravel, sediment to a hard artificial substratum) the "habitat structure change" pressure type relates to temporary and/or reversible change, e.g. from marine mineral extraction where a proportion of seabed sands or gravels are removed but a residual layer of seabed is similar to the pre-dredge structure and as such biological communities could re-colonize; navigation dredging to maintain channels where the silts or sands removed are replaced by non-anthropogenic mechanisms so the sediment typology is not changed; a single pass of trawling could displace seagrass shoots over its passage, but nearby meadow remains intact which could eventually recolonize the dredged area.

4.4.1.2. Bibliographic review

Substratum extraction via fishing activities is plausible from a series of fishing gear, namely trawlers, dredges, as well as static gear such as demersal longline, trammel nets, gillnets, traps but also ghost gear. This pressure is also thought to be generated by boat anchoring that is directly related to recreational activities ((Marco Milazzo *et al.* 2002), including fishing. The pressure may not be characterised by successive events of disturbance over large temporal and spatial scales, otherwise, it would have been considered as habitat loss.

A single trawling or dredge haul over seagrass beds can cause detrimental loss and seagrass shoot mortality over its passage (Table 12). This in turn creates a barren or semi-degraded corridor, where recolonization may or may not take place due to (1) secondary effects caused by the disturbance (Badalamenti *et al.* 2011), (2) the rapid colonization by other opportunistic species (i.e. *Caulerpa* spp. *H. stipulacea*, *C nodosa*) (Kiparissis *et al.* 2011), and (3) by the unfavoring life-history traits of the impacted habitat forming species (e.g. *P. oceanica*). The quantification of the short-term impact of otter trawling on *Posidonia* beds has been extensively studied only in Murcia (south-eastern Spain), home to an important trawling fleet (Sánchez-Lizaso and Esplá, 1997; Jiménez *et al.*, 1997; Espla *et al.*, 1997). Experimental trawling hauls show that a medium-size typical trawler would root out an estimated 99,200 and 363,300 *Posidonia* shoots per hour in the disturbed and undisturbed areas, respectively. The mechanical impact of the gear can indeed be higher in the most degraded area, as otter doors will cause a permanent furrow on the bed assisted by the already diminished complexity and consistency of the seafloor. Thus, the relative effect of the gear, depends on the state of conservation of the seagrass. Differences in fish assemblages inhabiting healthy and disturbed *Posidonia* beds have been recorded and suggest major changes in the structure of demersal communities caused by otter trawling (Sánchez Lizaso *et al.*, 1990; Sánchez-Jerez and Ramos 1996).

Other fishing practices, including dragging anchors and scraping anchor chains along the bottom by recreational fishing vessels (Francour *et al.* 1999; Milazzo *et al.* 2002; Milazzo *et al.* 2004) may also contribute to this pressure. Their environmental impact can be as equal as with demersal static gear. These include the trammel nets, gillnets, and demersal longline. When static fishing gear is set over *Posidonia* beds, direct physical effects (e.g. dislodgement of plant rhizomes, shoot fragments or leaves) will occur as the gear moves back and forth with wave action and upon retrieval. Nevertheless, the effects of a high concentration of nets in a specific area could have cumulative and or additive effects on the seabed. However, this issue remains a matter of speculation given the limited scientific attention it has received to date.

Similar effects can be observed with ghost fishing caused by the aforementioned fishing gears. Ghost gear will be drifted with surface and bottom gears and eventually stuck on bottom substratum (Figure 6). This in turn may extract considerable biogenic bottom material e.g. seagrass shoots when forced against strong currents.

Figure 6
Pieces of ghost gear stuck on Posidonia beds (Left) and rocky reefs (right).

Substratum extraction can be evident also on rocky reefs and sandy bottoms, whereby trawling and dredging can demolish softer rocks, damage to soft, large, fragile species, remove structurally important macrophytes such as *Cystoseira* forests or *C. nodosa* meadows (in the case of sandy seafloor), reduce structural complexity, biodiversity, remove erect epifaunal species and large sessile species, loss of reef species from ghost fishing by lost gear (Figure 5), snagging and breaking off sections of fragile biogenic reef. At a lesser extent, the pressure can be generated by static gear when dragged on the bottom via current motion and wave action as well as anchoring via recreational fishing activities. This can cause uprooting of biological material (i.e. seagrass shoots, sponges, anemones, macroalgae, etc).

4.4.1.3. Sensitivity assessment

Substratum extraction is characterised by a less severe (reversible/temporary) physical impact when compared to the complete loss of habitat, but still generates a considerable damage on the seabed and its biological features when assumed chronic. The sensitivity of assessed habitats on this pressure is provided on Table 14.

Table 14

Sensitivity Assessment table for Physical disturbance or damage - Substratum extraction

Habitat code	Resistance	CI Resistance	Resilience	CI resilience	Sensitivity	CI Sensitivity	Evidence Base	Evidence type
1110- Sandbanks	Medium	Low	High	Low	Low	Low	Due to the sediment characteristics the habitat is assumed quite resistant to this pressure. Any biological features affected by this pressure are most likely impacted locally, and due to their rapid turnover rates of dispersion and short-life cycle, the habitat could recover relatively fast.	Expert judgment, literature review on multiple locations; studies on empirical data (Hiddink et al. 2017).
1170 - Reefs	Medium	Medium	Low	Medium	Medium	Medium	Most of this habitat's characteristic species (Macrophytes, sponges, cnidaria, bryozoan polychaetes, bivalves, vermetids etc.) are sessile and will be lost along with the substratum. The time needed for characteristic species to recolonize the newly exposed substratum is estimated up to 5 years, because most of these species (i) have short life cycles and a strong recruitment and dispersion capacity, and (ii) this habitat is naturally exposed to high wave energy. For some species, recovery may take longer than 5 years (i.e. 10 years) due to their life-history traits e.g. Cystoseira spp. (Sala et al. 2012) and corals, and as a consequence to strongly reduce recruitment of littoral fish (Cheminée et al. 2013). Resilience depends on the presence of a healthy similar habitat (with mature individuals) in close vicinity.	Expert judgement. Confidence index is Medium due to the lack of scientific literature providing information on habitat loss by fishing activities, but not from other disturbances.

Habitat code	Resistance	CI Resistance	Resilience	CI resilience	Sensitivity	CI Sensitivity	Evidence Base	Evidence type
1120 - Posidonia beds	Medium	Medium	Low	Medium	Medium	Medium	The marine habitat composes many sensitive sessile species including its own biogenic material (e.g. shoots), macroalgae (i.e. Peyssonelia spp.), cnidaria, sponges and bryozoan. The recolonization of these largely depend on the formation of new shoots by the seagrass bed, a process that is	Expert judgment, literature review on various locations in the Mediterranean Sea.

4.4.2. Trampling

4.4.2.1. Pressure description

The vertical compression of the seabed and its associated species, which could cause localised loss of coverage either by the direct effects of trampling or by severe damage after the pressure has ceased.

4.4.2.2. Bibliographic review

Trampling is genuinely caused by few fishing gears including bottom trawlers, dredges and traps/pots. Regarding the two formers, the pressure is mostly associated to the initial settling of the gear at the bottom. When the gear is in motion, the dominating pressure is considered as abrasion or reworking of sediments, despite trampling may occur along the way. Anchors as well as traps/pots may also cause trampling upon deploying on the benthos, as they bear heavy weights on them (either in the form of concrete blocks or metal weights), hence crashing everything underneath. Limited evidence exists in the literature in relation to this pressure on seagrass beds, rocky reefs or sandbanks, and most of them are associated to human trampling (Brosnan and Crumrine 1994; Brown and Taylor 1999; Schiel and Taylor 1999; Eckrich and Holmquist 2000; Travaille *et al.* 2015) and not directly by the fishing gears. The effects of trampling on benthic systems have shown considerable damage on intertidal rocky reef assemblages (Brosnan and Crumrine 1994; Brown and Taylor 1999; Schiel and Taylor 1999), as well as on the seagrass *Zostera marina* meadows in New Zealand (Travaille *et al.* 2015), as a result to lower the coverage of biotic features, with potential recovery after the pressure has ceased. Most of these studies rely on an experimental basis, inducing various trampling intensities on the biological assemblages and habitat. These however may not reflect the pressure intensity generated by the fishing activities, and the impact of these are very localised.

4.4.2.3. Sensitivity assessment

Trampling can cause localised damage via the vertical force of traps/pots or even trawlers and dredges upon their settling on the benthos. The extent of damage generated depends on the intensity of the associated fishing activities. The sensitivity of assessed habitats on this pressure is provided on Table 15.

Table 15
Sensitivity Assessment table for Physical disturbance or damage - Trampling

Habitat code	Resistance	CI Resistance	Resilience	CI resilience	Sensitivity	CI Sensitivity	Evidence Base	Evidence type
1110-Sandbanks	High	Low	Very High	Low	Very Low	Low	Sandy sediments are more resistant to this pressure, and the impact on the biological features can be minimal.	Expert's judgment.
1170 - Reefs	High	Medium	Very High	Medium	Very Low	Medium	Most of this habitat's characteristic species are encrusting and/or have a hard exterior, and thus are highly resistant to vertical compression. Some biological components of great importance e.g. *Cystoseira* spp., may also prove resistant to vertical compression, particularly when the area of impact comprises of dense forest. Recover from potential minimal loss of biogenic and physical material is estimated up to 5 years. **NB**: in the case of chronic trampling, resistance and resilience capacities will be altered.	Expert judgement. Inference from directly relevant peer reviewed literature (Milazzo *et al.* 2004; Thibaut *et al.* 2005).
1120 - Posidonia beds	High	Medium	High	Medium	Low	Medium	Depending on the force of the trampling, the Posidonia shoots may show some resistant. Forceful vertical compression though, may crash the shoots and the associated sessile species within the meadow or attached on the shoots, causing localised mortality. **NB**: in the case of chronic and intensified trampling, resistance and resilience capacities will be altered.	Expert judgment, literature review on various locations and species (e.g. Travaille *et al.* 2015)

4.4.3. Abrasion

4.4.3.1. Pressure description

Physical disturbance or abrasion at the surface of the substratum in sedimentary or rocky habitats. The effects are relevant to epiflora and epifauna living on the surface of the substratum. In intertidal and sublittoral fringe habitats, surface abrasion is likely to result from recreational access and trampling (inc. climbing) by human or livestock, vehicular access, moorings (ropes, chains), activities that increase scour and grounding of vessels (deliberate or accidental). In the sublittoral, surface abrasion is likely to result from pots or creels, cables and chains associated with fixed gears and moorings, anchoring of recreational vessels, objects placed on the seabed such as the legs of jack-up barges, and harvesting of seaweeds (e.g. kelps) or other intertidal species (trampling) or of epifaunal species (e.g. oysters). In sublittoral habitats, passing bottom gear (e.g. rock hopper gear) may also cause surface abrasion to epifaunal and epifloral communities, including epifaunal biogenic reef communities. Activities associated with surface abrasion can cover relatively large spatial areas e.g. bottom trawls or bioprospecting or be relatively localized activities e.g. seaweed harvesting, recreation, potting, and aquaculture.

4.4.3.2. Bibliographic review

Most of the damage imposed on benthic habitats via fishing gear is caused by abrasion. This pressure is generated by bottom trawlers, dredges, anchoring (including chain motion) via recreational fishing activities over the surface of seafloor. Abrasion is the most dominating pressure caused by demersal towing fishing gear, causing simplification and homogenization of complex benthic habitats.

As previously mentioned, abrasion induces high mortality on *Posidonia* shoots and associated sessile species either by up-rooting, severe physical damage (tear off), or via secondary effects i.e. turbidity and siltation (Kiparissis et al. 2011). High percentage of mortality is also observed on rocky biogenic reefs, where considerable amount of both sessile and slowly mobile organisms are damaged, displaced and scraped off the hard substratum (Kaiser *et al*. 2001; Korpinen *et al.* 2013; Rossi 2013). Abrasion also simplifies the complex structure of rocky biogenic reefs and removes any erect living organisms or physical features. The impacts of abrasion on sandbanks are mostly related on the biological aspects of the habitat rather on the structure of the habitat itself. For instance, epifloral and epifaunal communities will face direct coverage loss in response to the effects of abrasion, but the substratum may not face drastic modification, except down to the grain size level, since sandy environments exposed to waves and currents can have the tracks and towing marks filled within a few hours (Krost *et al*. 1989). Bottom trawling induces high mortality of target and non-target species, but also of benthic species that are damaged by the towed fishing gear. The impact of abrasion on the benthic community increases with body size and fragility, as well as with decreasing mobility of the benthic organisms. In response to meiobenthos, investigations carried out so far have demonstrated significant impacts only on species composition, whilst abundance and biomass remained unaffected (Schratzberger and Jennings, 2002; Lampadariou *et al*, 2005). The selective mortality of benthic invertebrates has reduced the abundance of large, slow-growing species and shifted the benthic communities to a dominance of smaller, fast-growing species with high rates of reproduction in several areas of the North Sea (Jennings *et al.*, 2001; Duplisea *et al*., 2002).

4.4.3.3. Sensitivity assessment

Surface abrasion is usually associated with activities that can cover relatively large spatial areas like the bottom trawls. The extent of damage can be relatively large if caused by trawlers and dredges but can also exist in a localised form when associated to anchoring chains. The sensitivity of assessed habitats on this pressure is provided on Table 16.

Table 16
Sensitivity Assessment table for Physical disturbance or damage - Trampling

Habitat code	Resistance	CI Resistance	Resilience	CI resilience	Sensitivity	CI Sensitivity	Evidence Base	Evidence type
1110-Sandbanks	Medium	Medium	High	High	Low	Medium	Due to the sediment characteristics the habitat is assumed quite resistant to this pressure. Biological features are most likely impacted locally, and due to their rapid turnover rates and short-life cycle, the habitat could recover relatively fast.	Expert judgment, literature review on multiple locations; studies on empirical data (Hiddink *et al.* 2017).

Habitat code	Resistance	CI Resistance	Resilience	CI resilience	Sensitivity	CI Sensitivity	Evidence Base	Evidence type
1170 - Reefs	Low	Medium	Low	Medium	High	Medium	Most of this habitat's characteristic species (Macrophytes, sponges, cnidaria, bryozoan polychaetes, bivalves, vermetids etc.) are sessile and will be lost along with the substratum. The time needed for characteristic species to recolonize the newly exposed substratum is estimated up to 5 years, because most of these species (i) have short life cycles and a strong recruitment and dispersion capacity, and (ii) this habitat is naturally exposed to high wave energy. For some species, recovery may take longer than 5 years (i.e. over 10 years) due to their life-history traits e.g. *Cystoseira* spp. (Sala *et al*. 2012) and corals, and as a consequence to strongly reduce recruitment of littoral fish (Cheminée *et al*. 2013). Resilience depends on the presence of a healthy similar habitat (with mature individuals) in close vicinity.	Expert judgement. Confidence index is Medium due to the lack of scientific literature providing information on habitat loss by fishing activities, but not from other disturbances.
1120 - Posidonia beds	Low	High	Low	High	High	High	The marine habitat composes many sensitive sessile species including its own biogenic material (e.g. shoots), macroalgae (i.e. *Peyssonelia* spp.), cnidaria, sponges and bryozoan. The recolonization of these largely depend on the formation of new shoots by the seagrass bed, a process that is considered substantially slow.	Expert judgment, literature review on various locations in the Mediterranean Sea.

4.4.4. Reworking of the sediment

4.4.4.1. Pressure description

Reworking of sediments where there is limited or no loss of substratum from the system. This pressure is associated with activities such as anchoring, taking of sediment/geological cores, cone penetration tests, cable burial (ploughing or jetting), propeller wash from vessels, certain fishing activities, e.g. scallop dredging, beam trawling. Agitation dredging, where sediments are deliberately disturbed by and by gravity & hydraulic dredging where sediments are deliberately disturbed and moved by currents could also be associated with this pressure type. Compression of sediments, e.g. from the legs of a jack-up barge could also fit into this pressure type. Abrasion relates to the damage of the seabed surface layers (typically up to 50 cm depth). Activities associated with abrasion can cover relatively large spatial areas and include fishing with towed demersal trawls (fish & shellfish); bio-prospecting such as harvesting of biogenic features such as maerl beds where, after extraction, conditions for recolonization remain suitable or relatively localised activities including seaweed harvesting, recreation, potting, aquaculture. Change from gravel to silt substrata would adversely affect herring spawning grounds. Loss, removal or modification of the substratum is not included within this pressure (see the physical loss pressure theme). Penetration and damage to the soft rock substrata are considered, however, penetration into hard bedrock is deemed unlikely.

4.4.4.2. Bibliographic review

Reworking of the sediments as a result of penetration by fishing gear is associated with demersal trawlers and dredges over soft bottoms, including seagrass beds. The surficial sediment can be deeply disturbed by the action of demersal fishing in terms of vertical structure (mixing, lithology, e.g. Mayer *et al*. 1991; Oberle *et al*. 2015), habitat complexity (Schwinghamer *et al*. 1996), bottom roughness (Jennings *et al*. 2009), grain size and biogeochemical features (e.g. Bradshaw *et al*. 2012; Oberle *et al*. 2015). There is little doubt that dredges are most destructive than trawlers in regards to this pressure, since only the doors are the most 'intrusive part of a bottom trawl system on a per-unit-area basis (Sinclair and Valdimarsson 2003). Observations of trawl tracks have shown that they may dig into the substratum as much as 10–25 cm depending on the bottom's hardness, the door design and rigging, towing speed and other operational parameters (Sinclair and Valdimarsson 2003). However, the relative amount of bottom affected is relatively small, amounting to a track no wider than a few centimetres to a few metres for the largest doors.

Furthermore, reworking of sediments, can modify considerably the nutrient exchanges between the sediment and the overlying water column (Welsh, 2003). Bottom trawling can rework the sediment, down to a depth of several centimetres (Smith *et al*., 2000), with consequences on the quantity and early diagenesis of sediment organic matter (Pilskaln *et al*., 1998). Nonetheless, very few studies have considered the effects of bottom trawling on quantity, biochemical composition and bioavailability of sediment organic matter (Smith *et al*., 2000; Duplisea *et al*., 2001). Organic matter content and composition in marine sediments are the result of a complex array of biotic and abiotic factors, such as in situ production, lateral advection and allochthonous inputs, utilisation/degradation rates, export, interactions with mineral particles and oxygen availability (Mayer, 1995; Hartnett *et al*., 1998). Changes in the organic matter content and composition in the sediment, together with concurrent oxygen depletion (Pearson and Rosenberg, 1987) may alter microbial processes and be detrimental to the benthic communities (infauna and epifauna), inhabiting within *Posidonia* beds as well as sandbanks.

4.4.4.3. Sensitivity assessment

Reworking activity is mainly caused by demersal towed gear including bottom trawling and dredges, and to some extent by anchor chains of recreational fishing vessels. The sensitivity of assessed habitats on this pressure is provided on Table 17.

Table 17
Sensitivity Assessment table for Physical disturbance or damage - Trampling

Habitat code	Resistance	CI Resistance	Resilience	CI resilience	Sensitivity	CI Sensitivity	Evidence Base	Evidence type
1110-Sandbanks	Medium	Medium	High	Medium	Low	Medium	The impact of this pressure on the habitat largely depends on the locality, which determines the pollution status and the characteristics of the sediments, as well as the area impacted, which in most cases is relatively small (Sinclair and Valdimarsson 2003). The towed fishing gear does not penetrate deep into the sediments. Therefore, the significance of this pressure could be minimal.	Expert judgment, literature review on multiple locations (Hiddink *et al*. 2017)
1170 - Reefs	NA	NA	NA	NA	NA	NA	No sediments are involved in this habitat	NA
1120 - Posidonia beds	Medium	Medium	Low	Medium	Medium	Medium	The impact of this pressure on the habitat largely depends on the locality, which determines the health status of the *Posidonia* beds (Francour *et al*. 1999). The healthier the meadows, the more resistance they show against the intrusion of the towed fishing gear within the matte. Compared to grainy sandy sediments, the organic matter concentration within *Posidonia* matte is considered higher, while the microbial and biogeochemical processes are assumed quite significant in this system. Thus, this pressure may cause higher impact, even post the disturbance event.	Expert judgment, literature review on various locations in the Mediterranean Sea and general knowledge acquired from seagrass ecology.

4.4.5. Deposition/Smothering

4.4.5.1. Pressure description

When the natural rates of siltation are altered (increased or decreased). Siltation (or sedimentation) is the settling out of silt/sediments suspended in the water column. Activities associated with this pressure type include mariculture, land claim, navigation dredging, disposal at sea, marine mineral extraction, cable and pipeline laying and various construction activities. It can result in short-lived sediment concentration gradients and the accumulation of sediments on the sea floor. This accumulation of sediments is synonymous with "light" smothering, which relates to the depth of vertical overburden. "Light" smothering relates to the deposition of layers of sediment on the seabed. It is associated with activities such as sea disposal of dredged materials where sediments are deliberately deposited on the seabed. For "light" smothering most benthic biota may be able to adapt, i.e. vertically migrate through the deposited sediment. "Heavy" smothering also relates to the deposition of layers of sediment on the seabed but is associated with activities such as sea disposal of dredged materials where sediments are deliberately deposited on the seabed. This accumulation of sediments relates to the depth of vertical overburden where the sediment type of the existing and deposited sediment has similar physical characteristics because, although most species of marine biota are unable to adapt, e.g. sessile organisms unable to make their way to the surface, a similar biota could, with time, re-establish.

4.4.5.2. Bibliographic review

The pressure is mostly associated to the post-disturbance effects of demersal towed fishing gear including trawlers and dredges. While demersal fishing gear is in motion, its impact on the seafloor through abrasion and penetration within the sediments and seagrass matte causes remobilisation of the sediment in the water column, and as a result to increase siltation rates and smothering on the benthic systems.

In the case of seagrasses, several studies demonstrate the impacts of smothering due to excessive sedimentation (Erftemeijer and Robin Lewis 2006). Negative impacts from sedimentation may arise when the species-specific thresholds are exceeded. For instance, *P. oceanica* and *C. nodosa* (Marba and Duarte, 1994), face mortality over their threshold which is estimated at 5 cm year^{-1}. In particular *P. oceanica*, appears to be very sensitive to sudden increases in sedimentary rates. Experimental studies indicated that shoot burial as much as 8-11 cm caused total mortality (Manzanera *et al*., 1998), an outcome linked to the reduction of oxygen availability to the tissues and exposure to toxic compounds such as sulfides (Manzanera *et al*., 1998). Mortality on seagrasses and other perennial macrophyte assemblages may be further induced by settlement of suspended material on leaf blades and photosynthetic tissue, respectively. This interferes significantly with gas exchange processes, thus, photosynthesis and appears especially significant in low wave energy environments where fine sediments are present and can settle out (Erftemeijer and Robin Lewis 2006). The settling of suspended material on photosynthetic tissue may also the development of epiphytes, which further restrict light absorption and as a result to cause tissue necrosis. Furthermore, the impact of sedimentation is often increased where epiphytes are abundant on seagrass leaves (under nutrient enriched conditions) because epiphitized leaf blades collect a greater amount of sediment, and as a result leaf blades and epiphytes appear dull brown coated with a fine layer of sediment and they often sink to the bottom (Short *et al*., 1989).

Although limited studies, similar effects can be accounted for rocky reefs and sandbanks, where *C. nodosa* and other macroalgal communities may face burial stress by the dredging or trawling's sediment plume. Smothering by sand/silt particles could negatively affect benthic sessile epifauna (e.g. Erftemeijer *et al.* 2012; Pineda *et al.* 2017) down to the physiological level (Airoldi 2003). Chronic disturbance however, may potentially cause mortality and changes in the benthic communities.

Besides the effects of trawler's or dredger's sediment plume on the siltation rate, ghost gear may also contribute to this pressure, particularly heavy and thick nets, as well as abandoned traps/pots (Figure 7). Such abandoned fishing gear may contribute to direct mortality of all sessile organisms underneath it (either these are *Posidonia* beds or biological features of rocky biogenic reefs and sandbanks), as it restricts light and food availability (e.g. for filter feeders) and induces chronic suffocation, especially when assisted with bottom currents.

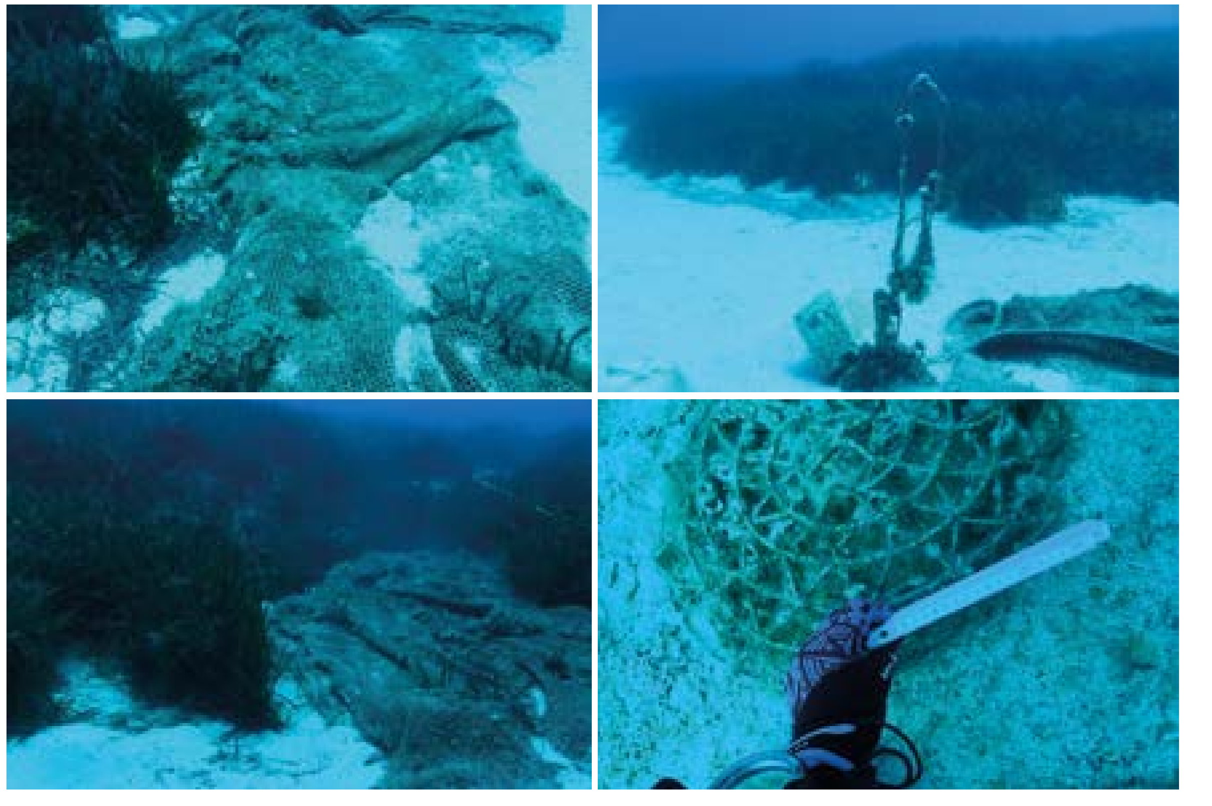

Figure 7
Heavy ghost gear, smothering the benthic habitats of the MPA of Cape Greco.

4.4.5.3. Sensitivity assessment

Deposition/Smothering is mainly caused by the sediment plumes generated via the impact of demersal towed gear including bottom trawling and dredges, and to some extent by anchor chains of recreational fishing vessels. Abandoned fishing gear also contribute to this pressure, including traps/pots and heavy nets particularly those originating from a trawler's net or a fish farm's cage unit. The sensitivity of assessed habitats on this pressure is provided on Table 18.

Table 18
Sensitivity Assessment table for Physical disturbance or damage – Deposition/Smothering

Habitat code	Resistance	CI Resistance	Resilience	CI resilience	Sensitivity	CI Sensitivity	Evidence Base	Evidence type
1110-Sandbanks	High	Low	Very High	Low	Very Low	Low	Most epibenthic species have short life cycles and high turnover rates, thus can recover relatively fast. Infauna is considered rather resistance to sedimentation, whereas C. *nodosa* may show regression if sedimentation rate is chronic and higher than annual background levels, which is not the case in the presence of a short-term pulse sedimentation event.	Expert judgment, literature review on multiple locations (Hiddink *et al.* 2017)
1170 - Reefs	High	Low	Medium	Low	Medium	Medium	The macroalgal (e.g. *Cystoseira* forests) and epifaunal communities will be affected (e.g. down to the physiological level) depending on the periodicity and frequency of the disturbance. Some very sensitive species may be lost in case of prolonged and heavy sedimentation.	Expert judgement. Inference from directly relevant peer reviewed literature (Airoldi 2003; Thibaut *et al.* 2005)
1120 - Posidonia beds	Medium	High	Low	High	Medium	High	*P. oceanica* may show regression if sedimentation rate is chronic and higher than annual background levels. The sensitivity to this pressure also depends on the nature of the sediments that are deposited, which may bring with them pollutants or a high nutrient load. In this case shoot mortality may be evident under a single disturbance event.	Expert judgment, literature review on various locations in the Mediterranean Sea (Erftemeijer and Robin Lewis 2006) and general knowledge acquired from seagrass ecology.

4.5. Chemicals and other pollutants

4.5.1. Changes in chemistry

4.5.1.1. Pressure description

Organic enrichment and increased levels of the elements: nitrogen, phosphorus, silicon (and iron) in the water column and superficial sediment compared to background concentrations. Organic matter and nutrients can enter marine waters by natural processes (e.g. decomposition of detritus, riverine, direct and atmospheric inputs) or anthropogenic sources (e.g. wastewater runoff, terrestrial/agricultural runoff, sewage discharges, aquaculture, atmospheric deposition). Organic matter and nutrients can also enter marine regions from 'upstream' locations, e.g. via tidal currents to induce enrichment in the receiving area or can be remobilised to the water from within the sediments, post-dredging events. Organic and nutrient enrichment may lead to eutrophication (see also organic enrichment). Adverse environmental effects include deoxygenation, algal blooms, changes in community structure of benthos and macrophytes.

4.5.1.2. Bibliographic review

The pressure is associated to demersal towed fishing gear, including trawlers, and dredges. As the fishing gears disturb soft sediment, they produce sediment plumes and re-mobilize previously buried organic and inorganic matter, as well as nutrients. Presumably, this increases the release of nutrients into the water column and surface sediments and has important consequences for rates of biogeochemical cycling (Sinclair and Valdimarsson 2003). In regard to *P. oceanica*, this pressure has significant implications on post-disturbance, as the meadow is experiencing prolonged exposure to the released material. *P. oceanica* is very sensitive to increased organic matter and nutrient release (Pérez *et al.* 2007). Organic carbon and nutrient inputs to the sediment stimulate bacterial activity, increasing sediment oxygen demand and the production of bacterial metabolites such as sulfides, which are toxic for seagrasses (Terrados *et al.* 1999) and specifically for the meristematic activity of *P. oceanica* (Pérez *et al.* 2007).

This pressure may also extent to rocky reefs, when organic compounds and nutrients are directed to this habitat via the sediment plume. In this case, it is expected a shift in the macrophyte communities, from sensitive to tolerant species and the overall homogenisation of the biological assemblages (e.g. Thibaut *et al.* 2005; Arévalo *et al.* 2007; Kletou *et al.* 2018). In respect to sandbanks, soft sediment habitats and their benthic assemblages, the effect of organic and nutrient enrichment are determined by the interplay between the presence of bioturbating macroinvertebrates, and sediment characteristics (O'Brien *et al.* 2009). The main biological element that characterises the sandbanks of Cyprus is the formation of *C. nodosa* meadows, a seagrass species that shows to withstand pulses of ammonium but not phosphorus content (Alexandre and Santos 2020). Its associated fauna assemblages may show a variable resistance to organic and nutrient enrichment, a phenomenon that largely depends on the habitat complexity (e.g. shoot density), which is strongly influenced by the seasonality effect (Jiménez-Ramos *et al.* 2017)

4.5.1.3. Sensitivity assessment

Changes in chemistry is mainly caused by the sediment plumes generated via the impact of demersal towed gear including bottom trawling and dredges, and to some extent by anchor chains of recreational fishing vessels. The sensitivity of assessed habitats on this pressure is provided on Table 19.

Table 19
Sensitivity Assessment table for Chemicals and other pollutants – Changes in chemistry

Habitat code	Resistance	CI Resistance	Resilience	CI resilience	Sensitivity	CI Sensitivity	Evidence Base	Evidence type
1110- Sandbanks	High	Medium	High	Medium	High	Medium	Sediments deriving from this habitat may vary in chemical composition and grain size, may contain various organic and inorganic pollutants, and may range from slurries with a high-water content to highly compacted sediments. The extent of impact largely depends on these features as well as the intensity and frequency of disturbance events. In most cases sediments are dispersed relatively quickly by natural processes and dilute the plume rather quickly in areas with high hydrodynamics.	Expert's judgment.
1170 - Reefs	High	Medium	Medium	Medium	Low	Medium	This habitat may consist sensitive species in response to changes in water biochemistry. Loss of species may be not be anticipated within a single pulse event. **NB**: in the case of continuous disturbance pulses, resistance and resilience capacities will be altered.	Expert judgement. Inference from directly relevant peer reviewed literature (Airoldi 2003; Thibaut et al. 2005; Cheminée et al. 2013).
1120 - Posidonia beds	High	High	Medium	High	Low	High	The marine habitat is considered rather sensitive to changes in the biogeochemical processes, overt chronic events. The system may initial react with changes in the physiological functions, and loss of seagrass and associated communities may be evident much later. In the case of a single pulse event, Posidonia beds can be quite resistant. **NB**: in the case of continuous disturbance pulses, resistance and resilience capacities will be altered.	Expert judgment, literature review on various locations and species (e.g. (Erftemeijer and Robin Lewis 2006)

4.6. Hydrological Changes

4.6.1. Hydrodynamic changes

4.6.1.1. Pressure description

Local changes in current movement, wave length, height and frequency. Exposure on an open shore is dependent upon the distance of open sea water over which wind may blow to generate waves (the fetch) and the strength and incidence of winds. Anthropogenic sources of this pressure include artificial reefs, breakwaters, barrages, wrecks that can directly influence wave action or activities that may locally affect the incidence of winds, e.g. a dense network of wind turbines may have the potential to influence wave exposure, depending upon their location relative to the coastline. Hydrological changes may be also influenced by the removal of a certain habitat such as rocky/biogenic reefs and long-lived seagrass beds.

4.6.1.2. Bibliographic review

The pressure is associated with the post-effects of intensive trawling or dredging, where a considerable loss of habitat has occurred. The loss of complex habitat can ultimately alter the hydrographic regimes in the area (Milazzo, Badalamenti, Ceccherelli, *et al.* 2004), including current direction, wave size and wave force (Badalamenti *et al.* 2011), which may have adverse (indirect) effects on the recovery and surviving of the seagrass meadows or the biological features of rocky/biogenic reefs (Erftemeijer and Robin Lewis 2006). Trawlers and dredges may as well alter the topographic features of sandy floors and sandbanks via the development of furrows and canals, and thus hydrodynamic features. However, due to the mobile characteristics of sandy seafloors, their high exposure to waves and currents, the microtopography is restored in a matter of hours (Krost *et al*. 1989).

4.6.1.3. Sensitivity assessment

Hydrodynamic changes are the result of considerable loss of the structural complexity of the habitats caused by demersal towed gear including bottom trawling and dredges. The sensitivity of assessed habitats on this pressure is provided on Table 20.

Table 20

Sensitivity Assessment table for Hydrological Changes – Hydrodynamic changes

Habitat code	Resistance	CI Resistance	Resilience	CI resilience	Sensitivity	CI Sensitivity	Evidence Base	Evidence type
1110-Sandbanks	High	Medium	Very High	Medium	Very Low	Medium	Sand habitats are commonly dominated by physical processes; thus, habitat restoration is relatively rapid (days to a few months).	Expert judgment, literature review on multiple locations (Kaiser *et al*. 2006; Hiddink *et al*. 2017)
1170 - Reefs	Medium	Medium	Low	Medium	Medium	Medium	Changes in hydrological regimes may have a direct impact on key engineering species such as *Cystoseira spp*, and emergent epifauna (e.g. sponges, bivalves, vermetids, corals, bryozoan, and hydroids), since some species are either adapted to very exposed or sheltered conditions. Recovery of the habitat may take more than 5 years, and even so, climax community may not be the same as the one prior the disturbance.	Expert judgement. Inference from directly relevant peer reviewed literature (Thibaut *et al.* 2005)
1120 - Posidonia beds	Medium	High	Low	High	Medium	High	Changes in hydrological regimes may have an indirect impact on the surviving portion of the *Posidonia* meadows driven by more turbid waters or changes in stratification during the summer. The pressure also affects the habitat on its recovery patterns, since highly turbulent waters may not allow successful seedling establishment on the lost habitat.	Expert judgment, literature review on various locations in the Mediterranean Sea (Erftemeijer and Robin Lewis 2006) and general knowledge acquired from seagrass ecology.

4.6.2. Changes in suspended solids

4.6.2.1. Pressure description

Changes water clarity (or turbidity) due to changes in sediment & organic particulate matter and chemical concentrations. It is related to activities disturbing sediment and/or organic particulate matter and mobilizing it into the water column. It could be 'natural' land run-off and riverine discharges or from anthropogenic activities such as all forms of dredging, disposal at sea, cable and pipeline burial, secondary effects of construction works, e.g. breakwaters. Particle size, hydrological energy (current speed & direction) and tidal excursion are all influencing factors on the spatial extent and temporal duration. Salinity, turbulence, pH and temperature may result in flocculation of suspended organic matter. Anthropogenic sources are mostly short-lived and over relatively small spatial extents. Changes in suspended sediment loads can also alter the scour experienced by species and habitats. Therefore, the effects of scour are also addressed here.

4.6.2.2. Bibliographic review

Demersal trawlers and dredges can generate sediment plumes along a single passing, and this sediment plume, making the water column more turbid and thus largely reduce the light availability to benthos. Increased turbidity can be very significant on the assessed habitats, when it is assumed prolonged, but its impact is commonly localised.

Reduction in light due to turbidity has been identified as a major cause of loss of seagrass worldwide (Erftemeijer and Robin Lewis 2006). There are various studies on the sublethal and lethal effects on seagrass beds due to prolonged exposure to high turbidity and in relation to dredging activities or even trawling (e.g. Sabol *et al*., 2005). Minimum light requirements of most seagrasses species seem to vary between 15 and 25% of surface irradiance (SI), but for some species can be as low as 3-7% of SI, including *C. nodosa*, *Halophila* spp. and some *Posidonia* spp. For *P. oceanica* the minimum light requirement is estimated between 7.8 and 16% of SI and for *C. nodosa* between 7.2 and 10.2% of SI (Erftemeijer and Robin Lewis 2006). The impacts of turbidity on seagrasses, however, is not associated only with the light reduction, but also the time of exposure. For instance, *P. oceanica*, which has a larger below-ground biomass is potentially better adapted to longer periods of sub-minimal light compared to those that do not e.g. *C. nodosa.*

The impacts of turbidity is also evident for rocky/biogenic reefs, particular on canopy forming macrophyte assemblages such as *Cystoseira* forests (Thibaut et al. 2005). For instance, Cormaci and Furnari (1999) blamed increased water turbidity to explain the decline of *Cystoseira* populations in the Tremiti islands, an isolated Archipelago in the Adriatic Sea, whereas the effects of turbidity may further explain the progressive decline of *C. spinosa* var. *compressa* and its replacement in Alberes coast in France, by a more tolerant species of higher photosynthetic efficiency, the *C. zosteroides*.

4.6.2.3. Sensitivity assessment

Changes in suspended solids are the result of reworking of sediments and thus generation of sediment plume into the water column, as a result to reduce light availability to the benthos. The sensitivity of assessed habitats on this pressure is provided on Table 21.

Table 21

Sensitivity Assessment table for Hydrological Changes – Changes in suspended solids

Habitat code	Resistance	CI Resistance	Resilience	CI resilience	Sensitivity	CI Sensitivity	Evidence Base	Evidence type
1110-Sandbanks	High	Medium	Very High	Medium	Very Low	Medium	*C. nodosa* may show regression if turbid waters become chronic and higher than annual background levels. Can be rather resistant to this pressure on the short-term but decline can be evident on the long-term due to small below-ground sugar reserves. **NB**: in the case of chronic turbidity, resistance and resilience capacities will be altered.	Expert judgment, literature review on various locations in the Mediterranean Sea (Erftemeijer and Robin Lewis 2006) and general knowledge acquired from seagrass ecology.
1170 - Reefs	Medium	Medium	Medium	Medium	Medium	Medium	The macroalgal (e.g. *Cystoseira* forests) communities will be affected (e.g. down to the physiological level) depending on the periodicity and frequency of the disturbance. Some very sensitive species may be lost in case of prolonged turbid waters. Recovery may take place up to 10 years after the pressure has ceased. **NB**: in the case of chronic turbidity, resistance and resilience capacities will be altered.	Expert judgement. Inference from directly relevant peer reviewed literature (Airoldi 2003; Thibaut *et al.* 2005)
1120 - Posidonia beds	High	High	Medium	High	Medium	High	*P. oceanica* may show regression if turbidity levels are higher than natural background levels and when pressure becomes prolonged. Can be rather resistant to this pressure on the long-term but decline can be evident once below-ground sugar reserves are nearly exhausted. **NB**: in the case of chronic turbidity, resistance and resilience capacities will be altered.	Expert judgment, literature review on various locations in the Mediterranean Sea (Erftemeijer and Robin Lewis 2006) and general knowledge acquired from seagrass ecology.

5

RISK IMPACT OF FISHING GEAR ON BENTHIC HABITATS

The following information revises the impact of each distinct fishing gear/technique on the assessed habitats by the literature already reviewed (e.g. Kaiser *et al.* 2001; Steele *et al.* 2002; Board 2002; Airoldi 2003; Erftemeijer and Robin Lewis 2006; Erftemeijer *et al.* 2012), by which their significance of resulting impacts (if any) will depend on the sensitivity of the habitat. Assuming the sensitivity of each habitat to the assessed pressures, and the potential impact of the interacting fishing gear on each habitat (Figure 8), a risk potential of fishing practices can be generated (Figure 9). Other factors may also play a role. For instance, the impact of a fishing gear deployed on a habitat in high energy environments, can be less significant or negligible compared to the same activity in low energy environments. Furthermore, the frequency and the extent of the activity as well as variation within gear types, such as size and weight, are key factors in understanding the likely impact, including the scale of any impact. It is also the case that impacts may be greatest the first time particular techniques are used or that there is an equilibrium with the range of species that can withstand current activities but that the habitat is nevertheless in unfavourable condition. These considerations mean that it is essential to undertake a site-specific analysis of the likely interactions as the basis for any management proposals.

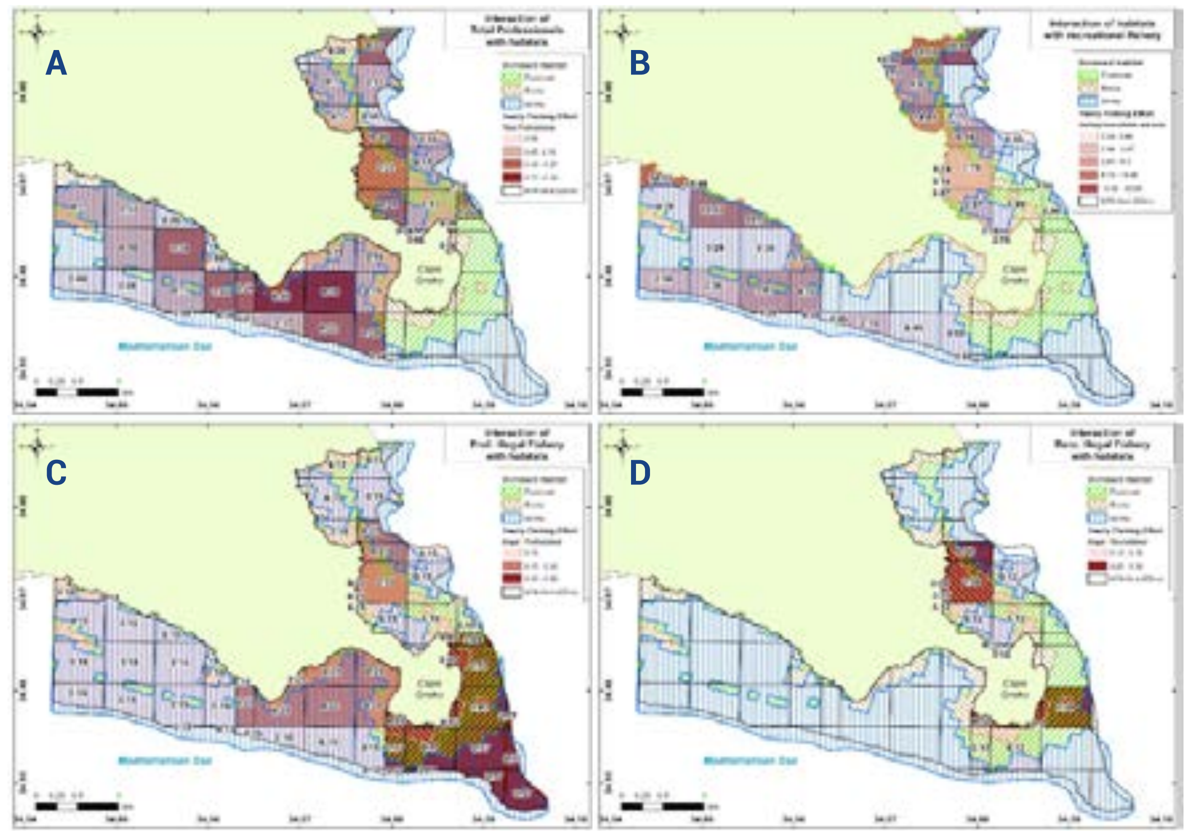

Figure 8

Maps of interaction between fishing activities (including professional - A, recreational - B and illegal activities by both sectors – C and D) and habitats. The maps will always demonstrate the most dominant habitat upon overlapping.

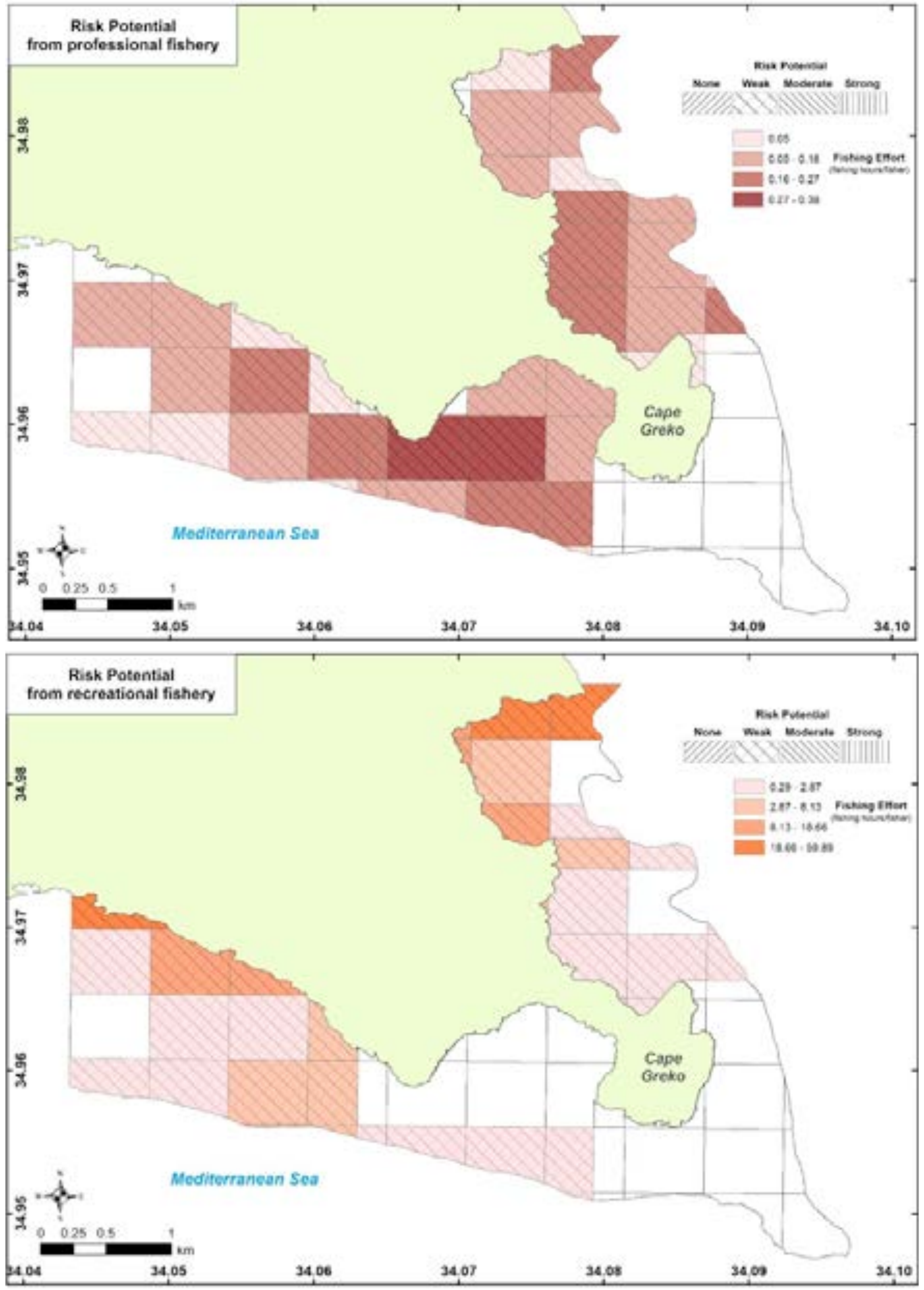

Figure 9

The risk potential of all practices pooled together for professional and recreation on the benthic habitats of Cape Greco. The risk potential is shown to increase with fishing effort, despite its initial scoring.

5.1. Dredges (absent in the Cape Greco MPA)

Two main types of dredges, boat dredges and suction dredges targeting bivalves (scallop, oyster, clams, mussels, razor shell). Gears are towed along the surface of the seabed or dig into the surface layers of sediment as part of the operation. All three assessed habitats interact with this gear and are under a certain degree of risk potential (Table 22).

5.1.1. Physical

- Substratum loss (boulders and stones may be removed or sorted).
- Suspension of sediment.
- Increased turbidity if conducted in areas where there is low natural disturbance of sediment.
- Formation of tracks, mounds, furrows, and ridges, which alter the surface topography .

5.1.2. Chemical

- Water quality may be reduced due to increasing nutrient loads, oxygen consumption and possibly phytoplankton production.
- Remobilisation of contaminated sediments.
- Release contaminants from sediment and sediment pore water.

5.1.3. Biological

- Removal of target species and by-catch, which provoke changes in community structure.
- Species compositions may change.
- Large fragile organisms particularly at risk (e.g. corals, sponges and gorgonians) as well as less attached epibenthic species including molluscs, and starfish. Increases in number of scavengers at recently dredged sites have also been reported.
- Effects on birds such as short-term increases of gulls and waders in the harvesting areas, followed by long-term significant reduction in feeding opportunities.
- Reduction in species abundance and biomass on various timescales.

5.1.4. Conclusions

Physical and biological effects from the use of this type of gear are well documented and principally on benthic habitats and processes. They include high mechanical impact with associated mortality on epibenthos, and changes in the topography and turbidity.

5.2. Trawler – Pelagic (absent in the Cape Greco MPA)

Mid-water otter trawls and mid-water pair trawls towed above the seabed to catch pelagic species.

5.2.1. Physical

- None identified

5.2.2. Chemical

- None identified

5.2.3. Biological

- Discards associated with pelagic trawl fisheries known to attract scavengers around the nets as well as on the seabed if they are concentrated in particular areas.
- The associated decaying process of discards/spill over may result in localised anoxic conditions.
- By-catch of seabirds, turtles, and marine mammals

5.2.4. Conclusions

Few effects on non-target species reported from use of this type of gear. No habitat effects identified.

5.3. Trawler – Demersal (absent in the Cape Greco MPA)

Bottom otter trawls, multi-rig otter trawls, bottom pair trawls & beam trawls. Gear towed along the seabed or partially in contact with the seabed and may also dig into surface sediments. Pulse trawls to be evaluated. Targeted species include demersal fish, Norway lobster, spiny lobster, shrimps, & cephalopods.

5.3.1. Physical

- Changes in topography by removal and flattening of seabed features.
- Disturbance of sediment surface and penetration into the substrate.
- Increasing turbidity and altering the physical structure of the sediment.

5.3.2. Chemical

- Remobilization of contaminated sediments and release contaminants from sediment and sediment pore water.

5.3.3. Biological

- Considerable impact on the abundance of several by-catch species
- Changes in benthic community structure (damaged and/or replaced) associated with beam trawl fisheries.
- Decreases in habitat heterogeneity.
- Increases in numbers of particular groups which can result in shifts to dominance of highly productive opportunistic species.
- Fragile infauna and sedentary and slow-moving animals in stable sediment are particularly vulnerable to damage. Increase in scavengers with some aggregating over beam trawl tracks to feed.
- Discards can provide additional food for seabirds.
- Otter trawls have been observed to have negative effect on benthic species richness and biomass including damage to erect epifauna and reduced diversity.
- Incidental catch of turtles and marine mammals in bottom trawls can be significant.
- Some seabirds feed on discards (e.g. gulls, skuas) and are known to alter movement patterns to feed on discards from bottom trawlers (Cory's and Balearic shearwaters).

5.3.4. Conclusions

Physical and biological effects are most apparent and focused on benthic habitats and communities as a result of contact of gear with the seabed. They include changes in seabed topography and reduction in the complexity of benthic communities. Effects have been observed on epifauna and shallow infauna and can extend over large areas.

5.4. Hook & Line (active in the Cape Greco MPA)

Includes demersal longlines, handheld hook and line including rod, and other artisanal techniques (i.e. Apiko, Bolognese, Egging, Trolling, Kalamariera, Line, Rod, Spinning, Surf Casting). The fishing gear may be mobile (i.e. drifting demersal and surface longlines). All three assessed habitats interact with these types of gears and are under a certain degree of risk potential (Figure 10; Table 22).

5.4.1. Physical

- Anchors, weights, hooks and the mainline can produce seabed effects depending on how far they travel over the seabed during setting or retrieval.

5.4.2. Chemical

- None identified

5.4.3. Biological

- Target fisheries (e.g. sharks) and by-catch.
- By-catch associated with pelagic longlining including elasmobranchs (e.g. blue shark, stingrays), turtles (e.g. loggerhead, and leatherback) and seabirds.
- Seabirds are also taken as by-catch in demersal longline fisheries.
- Incidental catches of marine mammals have also been reported e.g. striped dolphins, monk seal and a sperm whale entangled in abandoned gear.
- Some cetaceans such as long-finned pilot whales, striped dolphins and sperm whales have also been observed feeding opportunistically on illuminated handlines of squid fisheries in the Mediterranean.
- Demersal longlines (including lost lines) can snare sessile benthic species such as deep-water corals, seagrass shoots, rocky formations covered in epibiota (e.g. sponges), and other coralligenous assemblages.

5.4.4. Conclusions

The main reported effect is the incidental capture of seabirds, turtles, marine mammals and other species on the baited hooks of longlines. Demersal longlines may cause mechanical impact on the epibenthos and could also contribute to ghost fishing.

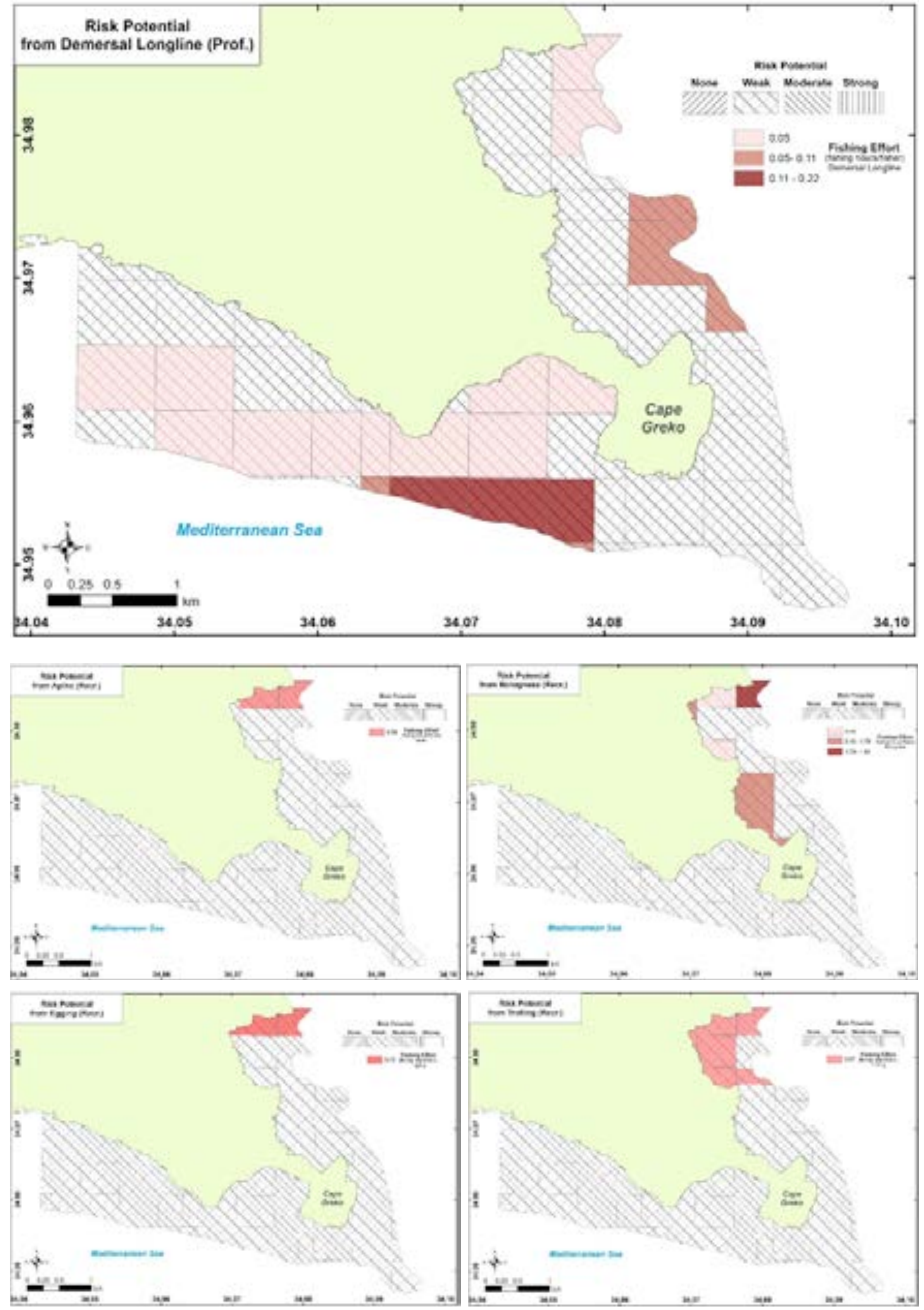

Figure 10

The Risk potential of professional demersal longlines (upper top panel) and of other recreational hook and line techniques on the benthic habitats of Cape Greco MPA. For all fishing gears and techniques, the risk potential was initially scored as weak, but the risk further increases with fishing effort as shown in each panel.

5.5. Traps (active in the Cape Greco MPA)

Pots & traps, fyke nets and uncovered pound nets used to catch crustaceans, molluscs and some fish (seabream, eel). Boat and shore-based deployment. All three assessed habitats interact with these types of gears and are under a certain degree of risk potential (Figure 11; Table 22).

5.5.1. Physical

- Potential localised physical effects on sediment when hauling and/or deploying traps.

5.5.2. Chemical

- None identified.

5.5.3. Biological

- Fragile benthic species potentially damaged during deployment and/or hauling of traps.
- By-catch and entanglement of marine mammals, seabirds, fish and turtles.
- Discarded pots are known to "ghost fish" catching both commercial and non-commercial species.

5.5.4. Conclusions

Physical and biological effects from the use of this type of gear are well documented and principally on benthic habitats and processes. They include moderate mechanical impact with associated mortality on epibenthos, and changes in the topography and turbidity.

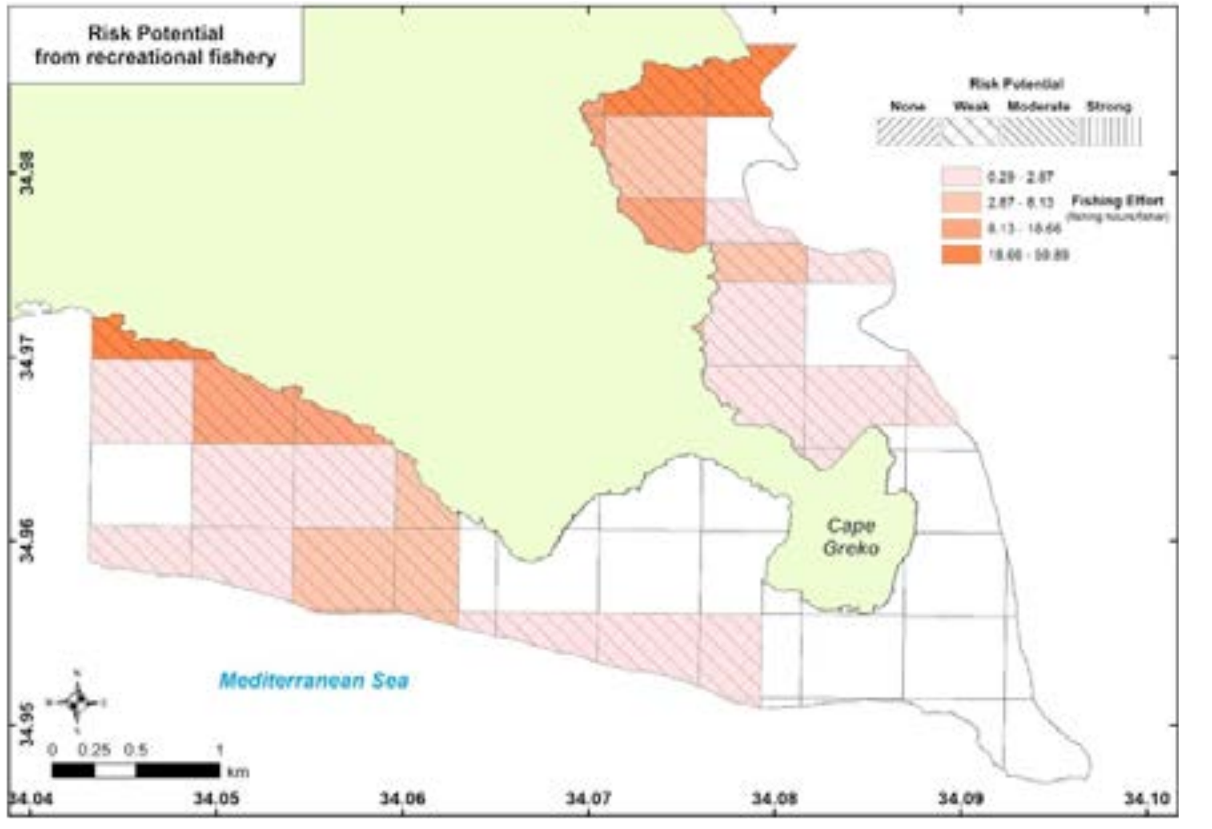

Figure 11
The Risk potential of traps on the benthic habitats of Cape Greco MPA. The risk potential of the traps was initially scored as weak, but the risk further increases with fishing effort.

5.6. Nets (active in the Cape Greco MPA)

Trammel, set gillnets, drift nets, and tangle nets. Bottom set gill nets used to catch demersal finfish, pelagic driftnets catches include mackerel, sardine, bluefin and swordfish. Boat and shore-based deployment. All three assessed habitats interact with these types of gears and are under a certain degree of risk potential (Figure 12; Table 22).

5.6.1. Physical

- Localised impact if gear is dragged across the seabed during hauling
- and potential impact on habitat forming species such as seagrasses, sponges, corals and *Cystoseira* forests.

5.5.2. Chemical

- None identified.

5.5.3. Biological

- Entanglement and by-catch of large pelagic elasmobranchs (e.g. blue shark), loggerhead and leatherback turtles, small marine mammals including cetaceans, bottlenose dolphins, risso's dolphin, common dolphin and pinnipeds, seabirds.
- In static nets seabird by-catch is reported for divers, grebes, sea ducks, diving ducks, auks, shearwaters and cormorants.
- Lost gillnets and trammel nets may also continue to have an effect through "ghost fishing".
- Dragging of gear across the seabed during hauling can potentially cause mortality to structural biota and epibenthos.

5.5.4. Conclusions

Main potential effects noted are incidental catch including marine mammals, seabirds and elasmobranchs. Ghost fishing as well as direct entanglement can take place. Effects on benthos may be some localised damage during hauling.

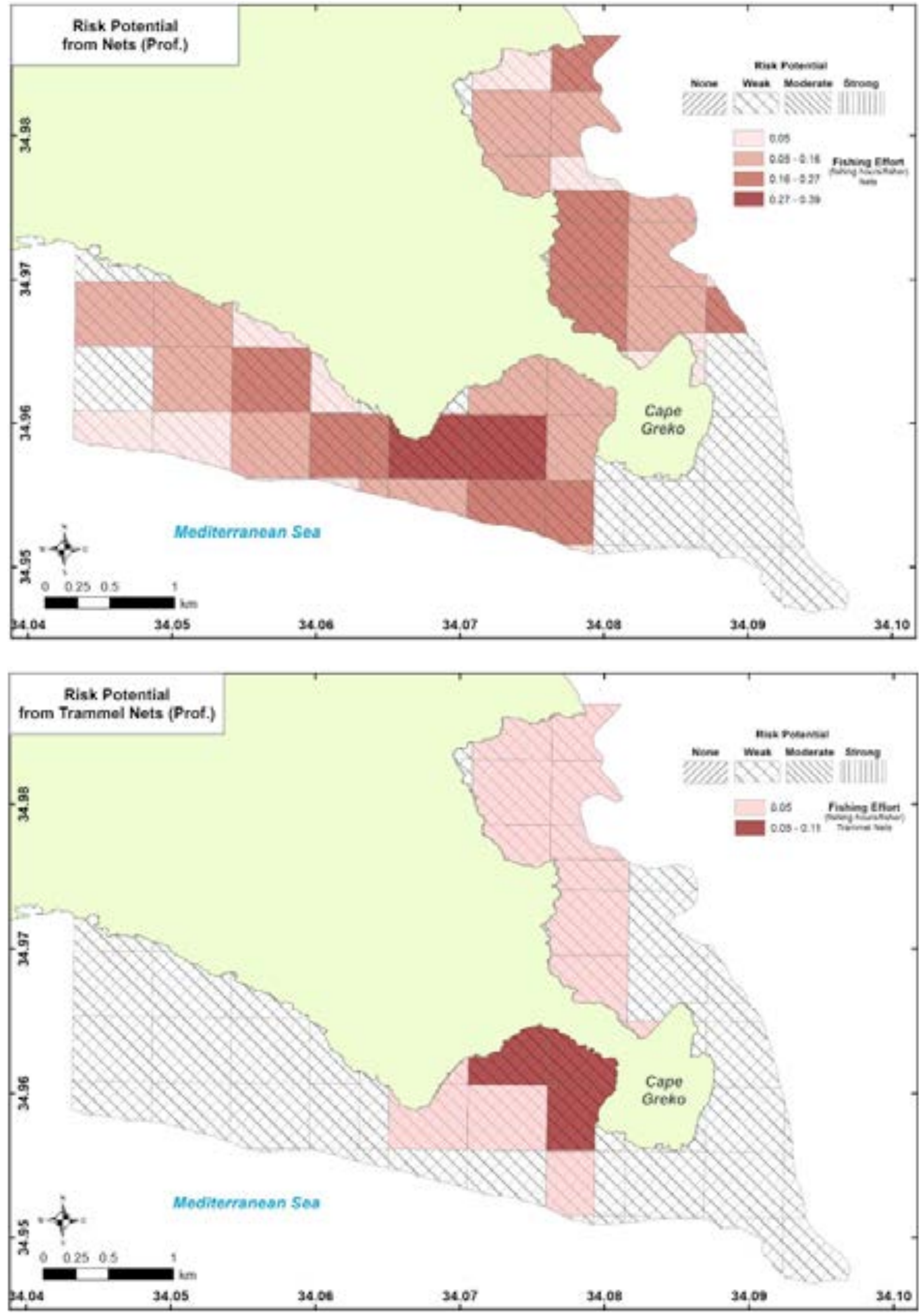

Figure 12
The risk potential of professional gillnets (top panel) and trammel nets (bottom panel) on the benthic habitats of Cape Greco MPA. For all fishing gears and techniques, the risk potential was initially scored as weak, but the risk further increases with fishing effort as shown in each panel.

5.7. Summary of Risk Potential

A summary of the impact potential and risk potential of each fishing gear/technique and habitat of Cape Greco MPA is shown in Table 22. Risk potential maps for each active gear is presented in the separated documents (Deliverables 2.4i – 2.4 xviii).

Table 22

Summary of sensitivity of habitats, impact potential of each fishing gear and the potential Risk of Natura 2000 habitats to different fishing methods. Blue font indicates fishing gears that are not active in the Cape Greco MPA at the present time.

Habitat	Habitat Sensitivity	Fishing Gear/Technique	Impact Potential	Risk Potential
1110-Sandbanks	Moderate	Dredges	Moderate	Moderate
	Weak	Trawler - Pelagic	None	None
	Moderate	Trawler - Bottom	Moderate	Moderate
	Weak	Handheld Hook & Line (Apiko, Bolognese, Egging, Trolling, Kalamariera, Line, Rod, Spinning, Surf Casting)	Weak	Weak
	Weak	Demersal Longline	Weak	Weak
	Weak	Traps/Pots	Weak	Weak
	Weak	Nets (Trammel nets, Gillnets, Tangle nets)	Weak	Weak
	Weak	Ghost Gear	Weak	Weak
	Weak	Spearfishing	Weak	Weak
1170 - Reefs	Strong	Dredges	Strong	Strong
	Weak	Trawler - Pelagic	None	None
	Strong	Trawler - Bottom	Strong	Strong
	Weak	Handheld Hook & Line (Apiko, Bolognese, Egging, Trolling, Kalamariera, Line, Rod, Spinning, Surf Casting)	Weak	Weak
	Weak	Demersal Longline	Weak	Weak
	Weak	Traps/Pots	Weak	Weak
	Weak	Nets (Trammel nets, Gillnets, Tangle nets)	Weak	Weak
	Weak	Ghost Gear	Weak	Weak
	Weak	Spearfishing	Weak	Weak
1120 - *Posidonia* beds	Strong	Dredges	Strong	Strong
	Weak	Trawler - Pelagic	None	None
	Strong	Trawler - Bottom	Strong	Strong
	Weak	Handheld Hook & Line (Apiko, Bolognese, Egging, Trolling, Kalamariera, Line, Rod, Spinning, Surf Casting)	Weak	Weak
	Weak	Demersal Longline	Weak	Weak
	Weak	Traps/Pots	Weak	Weak
	Weak	Nets (Trammel nets, Gillnets, Tangle nets)	Weak	Weak
	Weak	Ghost Gear	Weak	Weak
	Weak	Spearfishing	Weak	Weak

6 CONCLUSIVE REMARKS

This report contributes to the sensitivity assessment of marine Natura 2000 habitats of the Marine Protected Area of Cape Greco to fishing activities. Peer reviewed and grey literature sources have been used to score the (a) sensitivity of the three marine benthic habitats to associated pressures and (b) the risk potential of each fishing gear/technique on the assessed habitats based on the sensitivity scores of each habitat, the impact potential of the gear used and the fishing effort within the area of study. The information presented here, only highlights the sensitivity of habitats to each pressure, and does not consider the cumulative effects of the pressures generated via a single fishing gear or via the combination of multiple fishing gears practiced in the MPA of Cape Greco.

Overall, the most sensitive marine benthic habitats were 1170 - Reefs and 1120 - Posidonia beds, particularly to pressures generated by dredges and demersal trawlers. In some cases, the habitat or the habitat's species components are known to be vulnerable to the fishing method/pressure other than trawlers and dredges, and their impact on the assessed habitats increases with fishing intensity. Although these habitats can be quite resistance to natural and mild anthropogenic perturbations, once moderately degraded, their recovery to pre-disturbance conditions is extremely slow. The risk potential of these habitats by the dredges and demersal trawlers were indeed scored as "strong", despite their absence in the Cape Greco, whereas other fishing practices from professional and/or recreational sector were initially scored as "Weak". The risk potential for these however, can be largely altered when the fishing intensity/effort is increased in an area, as also shown here, and can be further increased when other factors take place such as the diversity of gear used in a given area, as well as the degree of natural disturbance (i.e. high energy environment vs. low energy environments). The presence of fishing-related litter in rather high densities is quite startling within the MPA of Cape Greco, and it should raise the alarm to the local authorities for a rigorous action plan to address and minimize this issue.

It is important to note that the sensitivity assessments are generic and have many limitations, are very dependent on the pressure duration and magnitude, are not considering the synergistic and indirect effects of pressures on organisms and habitats. These results, however, can be of immediate use by the Cyprus' authorities as part of their assessment of activities and a strategic management plan that have the potential to affect the conservation status of habitats and species which are protected in marine Natura 2000 sites and Marine Protected Areas.

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PART 5

Measures for the **management**
of the **fishing activities**
in **order** to **safeguard**
the **most sensitive habitats**
in **Cape Greco MPA**

PART 5

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1 INTRODUCTION

The wider effects of fishing on marine ecosystems and the impacts of fisheries has become the focus of growing concern among scientists, fisheries managers and the fishing industry in the past decades. Fishing gear that interacts or scrapes the bottom is the one that produces the most damage to habitats; and the use of towed gear with reduced bottom contact, or even prohibition of certain gears, e.g. trawlers in seagrass or corals, is usually recommended (FAO, 2003). Fishing gears such as trapping, longlining, or gillnetting, are considered to be low-impact fishing methods with less interference with the bottom habitats (FAO, 2003; Kopp *et al.,* 2020).

Fisheries impact on the seafloor largely depends on the presence of sensitive habitats and the presence of long-lived slow growing species (Bastardie *et al.*, 2020; Rendina *et al.*, 2020). For instance, *P. oceanica* meadows grow at a rate of 1-7 cm rhiz-1 year-1 (Marbà *et al.,* 1996; Marbà and Duarte 1998) and vertically between 0.4 and 1.1 cm rhiz-1 year-1 (Boudouresque and Jeudy de Grissac, 1983), and therefore, they have been considered as vulnerable and sensitive to pressures that cause substantial loss within a short amount of time. For the latter reasons, winch trawlers are prohibited to operate below 50 m depth and within of 1.5 nautical miles from the coast in Cyprus; in line with EU policy (EC/1967/2006).

Through this study, we found that the most sensitive marine benthic habitats in the entire Cape Greco MPA (including partially protected and fished areas) are '1170 – Reefs' and '1120 - Posidonia beds', particularly to pressures generated by dredges and demersal trawlers. However, these practices are absent from Cape Greco whereas other fishing practices from professional and/or recreational sector have been scored as "Weak" (Deliverable 2.3-2.4). The risk potential for these however, can be largely altered when the fishing intensity/effort is increased in an area, as also shown in the sensitivity and impact of degradation assessment, and can be further increased when other factors take place such as the diversity of gear used in a given area, as well as the degree of natural disturbance (i.e. high energy environment vs. low energy environments). More information about the fishery activities in the area can be found at the 'Deliverable 1' and on the sensitivity of the habitats to active fishing practices at the 'Deliverable 2.3-2.4'.

If correctly monitored and managed (with proper enforcement), the MPA of Cape Greco could help restore the complexity of ecosystems through a chain of ecological effects (trophic cascades) once the abundance of large animals recovers sufficiently (Sala and Giakoumi 2018); and protect benthic ecosystems from direct interactions with fishing gears. Restoration of the Cape Greco MPA after its recent establishment (year 2018) needs time; it has been estimated that the average annual recovery is less than 3% and a site would need in the best scenario (without considering increasing pressures) about 20 years to reach 90% of undisturbed baseline level (Duarte *et al*., 2020). The restoration is indirectly linked to the health of the benthic sensitive habitats, and reduction/control of threats and pressures needs to be ensured.

The major threats to habitats from fishing activities that have been identified through this project and where measures could be applied include (i) illegal activities (described in 'Deliverable 1'), (ii) overfishing and other pressures (e.g. invasive species) (described in 'Deliverable 2.1'), and (iii) fishery related litter and ghost gear (described in 'Deliverable 2.3-2.4'). Our document has focused on possible measures that could be applied to minimize the impacts from active fishing and lost fishing gear, on the benthic ecosystem. Emphasis has been given to the active fishery gears with the highest potential impacts; namely demersal longlines, trammel nets and gillnets, and fishing traps/pots. The issues of invasive species, and illegal fishing are also been discussed.

2
LOST DEBRIS FROM **FISHING**

Lost debris from fishing activities often characterize the major direct impacts from fishing to the benthic habitats which is often evidenced by fragmentations, broken species and strips (Bo *et al.*, 2014). Since the mid 1980 the issue of 'ghost fishing' first gained global recognition and it can been defined as the mortality of fish and other species that takes place after all control of fishing gear is lost by a fisher (Way, 1976). In more detail, ghost fishing occurs when passive gears such as gillnets, trammel nets, wreck nets, pots and traps, are lost or discarded and continue to catch commercially important species of fish and crustaceans as well as non-commercial species of fish and crustaceans, birds, marine mammals and turtles (Brown and Macfyden, 2007). In addition, abandoned gear can potentially pose safety risks for fishers if they become entangled with active fishing gear and vessel propulsion systems. Fishing gears may also damage benthic habitats while in use, through abrasion, 'plucking' of organisms or meshes closing around them during the setting and retrieval phase (*Ioakeimidis et al.*, 2014).

In many countries of the modern world, commercial fishermen still use fishing gear that has been scientifically proven to cause habitat degradation (Barnette, 2001; Watling, 2005). As marine habitat degradation awareness grows, scientists and managers are challenged to re-design, create, and adopt new fishing practices to counteract or prevent the damages caused by fishing gear. This guide aims to give managers a baseline tool on how to protect the most sensitive habitats from destructive fishing gears and practices and to suggest the use of alternative primary materials for constructing fishing gear as well as gear setups which have been proven to be less destructive.

The most common active fishing gear and practices in the Cape Greco for both recreational and commercial fisheries were identified through the project as part of Action 1 and are presented bellow along with a brief description of the impacts that each gear opposes on sensitive habitats.

2.1. Demersal longlines

Limited scientific information exists regarding the direct impacts that demersal longlines oppose towards marine vegetation, benthic epifauna and the marine ecosystem in general. However, it is widely known that bottom-set longlines often get easily entangled on irregular objects protruding on the seafloor, leading to total abandonment of gear on the seafloor or significant destruction of the surrounding microhabitat (Macfadyen *et al.*, 2009). In more detail, demersal longlines are composed of two downlines with weights attached on each end for anchoring, a pair of marker buoys, a main line, snood lines and baited hooks at the end of each snood line. In most longline setups the main line has a substantially higher breaking point than the snood line in case the hook attached on the leader line gets snagged on the seafloor (Figure 1). Such a setup will allow the snood line to break well before the breaking point of the main line, making it possible to retrieve the rest of the gear.

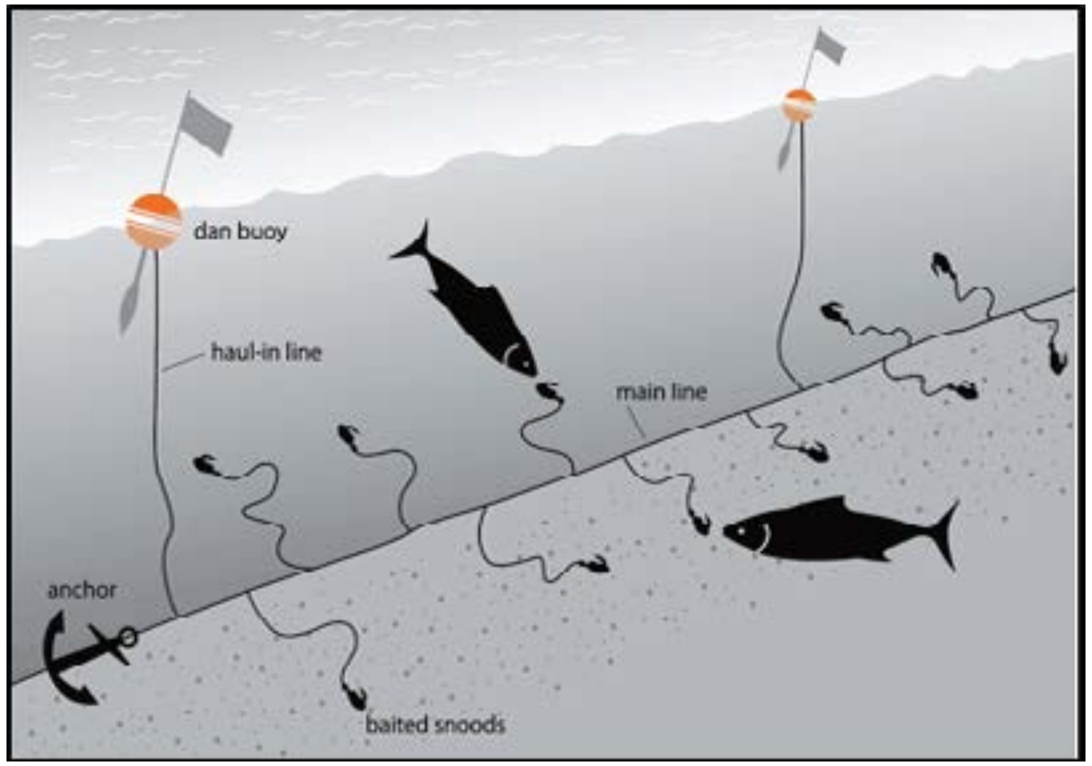

Figure 1

A typical demersal longline setup.
(Source: **http://fish.gov.au/Fishing-Methods/Hook-and-line?_escaped_fragment_=**).

Although the mainline can withstand a significant amount of pulling force, sometimes it can break due to a bad entanglement or due to operational error. Such incidents lead to fishing gear to gradually entangle on nearby features and to become the so called "ghost gear".

Moreover, during the setting and retrieving phase, the longline mainline scrapes the seabed especially during the retrieval phase, at which high pulling forces are exerted on the line (Sinclair *et al.*, 2002; Macfadyen *et al.*, 2009). In addition, anchor weights can be pulled considerable distances across the seafloor before accenting, scraping everything on its pass (Sinclair *et al.*, 2002).

2.1.1. Possible measures for protecting sensitive habitats from demersal longlines

2.1.1.1. Biodegradable fishing lines

Biodegradable fishing lines do exist in the fishing industry for some years now, however they are rarely used due to the fact that anglers are not ready to embrace the risk of trying something new as it might cause them to lose their catch. Scientists have managed to produce a biodegradable polymer that has the ability to disintegrate upon prolonged exposure to ultraviolent light and/or in aqueous environment (Ferguson, 2010; Deroine *et al.*, 2018). Some companies have produced biodegradable fishing lines, however often their supply is limited (Figure 2). Using such product could greatly benefit the marine ecosystem as it can give an end to the 'ghost gear' problem from methods that use lines.

Figure 2

Biodegradable fishing lines.

2.1.1.2. Changing the longline setup

The mainline in most longline setups is a thick monofilament line that can withstand strong pull forces exerted by vessel's pulling winch. Due to the line's high diameter and weight it sinks to the bottom faster than conventional fishing lines. This type of lines is highly affected by underwater currents, which can increase the tension on the mainline or push it on underwater features (Figure 3a). In complex habitats, the mainline can easily wedge under rocks or tangle around seagrass shoots, causing the mainline to break or to pull everything on the surface. A solution to this is to add small floats every few meters on the main line, keeping it above the seafloor thus, decreasing the chances of gear loss or habitat destruction (Figure 3b) (Cortes and Gonzales, 2018).

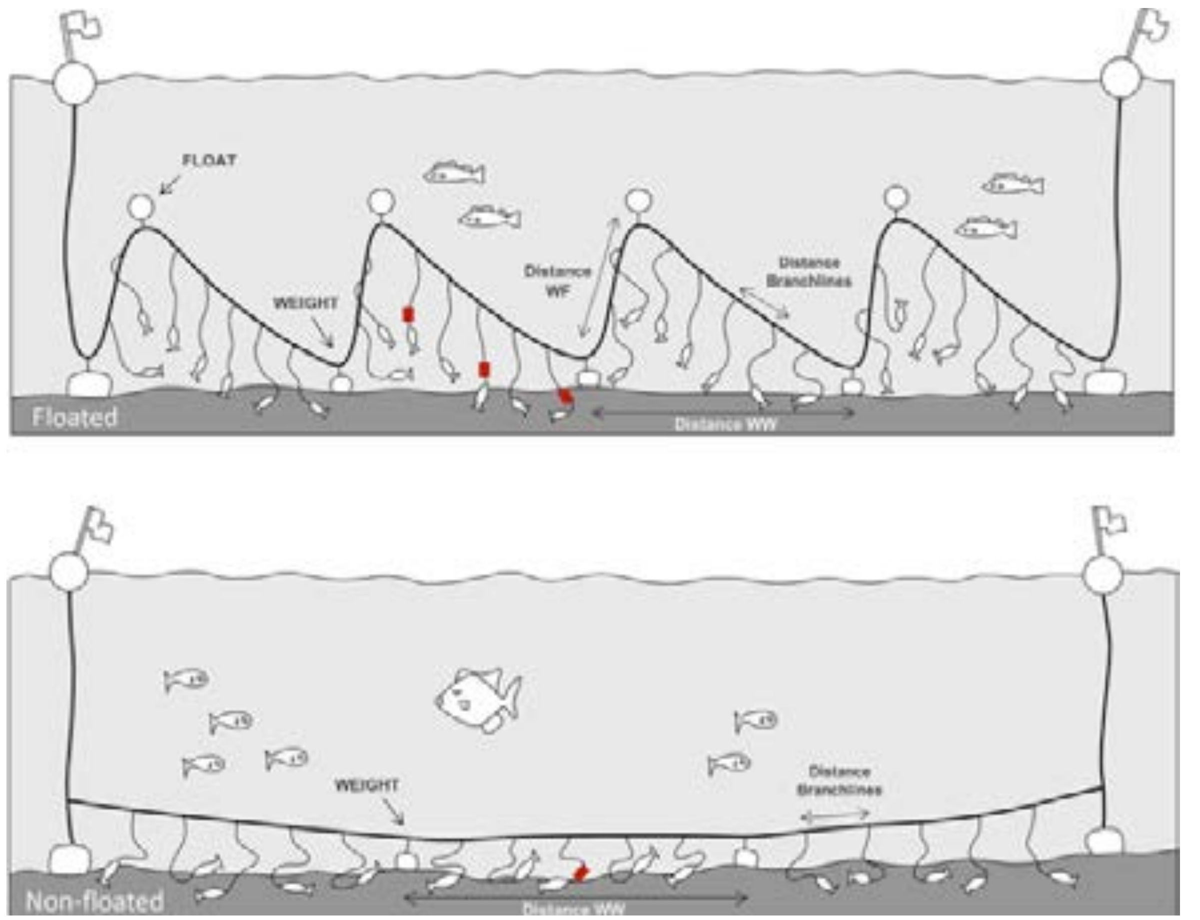

Figure 3

(3A) A floated demersal longline setup. (3B) A non-floated demersal longline setup (Source: Cortes and Gonzales, 2018).

2.2. Trammel nets and gillnets

In Cyprus and especially at Cape Greco area, the small-scale commercial fishermen mainly use only two types of fishing nets, gillnets, and trammel nets in various mesh diameters. A gillnet is a wall of single netting that hangs in the water column, typically made of monofilament or multifilament nylon (Figure 4). A trammel net is similar to a gillnet, however, the netting wall consists of 2-4 layers of netting with a slack small mesh inner netting between two layers of large mesh netting within which fish will entangle (Figure 5). These nets are strings of single, double, or triple netting walls kept vertical by floats on the headrope and mostly by weights on the groundrope.

The direct benthic effect of trammel and gill nets fishing operation is likely to occur during retrieval of the gear, during which the nets and leadlines are more likely to snag on bottom structures. Reef-forming organisms, seagrass and other sessile epibenthic organisms frequently become entangled in benthic nets and are damaged when they are hauled (Sinclair *et al.*, 2002). In addition, a bad entanglement of nets on reef structures can lead to permanent loss of fishing gear contributing to the well-known phenomenon of ghost gear. Bottom setting nets are classified as the most common ghost gear with approximately 55% of all ghost gear found belonging to the nets category (Stelfox *et al*, 2016)

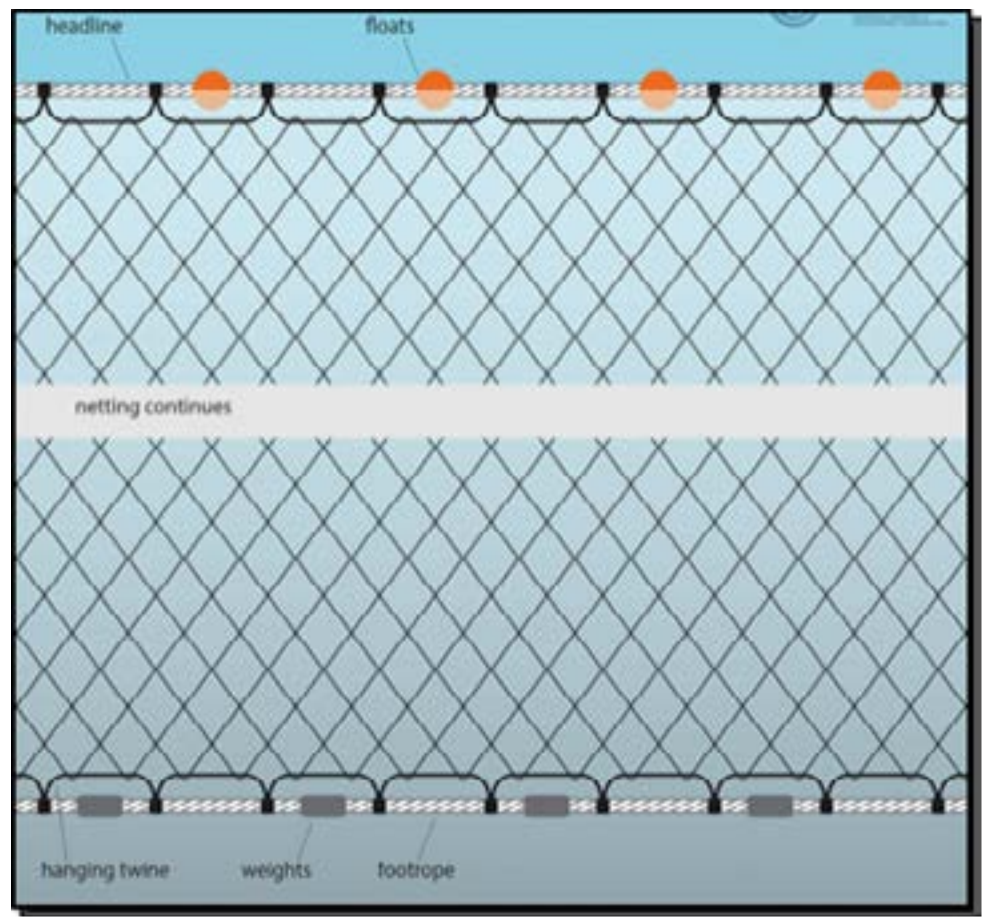

Figure 4

A typical gill net setup. A single layer of net held open in the water column by headline floats and anchored by lead weights on the groundrope.

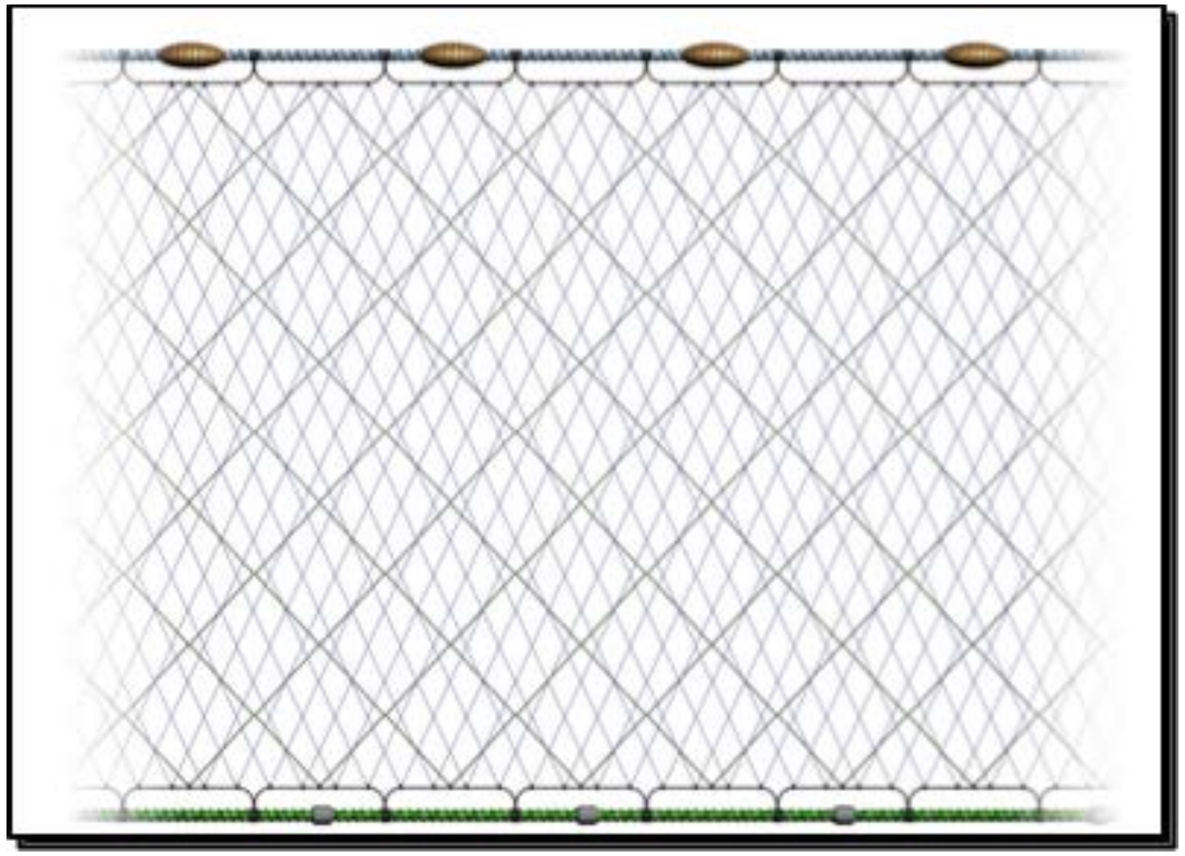

Figure 5

A typical trammel net. On top floats keep the net wall open and on the bottom small lead weights keep the net anchored at the seafloor (Source: https://www.cornwallgoodseafoodguide.org.uk/fishing-methods/trammel-net.php).

2.2.1. Possible measures for protecting sensitive habitats from trammel nets and gillnets

2.2.1.1. Gear maintenance

Gear abandonment usually is the result of gear failure due to inadequate maintenance or repair. A worn-out net rope can cause the whole net to fail, making it impossible for the fisherman to haul the gear back onboard. Frequent gear inspection will significantly contribute to the decrease of ghost nets resulting from gear failure.

2.2.1.2. Use of alternative materials

Until the early 1960s, natural materials such as cotton and hemp were commonly used for fishing nets construction. With the advent of polyamide-based nylon after World War II, synthetic fibres quickly replaced natural materials (von Brandt, 1984). The excellent fishing performance, high strength and low price of synthetic materials contributed to the development of worldwide net fisheries (Kim *et al.*, 2015). The major drawback of synthetic nets is that they are very resistant to degradation once they have been lost, abandoned, or discarded at sea.

The need for combating ghost nets has pushed scientists to create a new type of net strings made from biodegradable material. Such nets can lose their catching efficiency in less than 48 months compared to monofilament nets which can hold their catching efficiency for many years or even decades (Kim *et al.*, 2015). Such materials can be incorporated in the Cyprus small scale fisheries especially at areas of high ecological importance.

2.2.1.3. Gear recovery campaigns

Gear retrieval campaigns are common in EU waters and can successfully keep small areas protected from ghost gear, however this kind of measures are limited to depth and gear loss reporting (Brown and Macfyden, 2007). The use of transponders on fishing gear could potentially work co-synergistically with retrieval campaigns and increase the efficiency of such practises especially in small areas, such as Cape Greco.

2.3. Fishing traps/pots

Fish traps (pots) are gears in which the fish are retained or enter voluntarily. They are designed in such manner that the entrance itself became a non-return device, allowing the fish to enter the trap but making it impossible to leave. Traps can be used baited or not. Different materials are used for building a trap: wood, split bamboo, netting wire are some examples. Fish traps are a commonly used fishing gear from many civilizations around the world and is probably the oldest form of fishing (Smith, 2001; Newman *et al.*, 2011).

A typical pot setup consists of a fish trap with an opening either to the top of the trap (Figure 6a) or to the side (Figure 6b). Top openings are funnel shaped with a downward angle making it easier for fish to enter the trap and extremely difficult to get out. Traps with a side opening are commonly used for crustaceans. Mesh surrounding the metal frame of the pots is either made of metal wire or nylon strings. For retrieval and marking purposes, the pot is attached on a line that is connected to a surface float and a marking buoy (Figure 7). No anchoring weight is needed as the pot has sufficient weight to sink by itself.

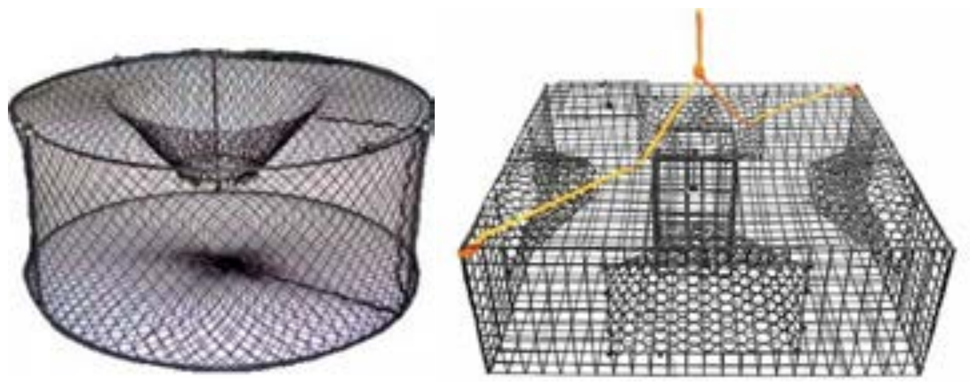

Figure 6

Two different pot types that are most commonly used. (Source: https://www.lobstertraps.org/lobstertrap/shrimp-trap.html).

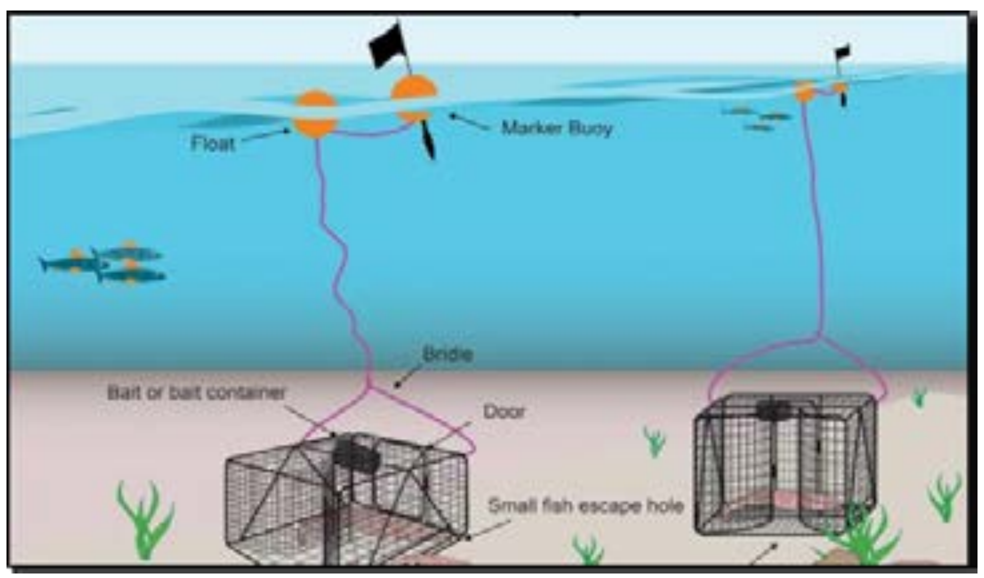

Figure 7

A typical pot setup.(Source: https://www.afma.gov.au/fisheries-management/methods-and-gear/traps).

During setting, and especially during hauling, traps and pots often drag over the bottom for some distance, which may cause seabed damage. One trap by itself may cause little damage, but when large numbers are employed in a fishery or on a single fishing ground, as is commonly the case, the cumulative impacts can be substantial (Sinclair *et al.*, 2002). In addition, lost and abandoned traps continue to catch fish, eventually leading to high mortality of trapped fish as they cannot escape the trap and die from starvation (Bullimore *et al.*, 2001; Kruse and Kimker, 1993; Newman *et al.*, 2011). Fishing pots is a popular fishing method at Cape Greco area, with the most targeted fish to be the alien species of *Siganus luridus* and *Siganus rivulatus*.

2.3.1. Possible measures for protecting sensitive habitats from fishing pots

2.3.1.1. Biodegradable mesh opening

A solution widely used to combat fish/crustacean mortality from lost or abandoned fishing traps is the use of degradable escape mechanisms. This escape mechanism is usually a biodegradable string that dissolves after being exposed to a certain period to marine environments (Kruse and Kimker, 1993). In areas of high importance such as Posidonia *oceanica* meadows this can allow juvenile fish or important species to escape the trap and survive in a relatively good fitness. Such practices can be enforced to combat ghost gear fishing in small scale fisheries in the Cape Greco area.

2.3.1.2. Pot weight

One consideration is to ensure that the demersal traps are not heavier than is needed to land upright and keep a steady position on the seabed. This will minimize the local impacts caused by the weight of the pot, especially in seagrass meadows (Sinclair *et al.*, 2002). Lighter pots will prevent sinking in soft bottom habitats.

2.3.1.3. Trap string setup

Although uncommon in Cyprus waters, some commercial fishers set their pots attached to each other, forming a long string of pots (Figure 8). Such pot setups can potentially drag over the bottom for some distance especially during the hauling phase, which may cause seabed damage. Such setups should be avoided, and each pot should have its own line attached to a float. This will help to lift the pot perpendicularly, avoiding any scraping or dragging over the seafloor.

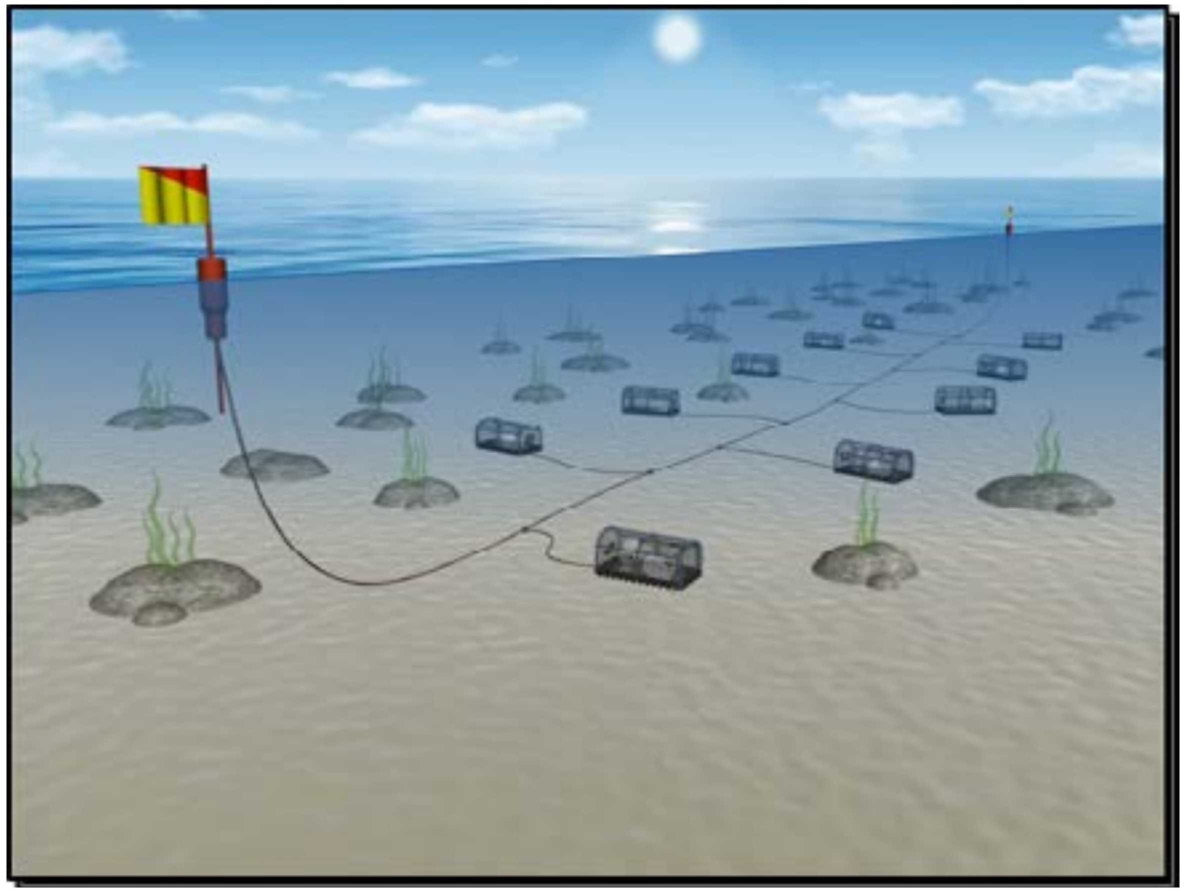

Figure 8

A string of pots (Source: https://www.cornwallgoodseafoodguide.org.uk/fishing-methods/potting.php).

2.4. Other fishing gear

Most of the recreational fishermen at the overall Cape Greco area use a rod and reel as their preferred fishing method. Small, baited hooks or silicone/metal lures are often used to attract fish, however, recreational fishermen try to avoid benthic interaction as it can lead to permanent loss of expensive gear. Recreational rod and reel fishing techniques oppose little risk towards sensitive habitats and their immediate minimal impacts are attributed to accidental gear snugging on hard substrate. Furthermore, fishing lures are frequently made from biodegradable or natural materials (metal, wood, brass, rubber) with exception to fishing lines. Due to the equipment used and the low fishing intensity, recreational fishing has minimal contribution to the local ghost gear issue.

3
NON-INDIGENOUS SPECIES

Our study has confirmed that non-indigenous species (NIS) have become a major part of the ecosystem and subtle but urgent management is needed ('Deliverable 2.1'). The NIS effects will likely exacerbate as other human pressures intensify (Geraldi *et al.*, 2020). Visual census surveys have shown that the no-take zone is susceptible to NIS with higher proportions compared to the other areas. It's important to protect those areas from the potential adverse effects of invasive species.

The effects of NIS are dynamic and diverse; many of them have become highly commercial and demanded while some are posing a great threat for ecosystems. An ecosystem-based management is needed with respect to the ecosystem services trade-offs of each species in a socioeconomic and ecological framework. It's important to acknowledge the dynamic trade-offs of each NIS and the traits of each species. Isolated control measures through commercial fisheries with financial incentives to target the poisonous pufferfish (*Lagocephalus sceleratus*) in Cyprus, have been identified as costly with no long-term positive results (DFMR, 2012). On the other hand, trials of targeted measures of lionfish (Pterois miles) conducted in the framework of the LIFE RELIONMED project (**www.relionmed.eu**) have shown promising results but sustainability of removals needs to ensured. Targeted removals of NIS could be further promoted; given that it is practiced with gears that do not cause destruction of habitats, have no or low by-catch, and are strictly monitored.

Apart from targeted removals, investment in research and monitoring programs is of paramount importance, and the establishment of stationary monitoring stations in the sentinel location of Cyprus for monitoring the impacts of Lessepsian immigrations at an early stage is strongly recommended. Adaptation to the current situation of the eastern Mediterranean is needed through market promotion of edible NIS in order to turn pressure towards them and reduce it from other. A similar campaign has been recently initiated in Greece with the project 'Pick the alien' which aims to raise awareness of the local community and all the stakeholders in Greece regarding alien species and the consequences of their presence on the local economy, tourism, indigenous species, and environment, and to human health. At the same time an effort is made to promote the consumption of edible alien species as a mitigation measure to their expansion and the growth of their population (more information can be found here: https://isea.com.gr/pick-the-alien-2/?lang=en).

4
ILLEGAL ACTIVITIES

Management measures require compliance monitoring and strong enforcement mechanisms in order to be successful. When the goals of an MPA are not met, and the potential benefits are not obtained, stakeholder's support towards MPAs can be negatively influenced, potentially leading to a negative attitude and reduction in compliance (Chaigneau and Brown, 2016). This is likely the case of MPAs, whereby, current methods of compliance might have not been totally effective in eliminating the presence of illicit activities. Although these were frequently reported by the interviewees (see Deliverable 1), our team also observed several incidences of illegal activities in the Cape Greco MPA during our field work for this project. We recorded 33 incidences of illegal fishing (25 in the northern Buffer Zone and 8 in the No Take Zone) during only the first two-week period of intensive field work in the area. Most of recreational fishers stated that the main causes for the illegal incidents within the MPA were notion of the illegal fishers, the inadequacy of fishing controls, absence of information and knowledge and the low amount of fines imposed for the reported illegal fishery cases (Deliverable 1).

Absence of signs for the fishery-restricted area was a major bottleneck and raised by many interviewees in our study. We even approached shore fishers who were illegally fishing within the MPA and they attributed their lack of knowledge for the MPA to the absence of any signs. Although signs have been placed in the coastal areas, it is recommended that they cover the entire coast and include the marine area with marked buoys. The core (no fishing) zone A of the MPA could be further protected by adding an additional buffer zone towards the deeper waters of the zone. At the moment, fishing is allowed deeper than 50 m from all fishers and the existence of a buffer zone could minimize vicious or accidental fishing to the MPA. Most of the professional fishers stated that the fines of the illegal fishery were not harmonized with the type of the illegal fishery. In many Mediterranean countries, fines appear to be proportionately low compared to the potential income generated from the illegal catches, and coupled with the slow issuing of a fine, and the wide variety of penalty levels, further weaken the enforcement, encouraging illegal fishing and enhancing the sense of impunity (Moutopoulos *et al.*, 2016; Moutopoulos *et al.*, 2017). Fines/penalties can be proportionate and dissuasive to discourage individuals from conducting them.

Apart from strict sanctions and increased monitoring/enforcement programs, a behavioural science-based intervention can be used to reduce illegal fishing activities by challenging norms, beliefs, and modes to encourage desirable behaviours (Battista *et al.*, 2018). Educational and outreach activities can be organized to trigger behaviour and allow fishers understand the importance of the MPA and conservation and impacts of illegal activities. Trust and transparency are integral parts of this effort and can motivate fishers to establish self-control by contributing with their knowledge and experience to effective management measures acting as guardians of fisheries.

5
CONCLUSION

As previously mentioned, recreational fishing techniques are considered to pose little or no risk towards sensitive marine habitats at the Cape Greco overall area. However, commercial fisheries which use conventional fishing techniques have the potential to cause marine habitat degradation at some extend by mainly dragging of fishing gear on the seafloor and abandoned 'ghost' gear. Although new and improved commercial fishing techniques do exist, fishermen may fail to adopt them due to fears that gear modifications may make fishing equipment more expensive to construct, and more difficult to operate and maintain, catches of marketable fish may be reduced or they are just unaware of the available eco-friendly fishing materials.

Fishing gear modifications and the use of eco-friendly materials for gear construction is highly unlikely to totally diminish the impacts overnight. Therefore, realistic short- and long-term objectives are necessary when attempting to minimize ecosystem impacts of a fishery. In many cases, a combination of technological advancements, preventative legislations and other management actions may be necessary to protect a sensitive ecosystem in decline. Thus, close cooperation between the fishing industry, scientists and other stakeholders will be necessary in the process of developing and introducing environmentally friendly fishing technology. Restoration should also be considered by the managers, providing financial incentives to organize campaigns that will aim to remove the massive amounts of abandoned ghost fishing gear detected all around the Cape Greco area during the marine litter surveys of this study (Deliverable 2.3-2.4).

Finally, this short guide briefly summarizes the potential impacts that fishing gear opposes towards sensitive habitats and suggests more ecologically friendly and less destructive fishing approaches, nonetheless, shifting towards new and less destructive gear is in primal stages and more research is needed for highly efficient ways to combat habitat degradation due to fishing practices.

It is important to highlight that sensitive habitats of the MPA are not threatened only by fishery activities but also from the potential coastal development, tourism, demand for new buildings, and interventions to coastal ecosystems. Currently most area is far from coastal development, with the exception of the popular bathing area of Konnos Bay at the north of the MPA; where expansion of buildings and modifications of the coastal area was visible including illegal human interventions to the beaches (e.g. **https://dialogos.com.cy/termatizonte-i-paranomes-ergasies-se-pernera-konno-ke-skoutari/**). The entire MPA is a popular touristic site with intense activity during the summer period. The impacts through dredging, destruction, anchoring (locally, but accumulative due to the high touristic activity) and domestic sewage disposal need to be strictly controlled and managed. A serious impact to the biodiversity can also result from the touristic boat traffic and intense noise. Movement within or at least part of the MPA could be restricted to avoid disturbance of marine life, provide an attractive reproductive, nesting and feeding ground for the biota, but also enabling an easier fishery patrolling and enforcement.

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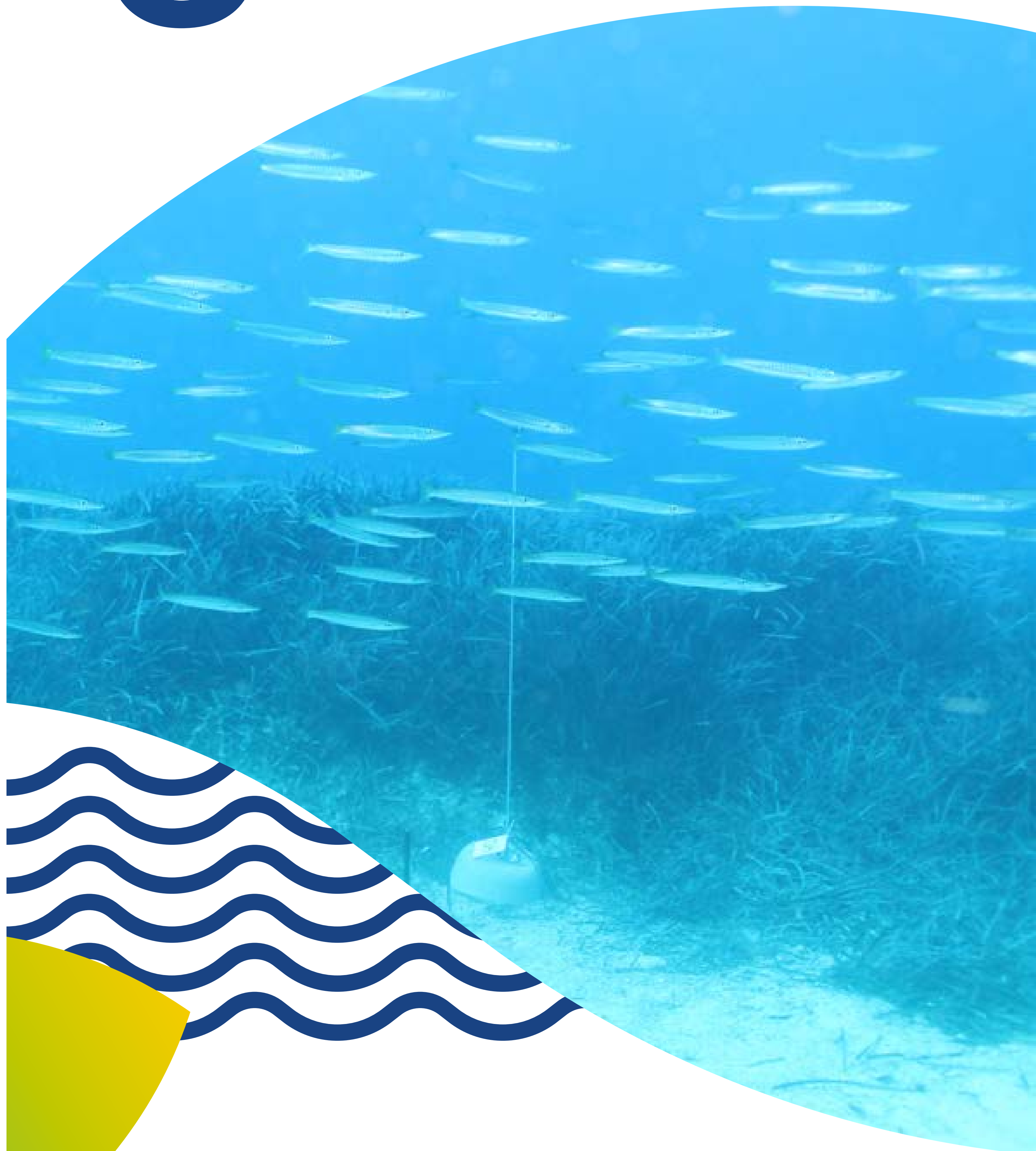
PART 6

Initiation of ***Posidonia oceanica*** **monitoring** in **Cape Greco MPA**



PART 6

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1 INTRODUCTION

Seagrass meadows are among the most productive ecosystems on earth but are declining at unprecedented rates (Waycott *et al.*, 2009; Costanza *et al.*, 2014). They provide key ecological services: coastal protection from erosion by attenuating waves and stabilising sediments, water purification by assimilating nutrients and pollutants, transfer of matter and energy up the trophic levels thus sustaining fisheries, carbon sequestration with implications to climate change, and provide habitat for enhanced biodiversity which boosts tourism, recreation, education and research. However, there are multiple growing pressures, including sediment and nutrient runoff, physical disturbance, invasive species, disease, commercial fishing practices, aquaculture, overgrazing, algal blooms and global warming, which have caused alarming declines and resulted in increased awareness of the need to protect, monitor, manage and restore seagrass habitats (Orth *et al.*, 2006; Barbier *et al.*, 2011). By far, the largest stores of organic carbon among seagrasses are found in the meadows dominated by the endemic to the Mediterranean, Posidonia oceanica (Linnaeus) Delile 1813, considered among the most representative and important Mediterranean coastal ecosystems (Buia *et al.*, 2004; Fourqurean *et al.*, 2012; Lavery *et al.*, 2013). The structurally complex meadows are the climax stage of the upper subtidal reaching depths of 40-45 m in oligotrophic waters and are associated with hundreds of species (Piazzi *et al.*, 2016). Although much of the Mediterranean coastline particularly, in the eastern basin remains uncharted, in the western basin where historical data exist, an estimated 34% of *P. oceanica* meadows regressed in half a century, classifying the *P. oceanica* habitat as an 'endangered' ecosystem (Telesca *et al.*, 2015). Full recovery of *P. oceanica* meadows is not possible in human time-scales, because of its slow growth and recovery rates (Boudouresque *et al.*, 2009). Up to twenty-five ecosystem services provided by *P. oceanica* meadows have been identified, which highlights the diversity of *P. oceanica's* contribution to human well-being and its major role in the Mediterranean Sea (Campagne *et al.*, 2015). The valuable ecosystem services offered by *P. oceanica* meadows depend largely on healthy functional meadows and as regressive meadows are increasingly reported so does the concern about the long-term sustainability of these services.

Across the Mediterranean Sea, seagrass monitoring is extensive, but the adoption of different sampling designs and methods may result in erroneous comparisons (Lopez y Royo *et al.*, 2010). Over the past decades, the Posidonia Monitoring Network (PMN) has refined a standardised methodology for setting up monitoring systems, which has been applied in the Euro-Mediterranean region (Boudouresque *et al.*, 2000; Pergent, 2007). Setting up monitoring systems using permanent markers is a durable and effective method to monitor the edge of seagrass meadows over medium to long timeframes (Pergent *et al.*, 2015). Comparable temporal monitoring along the edge of the meadow is possible through photography and measurements of vitality parameters from fixed positions. Slow growing seagrasses such as *P. oceanica* are especially suited to fixed-plot monitoring (Schultz *et al.*, 2015).

The first PMN systems to monitor the seagrass *P. oceanica* in the Levantine basin have been recently set-up in Vasiliko Bay-Moni, Cyprus (Kletou *et al.*, 2018). This project aims to expand the PMN systems to allow for comparable monitoring of the seagrass condition in the Natura 2000 site and Marine Protected Area (MPA) of Cape Greco, Cyprus. The PMN systems of this study have been set at the easternmost known biogeographic region of *P. oceanica* with the warmest water profile. The MPA of Cape Greco has an extended presence of *P. oceanica* which forms the only marine ecosystem considered as 'priority habitat' by the EU Habitats Directive. The results demonstrate the relative health status of *P. oceanica* meadows around Cape Greco and set the basis for a robust long-term monitoring that will be able to indicate if the seagrass meadows are facing regression or progression in the Natura 2000/MPA of Cape Greco.

2

METHODS

2.1. Posidonia Monitoring Network (PMN) Systems

Six PMN systems were set up at Cape Greco, two in each zone (No Take Zone, Buffer Zone, Wider Zone) **Deliverable 3.3 Map of monitoring sites (Appendix 1)**. The baseline data were collected according to the 'Protocol for the setting up of Posidonia meadows monitoring systems «MedPosidonia» Programme' (Pergent, 2007). The PMN systems were set up at intermediate depths (15-18 m) and in most cases near the upper limits of *P. oceanica*, in the summer-early autumn of year 2020 (**Table 1**). In each monitoring system 11 numbered cement markers were positioned at 5 m intervals and anchored with 12 mm iron stakes, at the edge of the meadow (total 50 m length) (**Figure 1**).

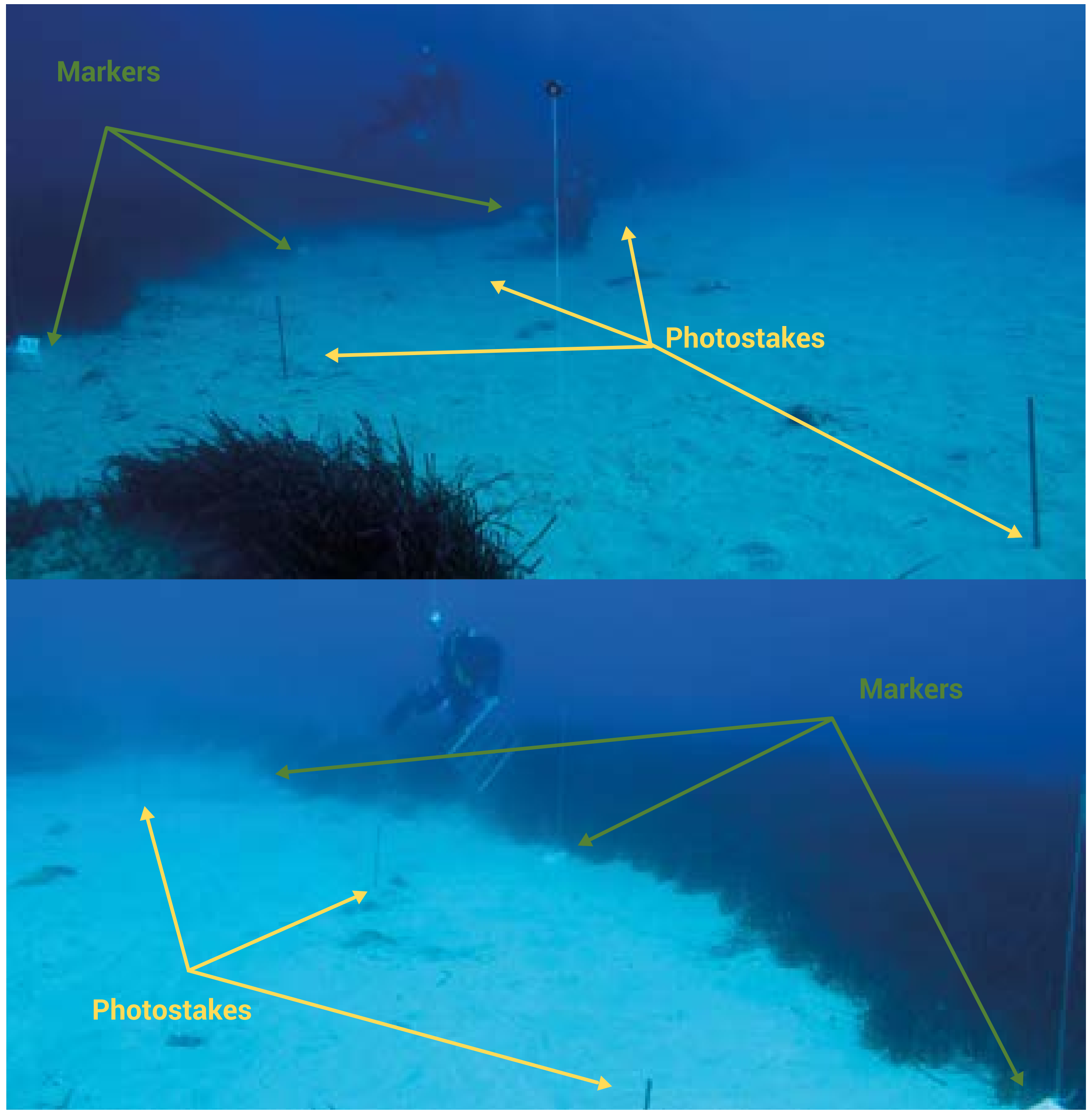

Figure 1
PMN monitoring systems set at meadows near the upper limits.

Moreover, 16 mm iron photo stakes were hammered in the sediment across each marker sticking out 50 cm from where photographs were taken (Figure 2), which were later joined in Adobe Photoshop to produce a wide-angle view of the marker from each photo stake (Figure 3). At each marker the following variables were recorded by scuba divers: depth and bearing to the next marker, shoot density and % of plagiotropic shoots were counted from three fixed quadrats (0.04 m^2), and shoot exposure or burial of orthotropic shoots with three replicates taken at the edge of the meadow. The % coverage was calculated in a 0.36 m^2 quadrat (split in nine 0.04 m^2 squares) placed above each marker (Figure 4) with a vertical photograph that was later processed with the Photoquad software (Trygonis and Sini, 2012).

Figure 2

Photographs of each marker were taken at different angles from the photostakes.

Figure 3

Photos joined to create a wide, panoramic photo of each marker.

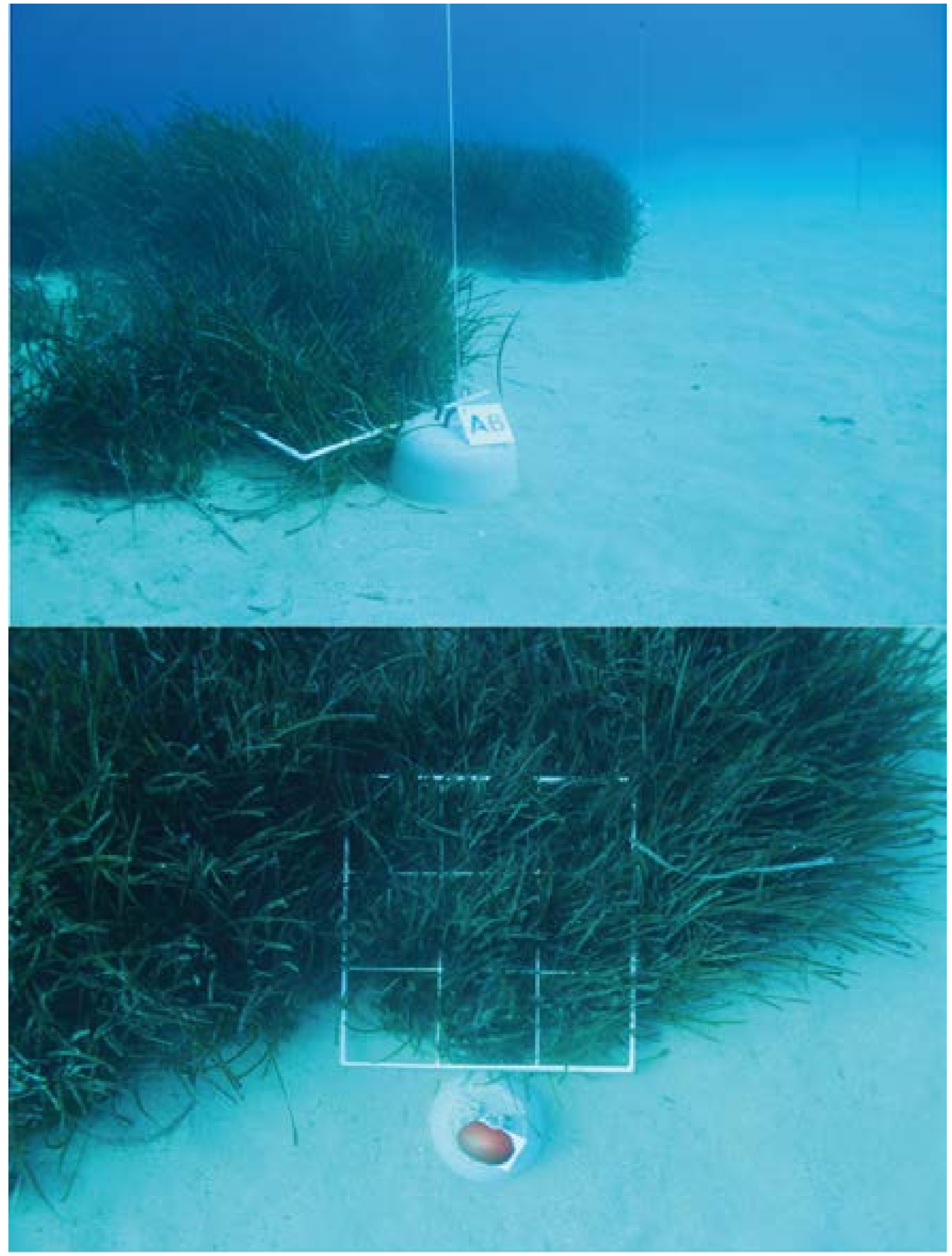

Figure 4

A 0.36 m2 was placed above each marker and was used to estimate shoot densities from three 0.04 m2 sub-quadrats (top). A vertical photograph was taken to later assess the % coverage (bottom).

Surface (top 5 cm) sediment was collected in 3 replicates from Marker 6. The sediment was dried, weighed and the granule size of sediment was determined using a granulometer. The organic matter (OM) content of fine sediment (1.5 g each replicate) was calculated using the Loss on Ignition method (550 °C for 2.5 hours). In addition, 20 randomly selected orthotropic shoots from each monitoring system were removed and leaf morphometric analyses were conducted using the technique of Giraud (1977). We recorded observations such as epiphyte presence, herbivory marks, necrosis and estimated the foliar surface per shoot (Figure 5). The dry mass of leaves was also measured after drying at 80 °C until constant weight. The past annual *P. oceanica* leaf production rate was calculated for 10 shoots from each monitoring system following a standardised procedure that uses the internodal length of the rhizome (Duarte *et al.*, 1994). Sections of the rhizome were cut at the annual minima using a scalpel while viewing the rhizome under a stereoscope (Figure 6). The length and dry mass of each rhizome section was measured after drying at 80 °C until constant weight.

Figure 5

Laboratory analyses (leaf morphometrics and biomass).

Figure 6

The internodal length method was used to estimate past leaf production, rhizome elongation and mass at every station.

A temperature data logger HOBO U22-001 - Water Temperature Pro v2 Data was installed at Site D while an additional data-logger of the same brand, as well as the software (USB/CD interface cable) and the communication system for downloading data, was provided to DFMR.

2.2. Deep Monitoring Stations

At another six sites (depths around 30-33 m) and near the lower limits of *P. oceanica* (limits were most times deeper), three permanent 0.16 m^2 quadrats were fixed at the edge (empty/available substrata was most times >50%) of the meadow. A quadrat was placed on the seafloor, four iron stakes were hammered in each corner of the quadrat and one was labelled with a tag and a submersible float. The quadrat was then collected (Figure 7). Seagrass coverage was estimated using a photo taken vertically above each quadrat and processed with the Photoquad Software (Trygonis and Sini, 2012). Densities of *P. oceanica* shoots within the quadrats was measured in situ by divers. The type of lower limit was assessed visually and using the ratio of plagiotropic rhizomes (Montefalcone, 2009; Lopez y Royo *et al.*, 2010).

Figure 7

An example of a permanent quadrat deployed at 30-33 m depth (four iron stakes hammered at the angles of a 40 cm sided quadrat with a label and a float on one of them).

Table 1 presents information about all the monitoring sites set in Cape Greco for this project (6 PMN systems set at 15-18 m depth and 6 deep stations at 30-33 m depth).

Table 1

Information (Name, Geographic Location, Average Depth and Dates of Sampling) for each monitoring system/site.

Site Name	Area	Site Coding	Latitude	Longitude	Mean Water Depth (m)	Date of baseline data collection
Site A	Wider Zone North	WZN_A	34° 58.921'N	34° 4.434'E	15.2	30.06.2020
Site B	Buffer Zone North	BFN_B	34° 58.026'N	34° 5.050'E	16.3	06.08.2020
Site C	No Take Zone	NTZ_C	34° 57.804'N	34° 5.299'E	18.7	15.09.2020
Site D	No Take Zone	NTZ_D	34° 57.678'N	34° 5.320'E	16.7	16.09.2020
Site E	Buffer Zone South	BZS_E	34° 57.558'N	34° 4.675'E	17	16.09.2020
Site F	Wider Zone South	WZS_F	34° 57.983'N	34° 2.800'E	16	02.07.2020
Site A Deep	Wider Zone North	WZN_A[d]	34° 58.880'N	34° 4.580'E	32.9	11.09.2020
Site B Deep	Buffer Zone North	BFN_B[d]	34° 58.145'N	34° 5.127'E	31.6	11.09.2020
Site C Deep	No Take Zone	NTZ_C[d]	34° 57.750'N	34° 5.370'E	32.1	09.09.2020
Site D Deep	No Take Zone	NTZ_D[d]	34° 57.394'N	34° 5.387'E	32.4	09.09.2020
Site E Deep	Buffer Zone South	BZS_E[d]	34° 57.347'N	34° 4.629'E	30	10.09.2020
Site F Deep	Wider Zone South	WZS_F[d]	34° 57.713'N	34° 2.624'E	32.5	10.09.2020

3
RESULTS

3.1. Posidonia Monitoring Network (PMN) Systems

Setting-up PMN systems at some zones was challenging since the dominant substrata type at Cape Greco (especially at the tip) is predominantly rocky and not ideal for setting up PMN systems that include hammering of iron stakes into the sediment. This issue was resolved by responsible i) planning, ii) exploring and iii) adapting. Planning included the analysis of aerial and satellite images to pin-point areas that seemed to have sand around *P. oceanica* meadows. Exploring included testing the depth of the sand with an iron stake at these different locations using either scuba-diving or freediving (Figure 8). Over 30 sites were tested to identify sites to set-up all six PMN systems. Adapting included the fact that meadows slightly deeper than 15 m were chosen to set up a PMN system if no available candidate sites at 15 m depth existed.

Figure 8

Explorations to identify potential sites for setting up PMN systems included testing the depth of soft substrata either with freediving (left) or scuba-diving (right).

The six PMN systems were successfully set-up (66 markers in total) around Cape Greco at mean depths of 15-19 m. Baseline data collected from each system are presented in **Deliverable 3.2i Baseline data collected at PMN systems (Appendix 2)**. The panoramic photos for each system and marker, merged in Adobe Photoshop are presented in **Deliverable 3.2ii Photographs of monitoring sites/markers (Appendix 3)**.

In the section below, P. oceanica parameters/metrics are compared across sites (A-F).

3.1.1. Coverage

The mean coverage of *P. oceanica* canopy ranged 63-97% among sites in 0.36 m^2 placed over the markers on the meadow side (**Figure 9**). Site F had the highest coverage while sites C and D had the lowest, but this is due to the fact that some quadrats at these sites were placed on dead matte that existed in the front of the meadow with very few living shoots and hence low coverage (<10%). This high variability is reflected in the error bars of **Figure 9**.

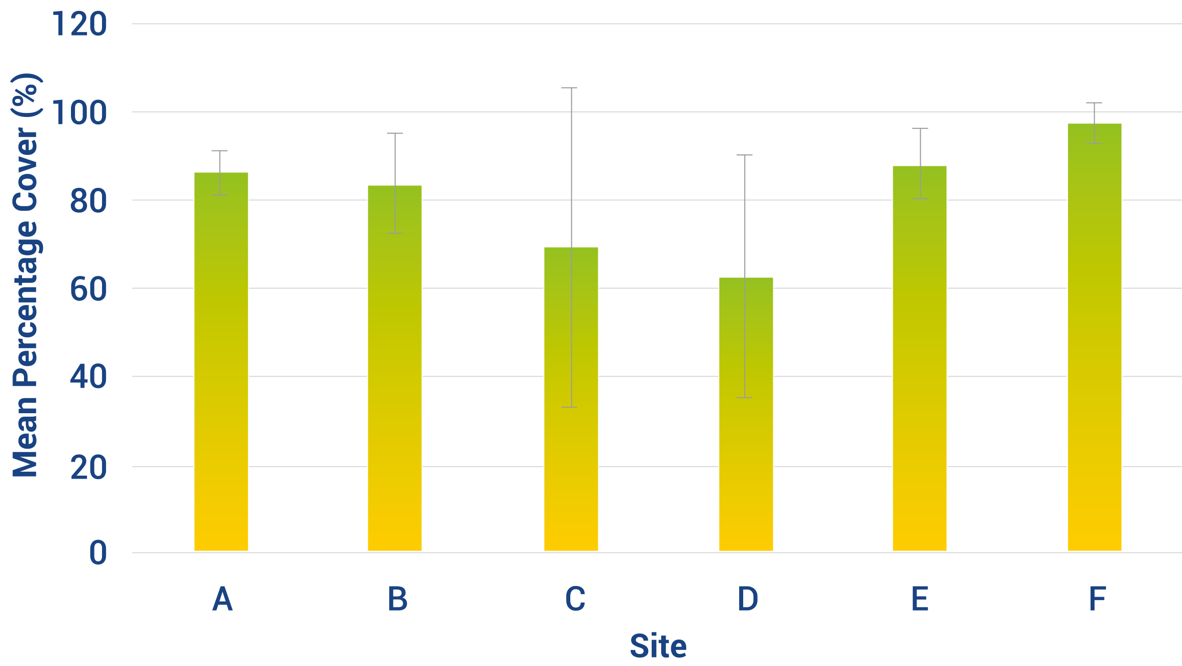

Figure 9
Mean % coverage at PMN Sites. Error bars denote standard deviation (n = 11).

3.1.2. Shoot Density

The mean shoot density across all sites ranged 346 -567 per m^2 (**Figure 10**). The pattern is very similar as the cover, the lower densities at sites C and D was due to the fact that some quadrats were placed over matte with few living shoots and the dense meadow edge was actually further behind the quadrat. According to the classification of the ecological condition of the meadow which is based on average shoot densities and depth (UNEP/MAP-RAC/SPA, 2011), all meadows studied have 'high' ecological condition except sites C and D which score 'good' ecological condition based on the shoot densities. However, it is biased to consider that sites C and D have lower ecological condition due to the fact that some quadrats here were placed on matte with few living shoots and the density measurements made here don't reflect the meadow densities just nearby. This is supported by the highest % of plagiotropic rhizomes detected at sites C and D which indicates better condition and expansion of the meadows.

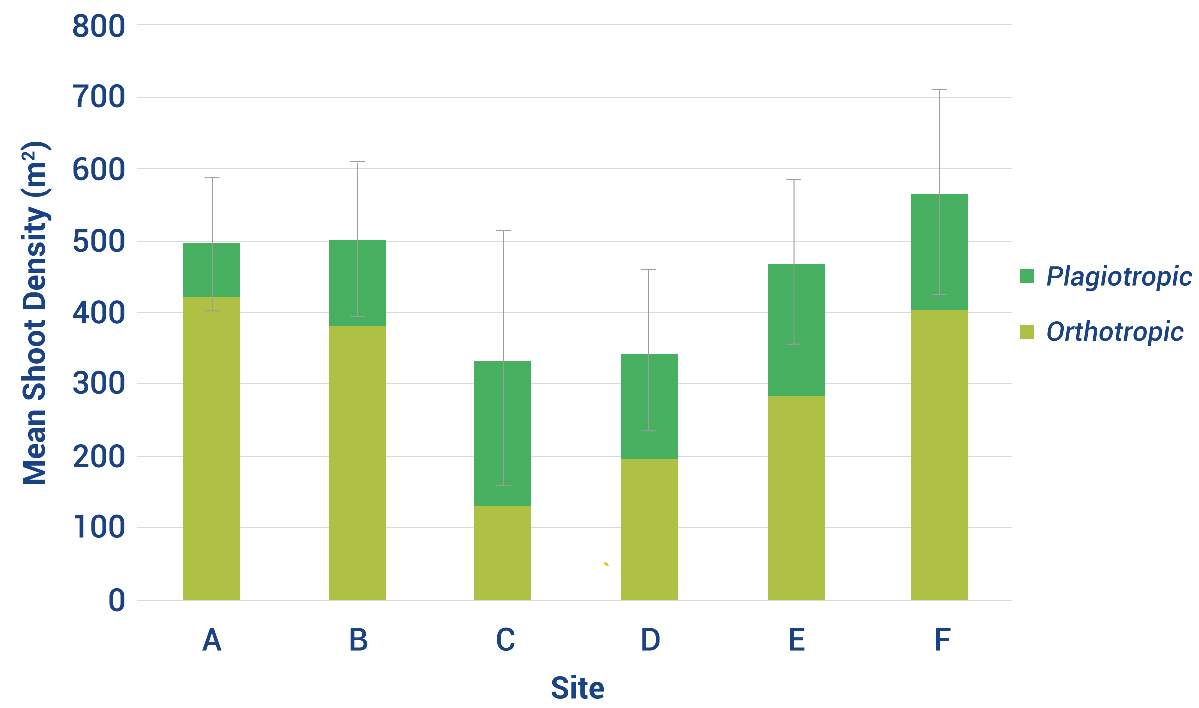

Figure 10
Mean shoot density (per 1 m^2) at PMN sites divided into orthotropic (light grey) and plagiotropic (dark grey) percentages. Error bars denote standard deviation (n = 11).

3.1.3. Shoot Exposure

The exposure or burial of the rhizome was determined in situ for 3 shoots per marker (33 shoots per site). Mean shoot exposure per site ranged from 1 – 3.82 cm (**Figure 11**). Most exposed shoots/rhizomes were detected at sites D and F. Some negative values (burial) were obtained at some markers but this was the exception at some markers (1-2) per site.

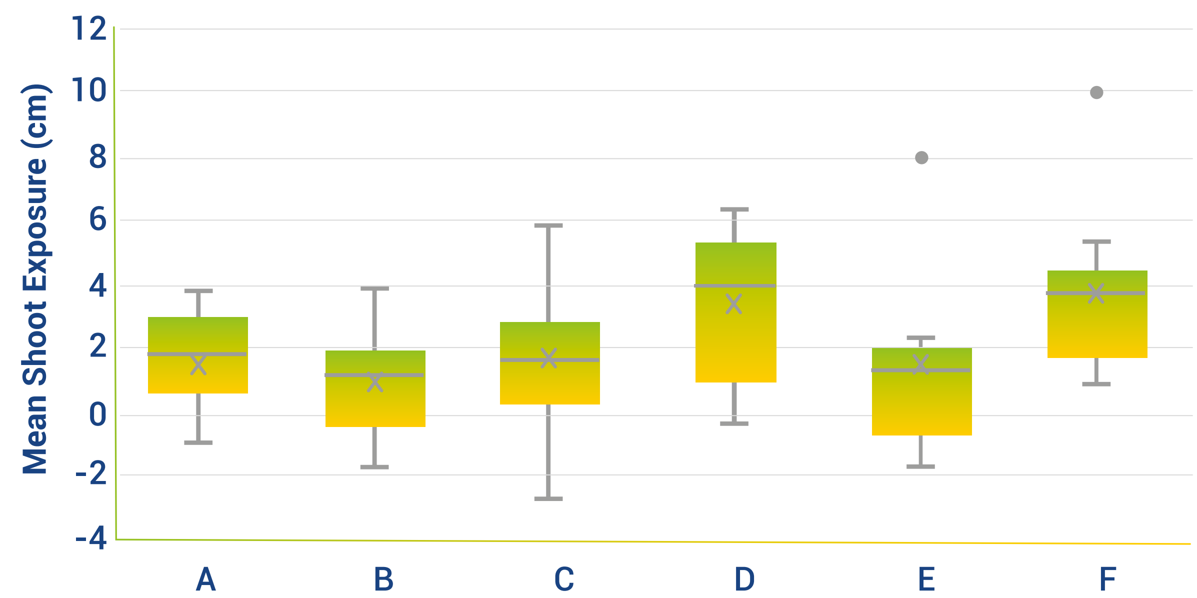

Figure 11
Mean shoot exposure (cm) at PMN sites. Error bars denote the interquartile range (n = 33).

3.1.4. Leaf Biometrics

Leaf morphometrics were determined for 20 shoots per site. The mean number of leaves per shoot was similar across all sites and ranged between 5.4 – 6.6 leaves per shoot (**Figure 12**). The lowest number of leaves per shoot were detected at site F and the highest at site D (**Figure 12**).

The dry mass of leaves per shoot showed greater variation among sites, ranging 0.5 – 1.45 g of dried leaves per shoot (**Figure 13**). Site D had the highest dry mass of leaves per shoot but was followed unexpectedly by site F which had the lowest number of leaves. The lowest dry mass of leaves per shoot were reported at sites A and C (**Figure 13**).

The Foliar Index (foliar surface area per shoot) had a very similar pattern with the leaf dry mass and ranged 143 -451 cm^2 per shoot (**Figure 14**).

The Leaf Area Index (LAI) calculated by multiplying the foliar Index by the shoot density at each site, ranged 6.2 – 20.5 m^2 of seagrass canopy per 1 m^2 of meadow among sites (**Figure 15**). Site F followed by B and D had the highest LAI scores while site C and A had the lowest (**Figure 15**).

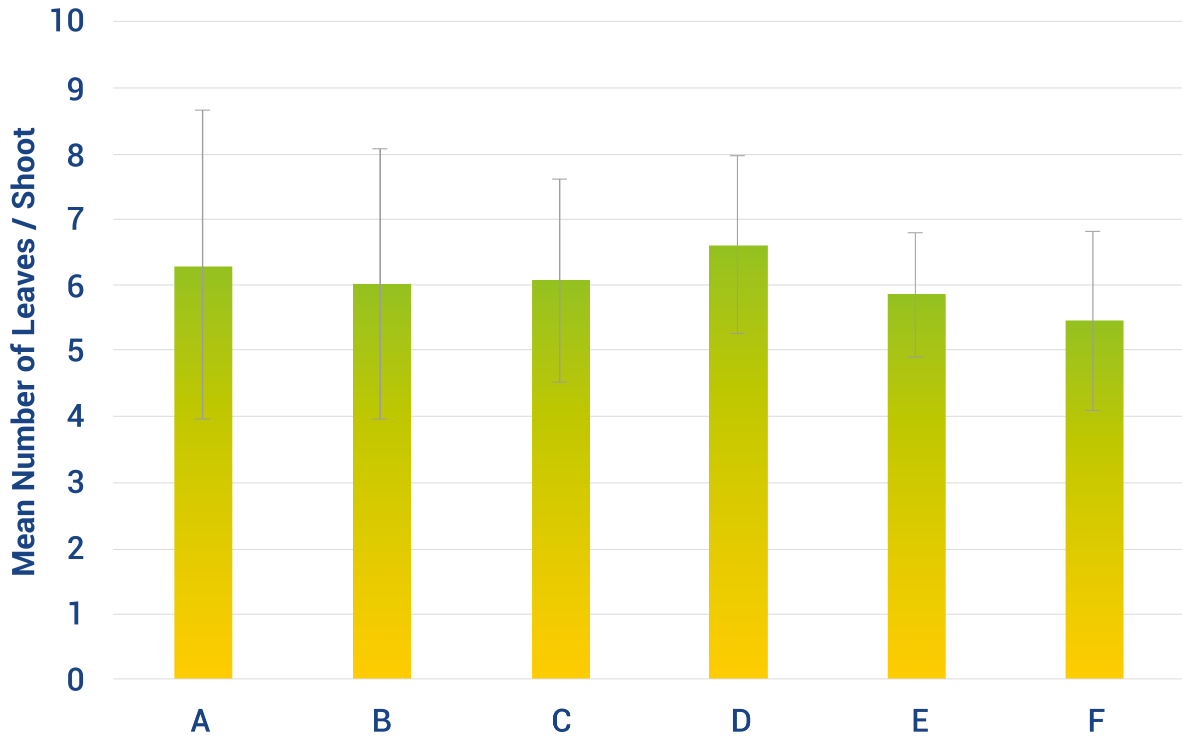

Figure 12
Mean number of leaves (per shoot) at PMN sites. Error bars denote standard deviation (n = 20).

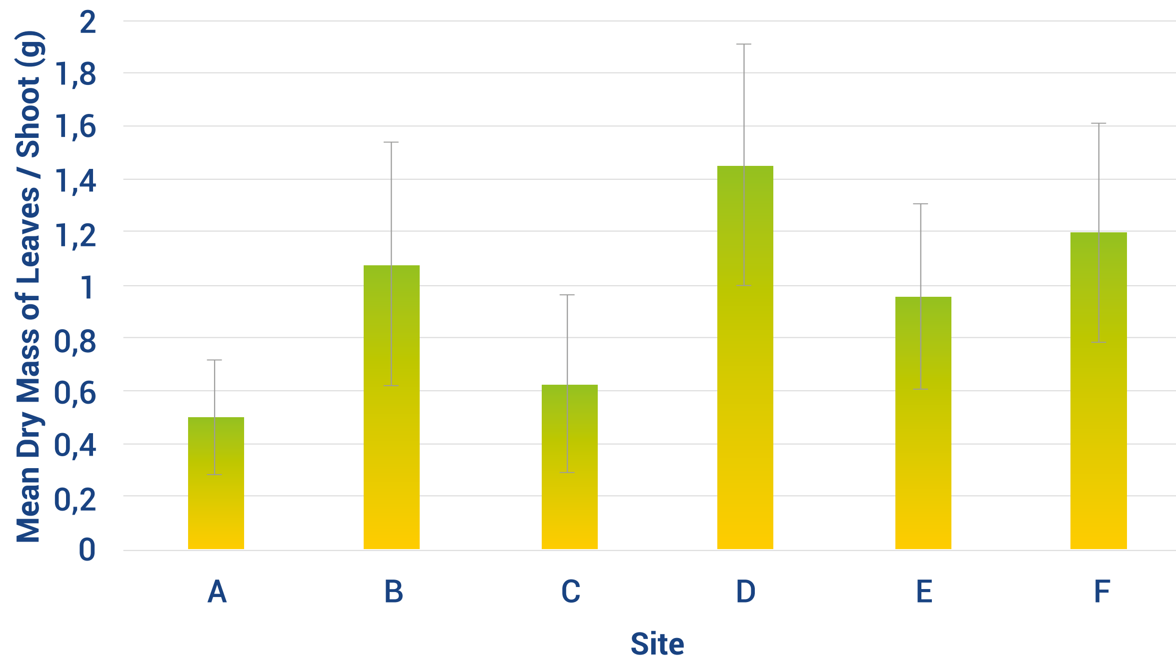

Figure 13
Mean dry mass of leaves (per shoot) at PMN sites. Error bars denote standard deviation (n = 20).

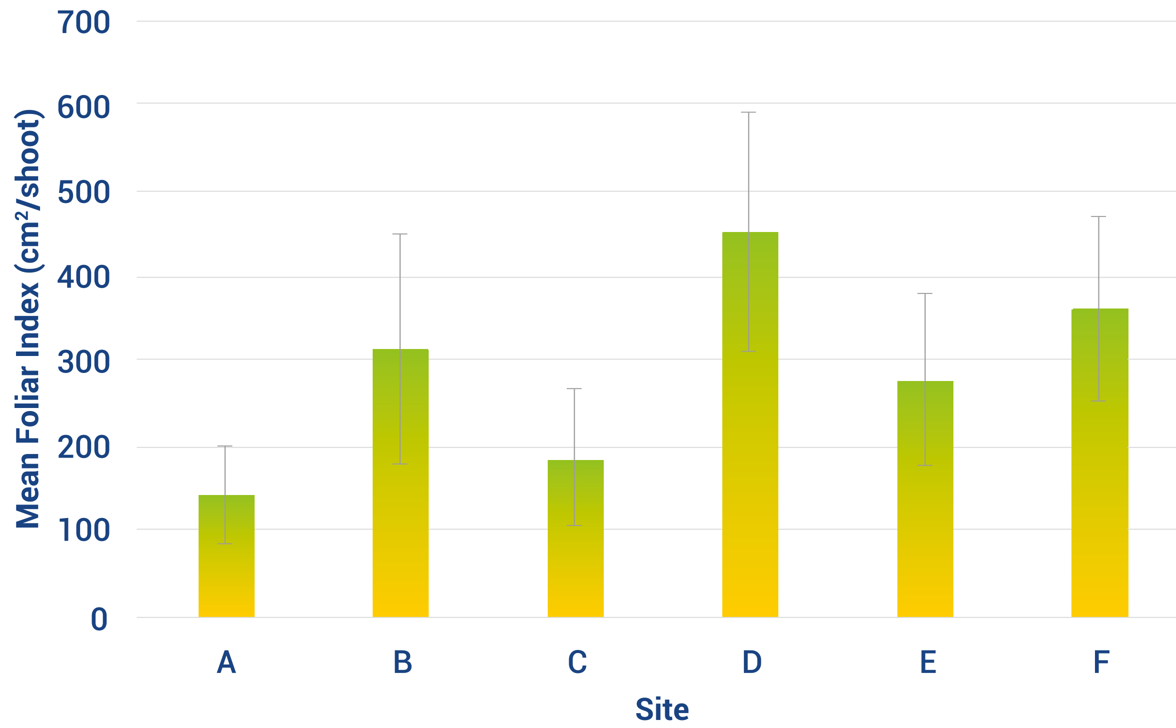

Figure 14
Mean Foliar Index (cm^2 of leaf surface per shoot) at PMN sites. Error bars denote standard deviation (n = 20).

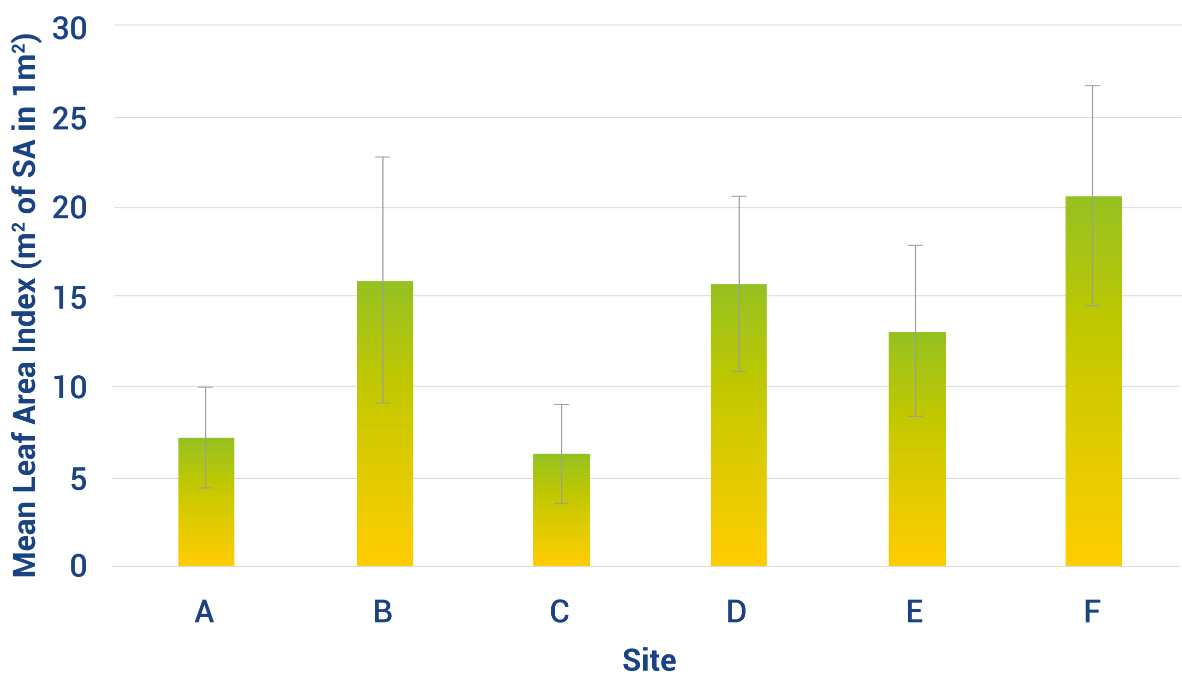

Figure 15

Mean Leaf Area Index (m^2 of seagrass canopy in 1 m^2 of seagrass meadow) at PMN sites. Error bars denote standard deviation (n = 20).

3.1.5. Past Leaf and Rhizome Production

Ten orthotropic shoots were analysed per site using the internodal method and the past annual production of each shoot in terms of number of leaves per shoot, length of rhizome (mm) and the dry mass of rhizome for each lepidochronological year was calculated. The mean of the above parameters (separated by site) are presented in Table 2. Generally, over the last two decades, site D had the largest production and site A the smallest production.

The annual leaf production per shoot throughout the past two decades averaged 6.9 leaves per shoot per year for site A, 8.6 leaves per shoot per year for site B, 9.8 leaves per shoot per year for site C, 11.1 leaves per shoot per year for site D, 11.2 leaves per shoot per year for site E and 9.4 leaves per shoot per year for site F.

The annual growth of rhizome (mm) over the past two decades averaged 4.5 mm per year for site A, 5 mm per year for site B, 7.1 mm per year for site C, 11 mm per year for site D, 6.4 mm per year for site E and 6.3 mm per year for site F.

The annual mass of rhizome (g) over the past two decades averaged 0.043 g per year for site A, 0.053 g per year for site B, 0.063 g per year for site C, 0.106 g per year for site D, 0.057 g per year for site E and 0.055 g per year for site F.

Table 2
Past reconstruction of annual leaf, rhizome and mass production per site.

SITE	Site A				Site B			
Year	N	Number of Leaves	Length of rhizome section (mm)	Dry mass of rhizome section (g)	N	Number of leaves	Length of rhizome section (mm)	Dry mass of rhizome section (g)
2019	10	8.1±1.4	3.5±0.6	0.024±0.012	10	8.0±1.8	3.5±0.9	0.032±0.025
2018	10	6.6±2.1	3.2±1	0.025±0.012	10	8.6±1.2	4.2±1	0.043±0.021
2017	10	6.4±1.2	3.5±1.1	0.028±0.019	10	9.1±2.8	4.8±1.4	0.049±0.028
2016	10	7.3±1.4	4.4±1.6	0.034±0.022	10	9.9±1.5	5.4±1.4	0.052±0.022
2015	10	7.0±1.9	4.4±1.6	0.031±0.015	10	9.1±2.9	4.4±1.5	0.052±0.030
2014	10	7.7±1.4	5.1±1.7	0.039±0.018	10	9.2±2	5.0±2.1	0.051±0.015
2013	10	6.9±1.6	4.8±1.8	0.046±0.032	10	9.1±1.4	5.1±1.1	0.048±0.014
2012	10	5.1±1.7	3.6±1.1	0.067±0.121	10	8.5±2.6	5.8±2.2	0.060±0.033
2011	10	6.9±1.9	4.8±1.6	0.048±0.023	10	7.6±3.5	4.4±1.7	0.043±0.018
2010	10	7.0±2.0	4.4±1.7	0.047±0.035	10	8.4±2.8	5.0±2.1	0.053±0.033
2009	9	6.8±1.6	4.6±1.5	0.046±0.029	10	9.0±3.1	4.7±2.2	0.049±0.022
2008	8	7.4±1.8	4.2±1	0.040±0.014	9	8.9±2.5	5.6±1.9	0.059±0.025
2007	7	6.7±2.1	4.5±1.8	0.047±0.038	9	9.2±2.3	5.4±1.3	0.058±0.019
2006	6	6.7±1.2	4.8±1.9	0.053±0.038	7	8.3±2.4	5.9±2.5	0.046±0.022
2005	5	7.2±1.9	4.7±2.1	0.058±0.052	5	8.8±2.8	5.7±2.8	0.059±0.024
2004	4	5.0±1.2	3.9±1.7	0.044±0.033	5	9.4±3.3	5.9±2.2	0.050±0.019
2003	3	8.0±3.5	5.4±0.1	0.049±0.012	5	7.0±0	4.3±1.1	0.062±0.039
2002	1	8.0	6.0	0.041	5	6.0±2.1	4.1±1.8	0.049±0.023
2001	1	8.0	6.1	0.043	3	8.3±1.2	5.5±1.9	0.058±0.022
2000					3	8.7±4	6.2±3.2	0.083±0.069
SITE	Site C				Site D			
Year	N	Number of Leaves	Length of rhizome section (mm)	Dry mass of rhizome section (g)	N	Number of leaves	Length of rhizome section (mm)	Dry mass of rhizome section (g)
2019	10	9.1±1.8	4.5±1.5	0.038±0.031	10	9.5±2.3	8.7±6.0	0.088±0.079
2018	10	9.9±2.0	5.1±2.2	0.049±0.040	10	9.0±1.8	8.0±4.7	0.083±0.061
2017	10	10.7±1.1	5.9±1.2	0.054±0.019	10	10.5±2.1	10.0±5.8	0.100±0.069
2016	10	9.6±1.8	5.6±1.0	0.050±0.017	10	9.8±2.7	8.9±5.0	0.092±0.065
2015	10	8.5±1.5	5.4±1.6	0.050±0.021	9	10.4±2.7	10.1±8.2	0.097±0.060
2014	10	11.4±1.8	7.9±2.4	0.078±0.038	9	11.4±2.9	13.7±10.6	0.130±0.111
2013	10	9.0±2.6	6.2±2.0	0.058±0.033	9	10.7±3.2	11.4±5.7	0.109±0.053
2012	10	11.0±1.8	6.9±2.0	0.052±0.026	9	9.1±3.8	8.2±5.0	0.084±0.056
2011	10	10.4±1.8	7.1±1.9	0.066±0.025	8	10.5±2.9	11.3±6.1	0.142±0.108
2010	10	10.9±2.2	7.1±2.1	0.067±0.026	4	11.3±3.5	10.2±3.8	0.130±0.081
2009	10	10.9±2.6	8.0±2.8	0.063±0.030	4	11.5±3.8	13.4±8.1	0.153±0.091
2008	9	10.6±2.1	8.0±2.4	0.079±0.030	3	10.0±4.0	16.3±15.6	0.147±0.122
2007	8	10.1±2.4	7.4±2.4	0.065±0.021	2	13.0±2.8	14.1±11.2	0.138±0.120
2006	5	10.6±1.8	9.6±3.3	0.081±0.026	2	9.5±2.1	10.4±2.5	0.094±0.033
2005	5	10.0±3.9	8.4±4.7	0.070±0.037	1	14.0	16.3	0.124
2004	4	9.3±4.6	7.7±4.3	0.066±0.039	1	12.0	10.3	0.065
2003	2	8.0±4.2	7.2±4.2	0.057±0.030	1	13.0	10.3	0.104
2002	1	10.0	10.5	0.092	1	13.0	10.1	0.074
2001	1	7.0	5.5	0.051	1	13.0	10.3	0.069
2000	1	10.0	8.2	0.082				

SITE	Site E				Site F			
Year	N	Number of Leaves	Length of rhizome section (mm)	Dry mass of rhizome section (g)	N	Number of leaves	Length of rhizome section (mm)	Dry mass of rhizome section (g)
2019	10	9.0±2.5	4.8±1.5	0.037±0.024	10	8.5±1.7	4.7±1.1	0.033±0.026
2018	10	10.1±2.4	5.1±1.3	0.040±0.018	10	8.7±1.8	5.4±2.5	0.041±0.040
2017	10	10.8±1.8	5.1±1.0	0.038±0.017	10	9.9±2.2	5.3±1.8	0.036±0.024
2016	10	10.1±2.9	5.7±1.5	0.044±0.019	10	11.4±2.5	6.2±1.4	0.046±0.024
2015	10	10.9±1.8	6.6±2.1	0.061±0.026	10	10.0±1.6	6.4±1.5	0.047±0.027
2014	10	10.6±2.0	5.9±2.1	0.061±0.029	10	8.5±1.4	5.7±1.6	0.045±0.024
2013	10	10.7±2.9	6.7±2.8	0.079±0.047	10	7.9±1.9	5.5±1.4	0.039±0.017
2012	10	12.1±2.5	6.8±2.7	0.080±0.050	9	8.7±1.3	7.0±2.0	0.051±0.018
2011	10	11.7±1.3	7.4±2.4	0.085±0.055	8	8.0±2.1	5.7±2.6	0.052±0.031
2010	8	11.8±2.3	6.5±1.2	0.058±0.019	8	8.9±2.3	7.0±2.6	0.063±0.027
2009	8	10.4±3.1	5.8±1.6	0.049±0.021	8	8.9±2.2	7.6±2.4	0.059±0.028
2008	8	11.1±1.9	6.5±1.5	0.054±0.024	7	11.0±1.5	8.5±1.4	0.063±0.018
2007	7	10.9±2.3	6.3±1.8	0.051±0.020	7	10.6±1.9	7.7±3.2	0.086±0.058
2006	6	12.7±1.6	7.3±2.9	0.062±0.018	5	11.2±2.3	9.4±3.3	0.090±0.045
2005	3	10.7±3.1	6.0±0.4	0.043±0.008	4	10.3±2.2	9.8±4.1	0.098±0.058
2004	2	10.5±3.5	4.5±2.1	0.029±0.025	4	8.8±3.4	9.8±8.0	0.060±0.034
2003	2	9.0±1.4	4.7±1.0	0.027±0.015	3	7.7±2.5	6.3±4.3	0.055±0.055
2002	1	14.0	7.9	0.047	2	10.0±5.7	6.3±2.4	0.039±0.009
2001	1	15.0	12.2	0.145	1	11.0	7.3	0.053
2000					1	8.0	5.8	0.051

3.1.6. Sediment

Sediment was collected in 3 replicates from marker 6 at each PMN site. The mean % of the Organic Matter based on the loss of weight of dried sediment following combustion was low and similar across sites; it ranged from 2.15 – 3.37% (**Figure 16**).

The granulometry analysis confirmed the visual observations that the area is characterised by coarse calcareous sand. Sediment samples of sites B, C, D, and F were composed of almost entirely coarse sand and some gravel which made up about two thirds of the samples of sites A and E (**Figure 17**).

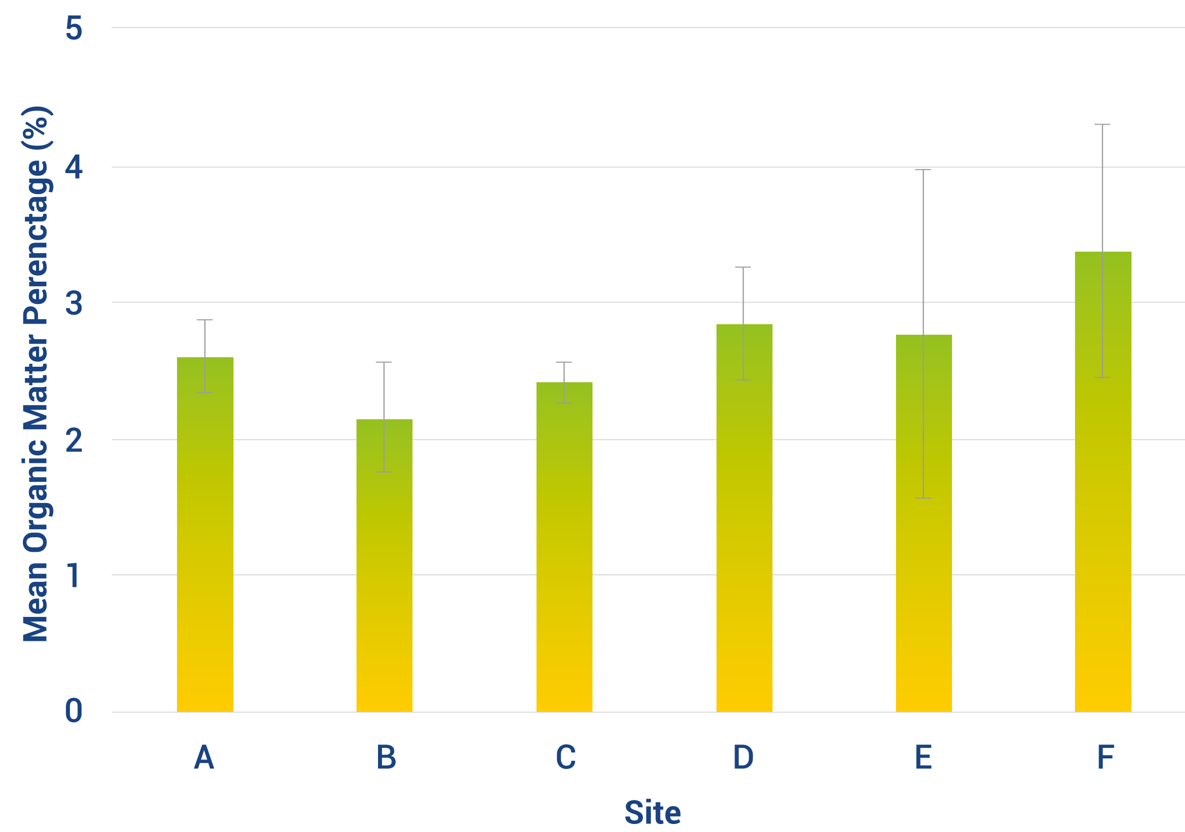

Figure 16
Mean organic matter (% loss of combusted sediment) collected from Marker 6 of each PMN site. Error bars denote standard deviation (n = 3).

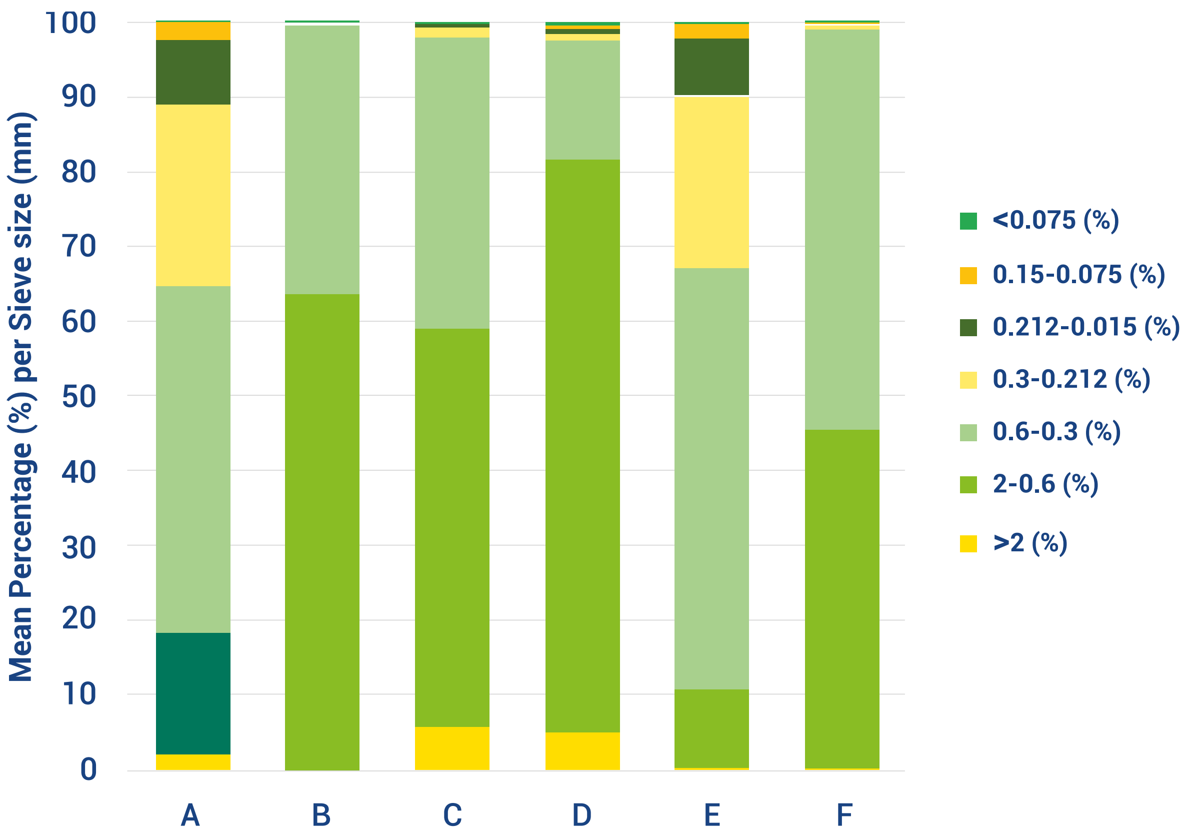

Figure 17

Mean granule size analysis from sediment collected from Marker 6 of each PMN site (n = 3).

3.2. Deep Monitoring Stations

The deep monitoring of *P. oceanica* comprises of three quadrats (0.16 m^2) fixed at the depths 30-33 m at six stations around Cape Greco (Table 1). All 18 quadrats were selectively fixed on the edge of the meadow. Baseline data are presented in Table 3.

Across all fixed quadrats, *P. oceanica* coverage ranged 13-71% and averaged 44% (Table 3). Mean *P. oceanica* coverage across sites ranged 21-58% (Figure 18).

Across all fixed quadrats, shoot density ranged 13-31 and averaged 20 shoots per 0.16 m^2 (Table 3). Mean shoot density across sites ranged 98-152 per 1 m^2 (Figure 19). The plagiotropic rhizomes were the dominant type of rhizome, making up 82-100% of the total shoots (Figure 19). The meadows studied at the deep sites are characterised as progressive due to the high plagiotropic ratio.

Table 3

Baseline data of the 0.16 m2 permanent quadrats established at 30-33 m depth.

Site	Quadrat (0.16 m^2)	*P. oceanica* Coverage (%)	Total shoots	*Plagiotropic rhizomes*	*Orthotropic rhizomes*
A	A1	17	19	*18*	*1*
	A2	29	20	*20*	*0*
	A3	17	30	*29*	*1*
B	B1	45	16	*16*	*0*
	B2	70	22	*22*	*0*
	B3	59	20	*20*	*0*
C	C1	36	21	*21*	*0*
	C2	13	13	*13*	*0*
	C3	45	28	*17*	*11*
D	D1	59	27	*24*	*3*
	D2	58	31	*28*	*3*
	D3	37	15	*15*	*0*
E	E1	23	13	*13*	*0*
	E2	71	19	*19*	*0*
	E3	54	15	*15*	*0*
F	F1	65	18	*18*	*0*
	F2	58	19	*19*	*0*
	F3	38	13	*13*	*0*

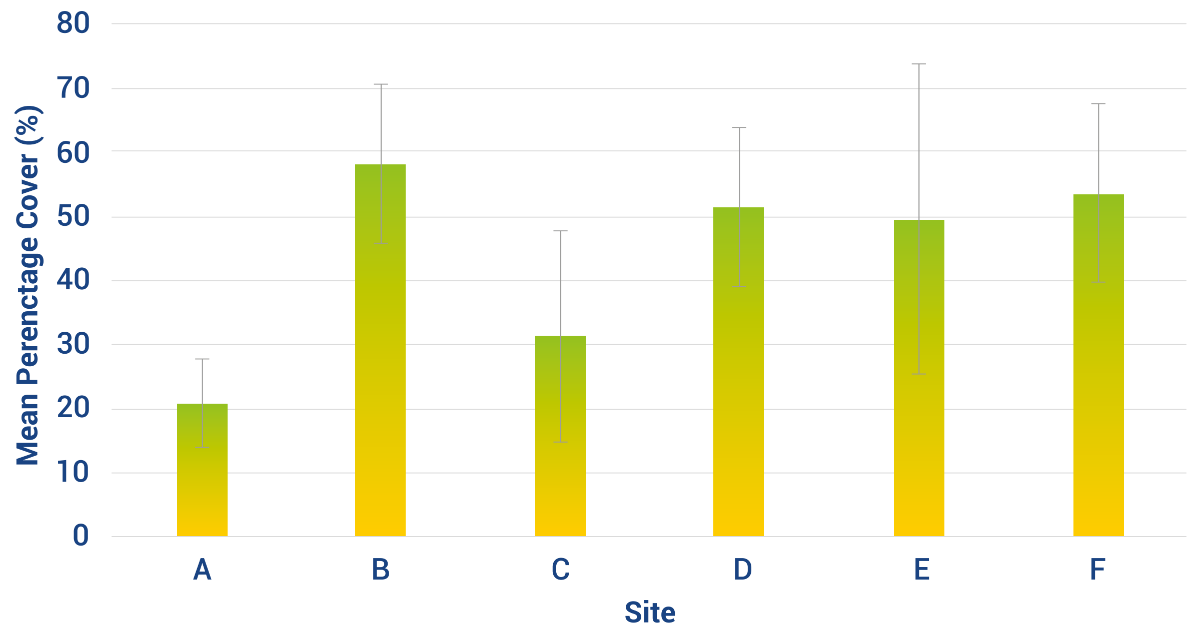

Figure 18

Mean percentage cover for the deep stations with error bars denoting standard deviation (n = 3).

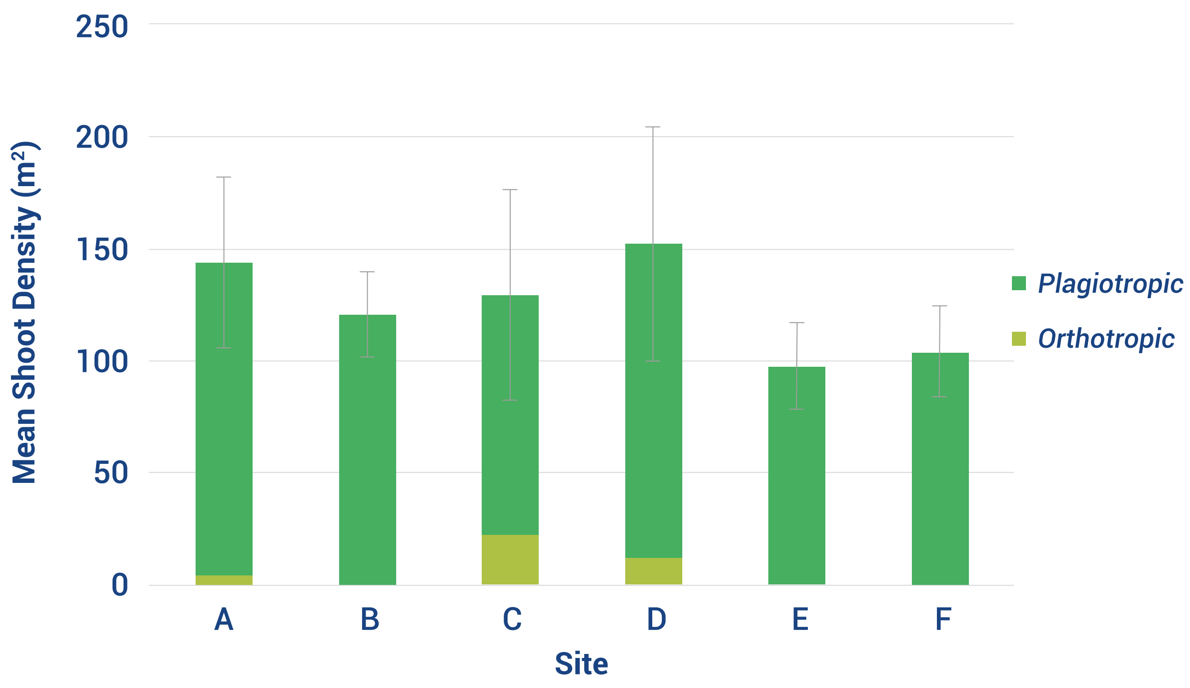

Figure 19

Mean shoot density (per 1 m²) for the deep stations divided into orthotropic (light grey) and plagiotropic (dark grey) percentages. Error bars denote standard deviation (n = 3).

4
CONCLUSION

This study provides baseline information of the *P. oceanica* meadows around the area of Cape Greco, which will be critical in future monitoring for detecting positive or negative shifts. The meadows of *P. oceanica* (i) play a pivotal role in ecosystem functioning and community structuring (ii) are the only marine ecosystem considered as 'priority habitat' by the EU Habitats Directive; (iii) are widespread almost across the whole of the European Mediterranean; (iv) their functioning is relatively well known (Mateo *et al.*, 1997; Alcoverro *et al.*, 2001; Prado *et al.*, 2007; Boudouresque *et al.*, 2012; Pergent *et al.*, 2012; Mazzuca *et al.*, 2013) and, (v) like many seagrass ecosystems in the world, *P. oceanica* meadows have been impacted or lost under the influence of direct and indirect effects of human activities and are therefore regarded as threatened (Boudouresque *et al.*, 2009; Coles *et al.*, 2013).

The *P. oceanica* monitoring systems set up and monitored in this study form valuable tools to researchers, managers and decision takers. Near the upper limits of *P. oceanica* at 15-18 m depth, 6 PMN systems were set up (11 markers each). Near the lower limits of the meadows at 6 sites at 30-33 m depth, 0.16 m^2 quadrats were fixed (3 quadrats each). In total, 66 permanent monitoring points/markers were placed on the seafloor at the edge of meadows at the PMN systems and 18 permanent monitoring quadrats were deployed at the deeper water.

In summary, across all PMN systems set-up in this study at the edge of meadows between 15-18 m depth, mean % coverage of *P. oceanica* ranged 63 - 97% among sites and mean shoot density ranged 346 - 567 per m^2. According to shoot density calculations, the meadows in Cape Greco appear to be in Good and High ecological condition (UNEP/MAP-RAC/SPA, 2011). The mean shoot exposure per site ranged 1 - 3.82 cm, indicating no major problems of sedimentation. The mean number of leaves per shoot ranged 5.4 – 6.6 leaves per shoot, the dry mass of leaves per shoot ranged 0.5 – 1.5 g, the foliar surface per shoot ranged 143 - 451 cm^2 per shoot and the LAI (seagrass canopy per 1 m^2 of meadow) ranged 6.2 – 20.5 m^2 among sites. All sites had healthy meadows, but dead matte was observed in the inner meadows at half of the sites (sites C, D and E at the tip of Cape Greco were exceptions), which indicates regression in those meadows.

Across all fixed quadrats in the deeper stations (30 – 33 m depth), mean *P. oceanica* coverage across sites ranged 21-58% and mean shoot density ranged 98-152 per 1 m^2. Based on the ratio of plagiotropic rhizomes and the absence of large expanses of dead matte the meadows here can be characterised as progressive.

These fixed monitoring points form an important indicator of the ecological quality and allow for timely detection of small losses which is critical for the slow growing *P. oceanica* meadows (Holmer *et al.*, 2003; Buia *et al.*, 2004). Future comparisons with the baseline data collected in this study will guide responsible management and increase our understanding regarding the condition of *P. oceanica* in the eastern Mediterranean. They can also be compared with other PMN systems set up in other places of the Mediterranean Sea to assess the *P. oceanica* population dynamics in different regions. The use of fixed plot methods using cement markers like the PMN method applied in the Mediterranean or using quadrats, allow reliable and effective microscale monitoring of key seagrass descriptors from the same positions using standardised methodologies, have high statistical power, and should be encouraged and widely adopted for monitoring slow growing *P. oceanica* meadows (Schultz *et al.*, 2015).

In the recent past, MER Lab was contracted by DFMR for the Interreg RECONNECT project and installed another 15 permanent 0.25 m^2 quadrats and nine 1 m^2 quadrats in *P. oceanica* meadows at intermediate depths of three sites (Cyclop's cave, Chapel, Canyon) of Cape Greco

Natura 2000 Area. These additional 24 permanent/fixed monitoring points together with the 66 + 18 monitoring points set up in this study form a robust monitoring tool, comprising over 100 fixed sampling points of *P. oceanica* meadows in the Cape Greco area from where future measurements and comparisons with the baseline data, will allow monitoring and detection of any regression or progression of the *P. oceanica* meadows and assist management decisions.

Over the past decades, the PMN has refined a standardised methodology for setting up *P. oceanica* monitoring systems, which has been applied in the Euro-Mediterranean region. The first PMN systems in Cyprus were set up in 2012-2013 but those were deployed in the lower limits of the seagrass and near mariculture units (Kletou *et al.*, 2018). In this project, the PMN systems have been set near the upper limits of *P. oceanica*, in pristine waters around the MPA of Cape Greco; the easternmost known biogeographic region of *P. oceanica* with the warmest water profile. They can contribute significantly to science and regional management in regard to *P. oceanica* as they can yield information from this understudied region using the same standardised methods from fixed positions and are comparable with other regions in the Mediterranean where PMN systems were established.

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SPA/RAC WORKING AREAS

SPA/ RAC, the UNEP/ MAP ***Specially Protected Areas Regional Activity Centre****, was created in 1985 to assist the Contracting Parties to the Barcelona Convention (21 Mediterranean contries and the European Union) in implementing the Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean (SPA/BD Protocol).*

POST-2020 SAPBIO

Strategic Action Programme for the **Conservation** of **Biodiversity** and **Sustainable Management** of **Natural Resources** in the **Mediterranean Region**

Marine turtles

Cetaceans

Mediterranean Monk Seal

Cartilaginous fishes
(Chondrichtyans)

Marine and coastal bird species
Listed in Annex II of the Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean

SPAMI

Specially Protected Areas of **Mediterranean Importance**

Specially Protected Areas

Monitoring

Coralligenous and other calcareous bio-concretions

Marine vegetation

Dark Habitats
Habitats and species associated with seamounts, underwater caves and canyons, aphotic hard beds and chemo-synthetic phenomena

Species introduction and invasive species

UN environment programme

Mediterranean Action Plan Barcelona Convention

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