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# 1 Human impacts on the endangered fan mussel, *Pinna nobilis*

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## 10 Abstract

11 1. *Pinna nobilis* is a sensitive and vulnerable species and hence considered a good indicator of  
12 anthropogenic pressures on marine ecosystems.

13 2. This study provides novel data on the density and distribution of endangered *P. nobilis* for  
14 the Turkish coasts. Threats to the status of *P. nobilis*, including by-catch and illegal collection  
15 were assessed, as was the general awareness of people about the endangered status of fan  
16 mussels.

17 3. The data sources consisted of direct observations from diving surveys and the use of the local  
18 ecological knowledge of fishers and SCUBA-divers.

19 4. Results demonstrated that the density of *P. nobilis* significantly changed with environmental  
20 parameters such as depth and among different sampling areas. The number of damaged  
21 individuals was lowest in the areas that were distant from human influences such as ports and  
22 tourist beaches. The density estimations of *P. nobilis* across a wide geographic area around the  
23 Turkish coasts revealed that the density of fan mussels was highest around west coasts in  
24 comparison with to southern coasts.

25 5. Fishers and divers indicated that the population of this species has decreased during the last  
26 decade. The main causes of this decline were suggested to be the impacts of fishing gears,  
27 poaching, pollution and boat anchoring. The highest amount of by-catch was estimated to be  
28 taken by trawls. In general, knowledge and local awareness of the conservation importance and  
29 status of fan mussels was poor.

30 6. The study has identified those areas where fan mussels occur at a high density, and hence  
31 may indicate areas for possible conservation protection status. Secondly, areas exposed to the  
32 illegal harvesting of fan mussels were highlighted. Societal concern would benefit from  
33 educational activities to raise awareness of the ecological importance and conservation needs  
34 for fan mussels in Turkey.

## 35 **KEYWORDS**

36 bycatch, conservation, density, endangered species, fan mussel, illegal fisheries, local  
37 ecological knowledge (LEK), marine ecology, trawling, Turkey

## 38 **1 | INTRODUCTION**

39 The Mediterranean Sea is subject to intense human activities due to its structure of semi-  
40 enclosed basin and its densely populated coastal status (Coll et al., 2010; Hendriks et al., 2013;  
41 UNEP-MAP 2012; Vázquez-Luis, Borg, Morell, Banach-Esteve, & Deudero, 2015). Examples  
42 of the many human impacts include the consequences of bio-invasion through the Suez Canal  
43 (Katsanevakis et al., 2014), the effects of marine gas and oil platforms on the Mediterranean  
44 marine ecosystems (Mangano & Sara, 2017) and high intensities of bottom fishing disturbance  
45 (Amoroso et al., 2018). These activities threaten not only commercially important species but  
46 also endangered species and habitats (Piroddi, Coll, Liqueste, Macias, & Greer, 2017). The  
47 Mediterranean basin is a hotspot of biodiversity where conservation initiatives have increased

48 through the inception of, at a local scale, scientific projects or specific working groups (e.g.  
49 Médail & Quézel, 1999). Effective conservation efforts that focus on endangered species need  
50 to be informed by an understanding of their population status and how human activities impact  
51 upon them. Conservation efforts concomitantly may be enhanced by increasing the level of  
52 awareness and the perceptions of local people regarding the existence and function role of  
53 endangered species (Liu, Huang, & Hsu, 2015; Pienaar, Lew, & Wallmo, 2017).

54 In the absence of direct ecological observations, information on the geographic  
55 presence/absence and changes in population status of endangered species can be obtained from  
56 the use of local ecological knowledge (LEK) (Carter & Nielsen, 2011; Turvey et al., 2013;  
57 Turvey et al., 2014). LEK can also be used to estimate current and historical levels of human  
58 impacts on the environment and species (Shepperson et al., 2014; Turvey et al., 2014) and to  
59 determine whether management measures are needed to arrest any population decline in status.  
60 Such management is likely to be more effective if it is combined with an understanding of  
61 people's perception of the species in question, the impacts of human activities upon that species  
62 and the management measures proposed. The use of LEK is particularly important tool for the  
63 regions such as Mediterranean especially in the south and east of this region where very little  
64 information is available on biodiversity (Coll, 2010). For example, LEK has been used to better  
65 understand the status of endangered species (e.g. Mavruk, Saygu, Bengil, Alan, & Azzurro,  
66 2018), spatial and temporal changes in the abundance of fish species (e.g. Azzurro et al., 2019),  
67 and the impact of invasive species on fisheries (e.g. Öndes, Ünal, Özbilgin, Deval, & Turan,  
68 2018). Accordingly, LEK was considered a useful source of information to derive information  
69 on the occurrence, abundance and impacts acting upon fan mussels.

70 The fan mussel *Pinna nobilis* Linnaeus, 1758 is an endemic bivalve of the  
71 Mediterranean Sea, and is a species considered to be highly vulnerable to a wide range of human  
72 impacts. *Pinna nobilis* is a large organism with a maximum recorded length of 120 cm

73 (Voultsiadou, Koutsoubas, & Achparaki, 2010), and can live for up to 50 years, although sexual  
74 maturity is reached relatively quickly, between the first and second year of growth (Coppa,  
75 2012; Alomar, Vázquez-Luis, Magraner, Lozano, & Deudero, 2015; Richardson, Kennedy,  
76 Duarte, & Proud, 1999; Rouanet, Trigos, & Vicente, 2015). *Pinna nobilis* occurs across a depth  
77 range of between 0.5 and 60.0 m (Butler, Vicente, & De Gaulejac, 1993), and generally occurs  
78 in *Posidonia oceanica*, *Cymodocea nodosa*, *Zostera marina* or *Zostera noltii* meadows, but also  
79 in bare sandy (unvegetated) bottoms (Addis et al., 2009; Rabaoui, Tlig-zouari, Katsanevakis,  
80 Belgacem, & Hassine, 2011; Voultsiadou et al., 2010). The shell is partially buried at the  
81 anterior portion of the shell and is anchored in the substratum by byssus threads (Richardson,  
82 Peharda, Kennedy, Kennedy, & Onofri, 2004; Figure 1a). *Pinna nobilis* provides a number of  
83 ecosystem services; it contributes to water clarity because its filter-feeding activities retain large  
84 amounts of organic matter from suspended detritus, and its shell provides a habitat for some  
85 species by enhancing topographic complexity (Basso et al., 2015).

86 Fan mussels are impacted by numerous anthropogenic effects (boat anchoring, habitat  
87 degradation, trawling, dredging, illegal extraction, coastal construction, sewage discharges and  
88 other pollution factors; see Figure 1) and non-anthropogenic factors such as global warming,  
89 acidification, food web alterations and disease, causing mass mortality (Alomar, Vázquez-Luis,  
90 Magraner, Lozano, & Deudero, 2015; Basso et al., 2015; Centoducati et al., 2006; Marba &  
91 Duarte, 2010; Coppa et al., 2013; Vázquez-Luis, et al., 2017). Finally, a mass mortality event  
92 has occurred as a result of *Haplosporidium pinnae* sp. nov., a haplosporidan parasite (Catanese  
93 et al., 2018; Vázquez-Luis et al., 2017) or through mycobacterial disease (Carella et al., 2019).  
94 As a result of these impacts the occurrence and population abundance of *P. nobilis* has declined  
95 in the last few decades (Katsanevakis et al., 2011). Although *P. nobilis* has not yet been  
96 evaluated in the International Union for Conservation of Nature (IUCN) Red List, it has been  
97 listed as an endangered and protected species under the European Council Directive 92/43/EEC

98 since 1992 (EEC, 1992). This species also has been protected in Turkey since 1998, and its  
99 exploitation has been prohibited (Acarli, Lök, & Acarli, 2011).

100 Fan mussels have been exploited for millennia and more recently the nacre within the  
101 shells was collected for the production of knife handles, buttons and jewellery in the 19th  
102 century (Basso et al., 2015). In the 21st century, *P. nobilis* was fished illegally in some areas,  
103 such as Lake Vouliagmeni, the islands of Symi and Kalymnos (Katsanevakis, 2007; Vafidis,  
104 Antoniadou, Voultziadou, & Chintiroglou, 2014). *Pinna nobilis* is the subject of a species-  
105 specific Action Plan for the Mediterranean Sea in the context of the Marine Strategy Framework  
106 Directive (MSFD) of the EU (Vázquez-Luis et al., 2017). Despite the recognised threats to the  
107 status of fan mussels, little is known about the scale of illegal collection that occurs, incidences  
108 of bycatch and the historical changes in occurrence and abundance of the species (Vafidis et  
109 al., 2014). Moreover, to date, knowledge regarding the density, population structure, ecology,  
110 growth, reproduction and epibiont species composition of fan mussels is restricted to a limited  
111 number of Mediterranean countries (Basso et al., 2015). Furthermore, nothing is known about  
112 the local people's perspective (awareness) on conservation status and ecological importance of  
113 this endangered species.

114 Using a combination of direct observations and interpretation of LEK, the aims of the  
115 study were: (i) to provide the first comprehensive baseline data for the present and historical  
116 distribution and density of *P. nobilis* in Turkish waters (eastern Mediterranean) prior to the  
117 occurrence of the mass mortality event in 2018 (B. Akçalı pers. comm., 2018; Katsanevakis et  
118 al., 2019), (ii) to determine which environmental (depth and habitat features) and anthropogenic  
119 factors may be related to the occurrence and density of fan mussels (iii) to evaluate fisheries  
120 effects on fan mussels such as illegal collection and by-catch associated with different fishing  
121 gears; and (iv) to assess the awareness of stakeholders (commercial fishers, spear fishers, and  
122 scuba divers) about the conservation status of this endangered species.

## 123 2 | METHODS

### 124 2.1 | Diving surveys

#### 125 2.1.1 | Density of *P. nobilis* across a depth gradient, and in vegetated and unvegetated 126 habitats

127 In order to determine the spatial differences in density of *P. nobilis* in relation to environmental  
128 gradients, observations were made at 10 locations that had low levels of human impact/activities  
129 (Şakran, Aliağa-Çaltıdere, Foça, Urla, Özbek, Eğriliman, Torasan, Akarca, Balıklıova,  
130 Gülbahçe) in the Aegean Sea (Eastern Mediterranean) between May 2017 and October 2017  
131 (Figure 2). We also investigated whether the density of fan mussels changed across five depth  
132 zones described below. Sampling stratification by depth zone was informed by the reported  
133 distributions of fan mussels in previous studies (Basso et al., 2015; Garcia-March & Nardo,  
134 2006). At each location and depth, divers surveyed five replicate plots, each with an area of 25  
135 m<sup>2</sup> (5 m x 5 m). These replicate plots were randomly (with a minimum spacing of 5 m between  
136 plots) assigned within 5 depth zones: 0-1.0 m, 1.1-2.0 m, 2.1-3.0 m, 3.1-5.0 m, 5.1-10.0 m.  
137 Previously, Garcia-March & Nardo (2006) found that plots of 25 m<sup>2</sup> gave the most precise  
138 estimate of density for fan mussels. The density of *P. nobilis* was compared in both vegetated  
139 and unvegetated habitats. The geographical coordinates for each plot were recorded.

#### 140 2.1.2 | Comparison of the damage of *P. nobilis* with increasing levels of human disturbance

141 A separate study was carried out at two sampling locations (Özbek and Şakran in İzmir  
142 Province). Both locations were selected to have 1) beaches, 2) ports and 3) less affected areas  
143 (LAAs), and were similar in terms of the number of boats utilising the harbour, distances to  
144 beach area and the LAA. Both beach locations were positioned at a distance of 500 m away  
145 from their respective ports and were visited by approximately 100 swimmers per day during

146 the tourist season, between May and October. The lengths of beaches are 400 m and 500 m for  
147 Özbek and Şakran, respectively. The Özbek fishing port covered an area of 20 000 m<sup>2</sup> and  
148 maintained 133 boats, whereas the Şakran fishing port is 5000 m<sup>2</sup> in area and had 113 boats.  
149 The sizes of the boats ranged from 3 and 10 m. The distance from the ports of Özbek and  
150 Şakran to the LAAs were 1000 m and 2000 m, respectively. Given the interaction between  
151 humans (beaches) and boats (ports), it was hypothesised that fan mussels would have suffered  
152 higher rates of damage at these locations than fan mussels found in LAAs with lower human  
153 interference. Divers recorded fan mussels based on a visual assessment: (i) no physical damage;  
154 (ii) physical damage apparent (cracks on shell visible); and (iii) dead individuals. The same  
155 methodology described in Section 2.1.1 was deployed across five depth zones with five  
156 replicates at beaches, ports, and LAAs in both Özbek and Şakran - a total of 150 sampling  
157 quadrats were sampled - to compare the anthropogenic impact. The vegetated / unvegetated  
158 habitats were determined posteriori. The results should be considered as indicative. It was  
159 considered that damage is unlikely to be a habitat dependent variable.

## 160 **2.2 | Local ecological knowledge (LEK)**

161 Garcia-March & Nardo (2006) indicated that quantitative data related to the impacts of the  
162 fishing gears on fan mussels was lacking, but suggested that questionnaire studies could provide  
163 insights into the interaction between fishing gears and fan mussels. For this reason, an LEK  
164 questionnaire was used to ascertain bio-ecological characteristics, historical changes in density,  
165 impacts of fisheries, status of consumption and awareness about the conservation status of fan  
166 mussels (Appendix S1; Table 1). Questionnaire studies were carried out with commercial  
167 fishers (n = 120), spear fishers (n = 35) and scuba-divers (n = 87) in 2017 and 2018. Only  
168 stakeholders with at least 10 years of experience were selected to participate in the questionnaire  
169 study. Scuba-divers were also asked about their diving locations and their estimates of fan



170 mussel density per 100 m<sup>2</sup>. Similarly, trawl fishers were asked to identify the locations where  
171 at least one-third of their catch was composed of fan mussels.

172 An additional questionnaire was undertaken in 2017 and 2018 to understand whether  
173 fan mussels are used for fish bait by recreational rod-and-line fishers (n = 120). The  
174 questionnaire study aimed to gather information on the volume of fan mussels collected per  
175 fisher per year in these locations.

176 In addition, interviews were conducted with owners or managers of 110 seafood  
177 restaurants in Balıkesir, Çanakkale, İzmir, Aydın, Muğla, and Antalya provinces. A phone-  
178 based questionnaire gathered information on the location of the restaurant, and whether they  
179 had sold fan mussels as part of their menu. As the present study findings revealed that the  
180 species was only consumed in Özbek, another questionnaire was developed to explore the  
181 patterns of use of fan mussels in this region/location/town.

## 182 **2.3 | Data analysis**

183 Statistical analyses were carried out using SPSS 20. A general linear model (GLM) was used to  
184 test the relationship between density of *P. nobilis* and: (i) sampling areas; (ii) depth; (iii) habitat,  
185 with sampling area, depth and habitat type treated as fixed factors. A Kruskal-Wallis test was  
186 used to compare the damage of *P. nobilis* in areas (beaches, ports and LAAs) with different  
187 levels of human disturbance. An estimate of mean fan mussel density of *P. nobilis* based on the  
188 scuba-divers' knowledge and the locations of the highest *P. nobilis* fields based on trawlers'  
189 knowledge was mapped using Arc-GIS 10.1.

## 190 **3 | RESULTS**

### 191 **3.1 | Density and distribution based on direct diving observations**

192 Based on the dive surveys, a total of 705 *P. nobilis* specimens were recorded from a total  
193 surveyed area of 1,250 m<sup>2</sup>. The distribution of fan mussels ranged from a depth of 0.4 m down  
194 to the deepest depth class surveyed in this study (10 m). During the dive surveys, the mean  
195 density was calculated as 11.28 individuals per 100 m<sup>2</sup> (min = 0 and max= 100 ind. per 100  
196 m<sup>2</sup>). The GLM indicated that the density of fan mussels varied significantly with depth, habitat  
197 and sampling area (Table 2). The highest density of fan mussels was recorded at the depth class  
198 of 1.1-2.0 m, but it is important to note that this is constrained by the depth limits of the dive  
199 component of this study (Figure 3a). Most of the individuals were recorded in seagrass  
200 meadows (Figure 3b). The locations with the highest densities of fan mussels found was at  
201 Torasan, whereas Akarca had the lowest density (Figure 3c). The highest density values with  
202 low numbers of damaged specimens were found in the areas least affected by human activities  
203 ( $\chi^2 = 21.84$ ,  $df = 2$ ,  $P = 0.001$ ) (Figure 4).

### 204 **3.2 | Local ecological knowledge (LEK)**

205 Questionnaire respondents indicated that the main habitat of *P. nobilis* was seagrass meadows  
206 (81% of scuba-divers, 80% of spear fishers and 88% of commercial fishers). In addition, 76%  
207 of scuba-divers, 46% of spear fishers and 26% of commercial fishers noted the coverage of the  
208 seagrass meadows has decreased over the last decade in the sampling sites. According to the  
209 SCUBA-divers and commercial fishers, *P. nobilis* lives at a depth range of 0.5-38.0 m and 0.5-  
210 80.0 m, respectively.

211 Scuba-divers reported that the fan mussel density varied between 0 and 40 individuals  
212 per 100 m<sup>2</sup>, and that the mean density of fan mussels is higher around the west coasts of Turkey  
213 (Aegean Sea), in comparison with the south coasts of Turkey (Mediterranean Sea) and coasts  
214 of Marmara (Figure 5).

215           The majority of all groups of fishers indicated that there has been a historical decrease  
216 in the density of fan mussels (76% of SCUBA divers, 63% of spear fishers and 76% of  
217 commercial fishers). They identified that the impacts of fishing gears, poaching, pollution and  
218 boat anchoring were the main causes of this decline (Figure 6). Stakeholders considered that  
219 predator pressure, climate change and other factors (e.g. coastal settlement and beach  
220 deepening) had less of an impact on fan mussel density. Less than half (37%) of scuba-divers  
221 claimed that they had observed damaged fan mussel beds.

222           The estimated annual by-catch of fan mussels for each fishing gear type was:  $1647 \pm$   
223  $2210$  individuals by trawls ( $n= 30$ ),  $217 \pm 260$  individuals by purse-seines ( $n = 21$ ), and  $57 \pm$   
224  $165$  individuals by set nets ( $n=46$ ). No bycatch was reported for the long-line fishery ( $n=23$ ).  
225 Trawlers reported that they generally fish in depths 30-300m; however, commercial fishers  
226 (30%) and scuba-divers (45%) indicated that illegal trawl operations occurred in the shallow  
227 waters, and that fishing occurred within the 1.5-nautical-mile trawl limit that coincides with the  
228 part of the marine littoral zone below 15 m depth. As a result, it may be that a large component  
229 of the fan mussel by-catch may occur as a result of illegal fishing close to the coast in shallow  
230 water.

231           Based on the questionnaire survey it appears that no recreational fishers ( $n=120$ ) used  
232 this species as a bait. Interviews with restaurant owners indicated that fan mussels are not (and  
233 were not in the past) served at seafood restaurant in the majority of Turkey; however, fan  
234 mussels are collected illegally and consumed in May and June in the village of Özbek located  
235 in İzmir. Results show that 40 people (commercial fishers) collected this species in Özbek.  
236 These people also reported that their annual collection was estimated about 1000 individuals  
237 for food.

238 In general, there was low stakeholder awareness regarding the protection status of fan  
239 mussels (Table 3). Only 9% of stakeholders knew about the endangered status of this species.  
240 These individuals had acquired this information through educational activities (38%), other  
241 stakeholders (24%), newspaper/magazines and social media (38%), only 18% of commercial  
242 fishers knew that fishing for fan mussels is prohibited in Turkey.

#### 243 4 | DISCUSSION

244 It has been reported previously that *P. nobilis* lives across a depth range of between 0.5 and  
245 60.0 m (Butler et al., 1993), which is confirmed here by the different sources of evidence from  
246 the present study. Evidence of the deepest depth at which fan mussels occur was derived from  
247 LEK from trawl fishers who reported finding fan mussels in hauls made at a depth of 80 m in  
248 the eastern Mediterranean. Although in the present study direct observations were limited to  
249 shallow water, these did reveal that fan mussels were most common at a depth of 1.1.-2.0 m;  
250 however, it is difficult to know whether the peak fan mussel density in the dive survey  
251 represents the ‘optimum’ depth range for fan mussels, as the different sources of information  
252 cannot be standardized in way that makes the data comparable. Fan mussels are known to occur  
253 more commonly in vegetated sea beds in comparison with the unvegetated bottoms (Addis et  
254 al., 2009; Rabaoui, Tlig-Zouari, Katsanevakis, & Ben Hassine, 2010; Voultziadou et al., 2010).  
255 This finding was re-emphasised by the diver survey in the present study and from the LEK  
256 (from the responses of scuba-divers and fishers). The present study also indicated that coverage  
257 of the seagrass meadows has decreased in Turkish waters over the last decade, however. Similar  
258 findings were reported by Marba, Diaz-Almela, and Duarte (2014) who emphasized a decline  
259 in the areal extent, cover and shoot density of *Posidonia oceanica* in the Mediterranean Sea  
260 during the last 50 years. Thus, this situation may threaten the status of the fan mussel population  
261 if there is an ecological dependence of fan mussels on seagrass meadows. The reported  
262 observations in the LEK study indicated that illegal bottom trawling occurred in water

263 shallower than 15 m. This observation concurs with similar observations elsewhere (e.g.  
264 Fonseca et al., 1984; Sánchez-Jerez & Ramos-Esplàa, 1996), and may explain in part why  
265 seagrass beds have decreased in extent and may also explain why the peak fan mussel  
266 occurrence and density occurred at such shallow depths (i.e. where there was a depth refuge  
267 from fishing).

268 Previous studies have demonstrated that the mean density of *P. nobilis* is around 1-10  
269 individuals per 100 m<sup>2</sup> (Garcia-March, Marquez-Aliaga, Wang, Surge, & Kersting, 2011;  
270 Moreteau & Vicente, 1982; Prado, Caiola, & Ibáñez, 2014). Little is known about the density  
271 of this species around the coastal areas of the eastern Mediterranean, particularly for Turkish  
272 waters, in comparison with the central and western Mediterranean, however (Basso et al., 2015;  
273 Vafidis et al., 2014). The mean density was estimated by Vafidis et al. (2014) as 2.7 individuals  
274 per 100 m<sup>2</sup> in Greek waters (the Aegean Sea, Eastern Mediterranean). In the present study,  
275 based on the diving surveys undertaken, the mean density of fan mussel was estimated as being  
276 relatively higher (11.28 individuals per 100 m<sup>2</sup>), whereas the highest density value was  
277 estimated as 100 individuals per 100 m<sup>2</sup>. Although the density estimates per unit area should  
278 be treated with caution, given the restricted number of localities surveyed, the LEK of scuba-  
279 divers provides a greater geographic coverage, and for this reason a useful data source to assess  
280 large regions in the absence of more formal survey data (Loerzel et al., 2017; Taylor et al.,  
281 2011). For example, the present study provided the density estimations of fan mussel over large  
282 areas and showed that the mean density values were higher in western parts compared with the  
283 southern parts of Turkey (Figure 5).

284 The evidence presented from the present study indicates that the density of fan mussel  
285 declined in Turkish waters over the last decade. Similar declines have occurred over the last  
286 20-30 years around other Mediterranean countries, and are largely attributed to anthropogenic  
287 impacts (Centoducati et al., 2006; Deudero, Vázquez-Luis, & Álvarez, 2015) where

288 stakeholders reported that the main causes of the decline in fan mussel populations were fishing  
289 gears, illegal collection, pollution, and boat anchoring, respectively. In addition, the recent mass  
290 mortality event of this species in the western and central Mediterranean Sea has added to the  
291 effects of these stressors (Catanese et al., 2018; Vázquez-Luis et al., 2017). The results  
292 presented here, demonstrate that the number of damaged individuals is lowest (and the density  
293 is highest) in the areas that are furthest from human activities in comparison with populations  
294 sampled at ports and beaches. Accordingly, the mean density values were lowest in the locations  
295 where anchoring occurred, as reported elsewhere (Hendriks et al., 2013; Vázquez-Luis et al.,  
296 2015). When fan mussel sustain damage, they may be more vulnerable to predators, thereby  
297 increasing mortality from predation. For instance, García-March, García-  
298 Carrascosa, Cantero, and Wang (2007) reported that when specimens became detached for a  
299 long period, predators such as octopus *Octopus vulgaris* were better able to handle and consume  
300 such individuals. Previous studies also indicated that the density and sizes of fan mussels inside  
301 the marine protected areas (MPAs) are higher than outside the protected areas (Vázquez-Luis,  
302 March, Alvarez, Alvarez-Berastegui, & Deudero, 2014; Vázquez-Luis et al., 2017).

303         The present study provides an initial insight into the estimated quantity of by-catch of  
304 *P. nobilis* taken by different fishing gears based on the fishers' interviews. High numbers of fan  
305 mussels were reported to have been caught by trawls, in particular when fishing was carrying  
306 out in shallow areas (at depth of less than 15 m). Although in the Mediterranean part of the  
307 European Union, the use of trawls is prohibited in water of < 50 m in depth (Garcia-March &  
308 Nardo, 2006), this does not apply in Turkish waters where there are seasonal prohibitions and  
309 a ban on trawling within 1.5 nautical miles off the coastline. Similarly, the high number of dead  
310 specimens of *P. nobilis* were found either at the trawling sites or around the mussel farms  
311 (Centoducati et al., 2006). Other fishing gears (i.e. set net, longline, and purse seine) had  
312 relatively low impact in comparison with trawls according to the questionnaire survey.

313 Nevertheless, Addis et al. (2009) also reported that trammel nets and gill nets used in the lagoon  
314 may influence the fan mussel populations. Many set netters and trawlers reported that fan  
315 mussel damage their fishing nets, thus they do not tend to fish areas where fan mussels are  
316 found in high densities.

317 Katsanevakis (2007) reported that in spite of the conservation status of *P. nobilis*, it is  
318 illegally fished in Lake Vouliagmeni by divers due to insufficient control by authorities and  
319 because locals do not have enough information about the legislation. Another example of illegal  
320 fisheries was reported by Vafidis et al. (2014); they noticed that about 45 small-scale fishing  
321 vessels were harvesting and processing this endangered species at the islands of Symi and  
322 Kalymnos, in spite of the official restrictions. The estimated annual production is estimated at  
323 1.5 ton in this region (Vafidis et al., 2014). Fan mussels are consumed only in Özbek (İzmir) in  
324 Turkey, where the estimated annual harvest was about 1000 individuals. Fishers who fish  
325 around Özbek reported that they only collect this species in May and June when gonads have a  
326 high gonado-somatic index (GSI). Similarly, Deudero et al. (2017) reported that the  
327 reproductive peak in Spain occurs in May. The consumption of this species appears to be  
328 minimal in seafood restaurants in Turkey, however, although it is more commonly served at the  
329 seafood restaurants in Greece and the Greek Islands (Katsanevakis et al., 2011). There is no  
330 information about the scale of collection of this species in other Mediterranean countries.

331 Information on the ecology of *P. nobilis* in Turkish waters is scarce, so the number of  
332 doctoral programmes and scientific projects should be increased. In particular, it is vitally  
333 important to monitor the density of endangered species periodically. The present study provides  
334 the novel information about the density of *P. nobilis* for Turkey (eastern Mediterranean Sea);  
335 however, the density of *P. nobilis* should be investigated every 3 or 5 years at the sampling  
336 areas of present study because the population of *P. nobilis* has been decreasing dramatically for  
337 the last decade. Furthermore, its density and distribution should be monitored by comparative

338 studies inside and outside the MPAs for the sustainability of marine ecosystems (Vázquez-Luis,  
339 et al., 2014).

340 One of the main conservation challenges was the lack of information on the endangered  
341 status of fan mussels among the locals and fishers. Moreover, the LEK results revealed that  
342 fishing operations, in particular illegal trawling in shallow waters, and also purse-seining over  
343 the benthic habitats resulted in the by-catch of fan mussels. Finally, LEK identified poaching,  
344 pollution and boat anchoring over the fan mussel beds as the other main threats. For the  
345 conservation of the species, it would be appropriate to firstly identify important areas for this  
346 species and then manage the pressures that impact negatively affect them. Shallow water sites  
347 of <15 m in depth appear to be the most important areas in present times, but this might be an  
348 artefact of human pressures curtailing the extent of the distribution of fan mussels in deeper  
349 water. A programme of observation, perhaps using citizen science, would be beneficial to  
350 improve knowledge of the distribution of this species in Turkish waters. In addition, the  
351 common fishery policy (CFP) of European Commission purposes to improve the data collection  
352 on discards and by-catch (Öndes, Kaiser, & Murray, 2017). Thus, not only target species but  
353 also by-catch species such as *P. nobilis* could be recorded by fishers using logbooks or return  
354 forms. The protection of fan mussels within MPAs would seem like a sensible approach if  
355 properly managed and enforced (Güçlüsoy, 2015, 2016). Sea grass meadows serve as important  
356 associated habitats and are effectively protected from illegal trawling elsewhere in the  
357 Mediterranean (e.g. Sánchez-Jerez & Ramos-Esplàa, 1996). Areas comprising commonly  
358 distributed locations should be closed for the purse-seiners. Small scale fishers can be  
359 encouraged to use long-lines instead of set nets; however, socio-economic pros and cons should  
360 be assessed, and a compensation scheme and/or alternative livelihood may be required. Mooring  
361 systems should be established or if they already exist, modernized in areas where fan mussels  
362 are most abundant, in order to decrease the negative impacts of anchoring (e.g. Garcia-March



363 & Nardo, 2006). For the locals and fishers, public awareness campaigns should be developed  
364 to increase the knowledge on the endangered status of fan mussels. The responsible  
365 governmental organisations should inform the public at public meetings. Where possible,  
366 information boards about *P. nobilis* and mitigation measures on the threats (e.g. prevent the  
367 illegal collection) on beaches, marinas and harbours should be erected. Eventually, all  
368 aforementioned mitigation measures should be incorporated into management plans if the  
369 concerned area is an MPA, and all commonly distributed locations of fan mussels should be  
370 monitored every 3 years to assess their status.

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### 381 **APPENDICES (APPENDIX A.)**

382 Supplementary data related to this article can be found at <http://>

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387 **CONFLICT OF INTEREST**

388 The authors are unaware of any existing conflicts of interest that would preclude or bias  
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390 **REFERENCES**

391 Acarli, S., Lök, A., & Acarli, D. (2011). Preliminary spat settlement of fan mussel *Pinna nobilis* Linnaeus  
392 1758 on a mesh bag collector in Karantina Island (Eastern Aegean Sea, Turkey). *Fresenius*  
393 *Environmental Bulletin*, 20, 2501-2507.

394 Addis, P., Secci, M., Brundu, G., Manunza, A., Corrias, S., & Cau, A. (2009). Density, size structure, shell  
395 orientation and epibiotic colonization of the fan mussel *Pinna nobilis* L. 1758 (Mollusca: Bivalvia)  
396 in three contrasting habitats in an estuarine area of Sardinia (W Mediterranean). *Scientia Marina*, 73,  
397 143-152.

398 Alomar, C., Vázquez-Luis, M., Magraner, K., Lozano, L., & Deudero, S. (2015). Evaluating stable isotopic  
399 signals at bivalve *Pinna nobilis* under different human pressures. *Journal of Experimental Marine*  
400 *Biology and Ecology*, 467, 77-86.

401 Amoroso, R. O., Pitcher, C. R., Rijnsdorp, A. D., McConnaughey, R. A., Parma, A. M., Suuronen, P., et al.  
402 (2018). Bottom trawl-fishing footprints on the world's continental shelves. *Proc. Natl. Acad. Sci.*  
403 U.S.A. 115, E10275–E10282. doi: 10.1073/pnas.1802379115.

404 Azzurro, E., Sbragaglia, V., Cerri, J., Bariche, M., Bolognini, L., Souissi, J. B., ... & Gianni, F. (2019).  
405 (2019). Climate change, biological invasions, and the shifting distribution of Mediterranean fishes: A  
406 large-scale survey based on local ecological knowledge. *Global Change Biology*, 1-14.

407 Basso, L., Vázquez-Luis, M., García-March, J.R., Deudero, S., Alvarez, E., Vicente, N., Duarte, C.M., &  
408 Hendriks, I. (2015). The Pen Shell, *Pinna nobilis*: A Review of Population Status and Recommended  
409 Research Priorities in the Mediterranean Sea. *Advances in Marine Biology*, 71, 109-160.

410 Butler, A., Vicente, N., & De Gaulejac, B. (1993). Ecology of the Pteroid bivalves *Pinna bicolor* Gmelin  
411 and *Pinna nobilis* L. *Marine Life*, 3, 37–45.

412 Carella, F., Aceto, S., Pollaro, F., Miccio, A., Iaria, C., Carrasco, N... De Vico, G. (2019). A mycobacterial  
413 disease is associated with the silent mass mortality of the pen shell *Pinna nobilis* along the Tyrrhenian  
414 coastline of Italy. *Scientific Reports*, 9, 2725.

415 Carter, B. T. G., & Nielsen, E. A. (2011). Exploring ecological changes in Cook Inlet beluga whale habitat  
416 though traditional and local ecological knowledge of contributing factors for population decline.  
417 *Marine Policy*, 35, 299–308.

418 Catanese, G., Grau, A., Valencia, J.M., García-March, J.M., Álvarez, E., Vázquez-Luis, M., ... Villalba, A.  
419 (2018). Haplosporidium pinnae sp.nov., a haplosporidan parasite associated with massive mortalities  
420 of the fan mussel, *Pinna nobilis*, in the Western Mediterranean Sea. *J. Invertebr. Pathol.* 157, 9-24.

421 Centoducati, G., Tarsitano, E., Bottalico, A., Marvulli, M., Lai, O., & Crescenzo, G. (2006). Monitoring of  
422 the Endangered *Pinna nobilis* L, 1758 in the Mar Grande of Taranto (Ionian Sea, Italy).  
423 *Environmental Monitoring and Assessment*, 131, 339-347.

424 Coll, M., Piroddi, C., Kaschner, K., Lasram, F., Steenbeek, J., Aguzzi, ... Voultziadou, E. (2010). The  
425 biodiversity of the Mediterranean Sea: estimates, patterns and threats. *PLoS One* 5:e11842.

426 Coppa, S. (2012). On the Ecology and Conservation of Marine Endangered Species, *Pinna nobilis* (Linnaeus,  
427 1758) and *Patella ferruginea* (Gmelin, 1791), in the Marine Protected Area of "Penisola del Sinis -  
428 Isola di Mal di Ventre" (western Sardinia, Italy) (PhD thesis) University of Tuscia, Viterbo, Italy.

429 Coppa, S., Andrea de Lucia, G., Magni, P., Domenici, P., Antognarelli, F., Satta, A. & Cucco, A. (2013).  
430 The effect of hydrodynamics on shell orientation and population density of *Pinna nobilis* in the Gulf  
431 of Oristano (Sardinia, Italy). *Journal of Sea Research*, 76, 201-210.

432 Deudero, S., Grau, A., Vázquez-Luis, M., Álvarez, E., Alomar, C., Hendriks, I. E. (2017). Reproductive  
433 investment of the pen shell *Pinna nobilis* Linnaeus, 1758 in Cabrera National Park (Spain).  
434 *Mediterranean Marine Science*, 18, 271-284.

435 Deudero, S., Vázquez-Luis, M. & Álvarez, E. (2015). Human stressors are driving coastal benthic long-lived  
436 sessile fan mussel *Pinna nobilis* population structure more than environmental stressors. *PloS one*,  
437 10, e0134530.

438 EEC (1992). Council directive on the conservation of natural habitats and of wild fauna and flora (The  
439 habitats and species directive), 92/43/EEC. Official Journal of the European Communities No L  
440 206/7, Brussels Council Directive.

441 Fonseca, M.S., Thayer, G.W. & Chester, A.J. (1984) Impact of scallop harvesting on eelgrass (*Zostera*  
442 *marina*) meadows: implications for management. *North American Journal of Fisheries Management*  
443 4: 286–293.

444 Hendriks, I. E., Tenan, S., Tavecchia, G., Marba, N., Jorda, G., Deudero, S., Alvarez E., & Duarte, C. M.  
445 (2013). Boat anchoring impacts coastal populations of the pen shell, the largest bivalve in the  
446 Mediterranean. *Biological Conservation*, 160, 105–113.

447 García-March, J.R., García-Carrascosa, A. M., Cantero, A. L. P., & Wang, Y.G. (2007). Population  
448 structure mortality and growth of *Pinna nobilis* Linnaeus, 1758 (Mollusca, Bivalvia) at different  
449 depths in Moraira bay (Alicante, western Mediterranean). *Marine Biology*, 150, 861–871.

450 Garcia-March, J. R., Marquez-Aliaga, A., Wang, Y. G., Surge, D., & Kersting, D. K. (2011). Study of *Pinna*  
451 *nobilis* growth from inner record: how biased are posterior adductor muscle scars estimates? *Journal*  
452 *of Experimental Marine Biology and Ecology*, 407, 337–344.

453 Garcia-March, J. R., & Nardo, V. (2006). Protocol to study and monitor *Pinna nobilis* populations within  
454 marine protected areas. Malta Environmental & Planning Authority (MEPA), 62 pp.

455 Güçlüsoy, H. (2015). Marine and Coastal Protected Areas of Turkish Aegean Coasts. THE AEGEAN SEA  
456 MARINE BIODIVERSITY, FISHERIES, CONSERVATION AND GOVERNANCE, Edited by T.  
457 Katağan, A.Tokaç, Ş. Beşiktepe, B. Öztürk, 12/2015: pages 669-684; Turkish Marine Research  
458 Foundation., ISBN: 978-975-8825-33-2.

459 Güçlüsoy, H. (2016). Marine and Coastal Protected Areas of Turkish Levantine Coasts (Eastern  
460 Mediterranean). The Turkish Part of the Mediterranean Sea Marine Biodiversity, Fisheries,  
461 Conservation and Governance, 1 edited by Cemal Turan, Barış Salihoğlu, Elif Özgür Özbek, Bayram

462 Öztürk, 12/2016: pages 522-535; Turkish Marine Research Foundation (TUDAV), ISBN: ISBN 978-  
463 975-8825-35-6.

464 Katsanevakis, S. (2007). Density surface modelling with line transect sampling as a tool for abundance  
465 estimation of marine benthic species: The *Pinna nobilis* example in a marine lake. *Marine Biology*  
466 *152*, 77–85.

467 Katsanevakis, S., Coll, M., Piroddi, C., Steenbeek, J., Ben Rais Lasram, F., Zenetos, A., & Cardoso, A. C.  
468 (2014). Invading the Mediterranean Sea: biodiversity patterns shaped by human activities. *Frontiers*  
469 *in Marine Science*, 1, 32.

470 Katsanevakis, S., Poursanidis, D., Issaris, Y., Panou, A., Petza, D., Vassilopoulou, V., Chaldaiou, I., & Sini,  
471 M. (2011). “Protected” marine shelled molluscs: thriving in Greek seafood  
472 restaurants. *Mediterranean Marine Science*, 12, 429–438.

473 Katsanevakis, S., Tsirintanis, K., Tsaparis, D., Doukas, D., Sini, M. et al.i, 2019. The cryptogenic parasite  
474 *Haplosporidium pinnae* invades the Aegean Sea and causes the collapse of *Pinna nobilis* populations.  
475 *Aquatic Invasions* 14.

476 Liu, T.K., Huang, H.Y., & Hsu, S. L. (2015). Saving the critically endangered Chinese white dolphin in  
477 Taiwan: debate regarding the designation of an MPA. *Marine Policy*, 61, 113–120.

478 Loerzel JL, Goedeke TL, Dillard MK, Brown G., 2017. SCUBA divers above the waterline: using  
479 participatory mapping of coral reef conditions to inform reef management. *Marine Policy*, 76, 79–89.

480 Mangano, M.C., & Sarà, G. (2017). Collating science-based evidence to inform public opinion on the  
481 environmental effects of marine drilling platforms in the Mediterranean Sea. *Journal of*  
482 *Environmental Management*, 188, 195-202.

483 Marba, N., Diaz-Almela, E., & Duarte, C. M. (2014). Mediterranean seagrass (*Posidonia oceanica*) loss  
484 between 1842 and 2009. *Biological Conservation*, 176, 183–190.

485 Marba, N., & Duarte, C. M. (2010). Mediterranean warming triggers seagrass (*Posidonia oceanica*) shoot  
486 mortality. *Global Change Biology*, 16, 2366e2375.

487 Mavruk, S., Saygu, İ., Bengil, F., Alan, V., & Azzurro, E. (2018). Grouper fishery in the Northeastern  
488 Mediterranean: an assessment based on interviews on resource users", *Marine Policy*, 87, 141-  
489 148.

490 Médail, F., & Quézel, P. (1999). Biodiversity hotspots in the Mediterranean Basin: setting global  
491 conservation priorities. *Conservation Biology*, 13, 1510-1513.

492 Moreteau, J.C., & Vicente, N. (1982). Evolution d'une population de *Pinna nobilis* L. (Mollusca, Bivalvia).  
493 *Malacologia*, 22, 341–345.

494 Öndes, F., Kaiser, M.J. & Murray, L.G. (2017). Fish and invertebrate by-catch in the crab pot fishery. *Journal*  
495 *of the Marine Biological Association of the UK*, 1-13. DOI: 10.1017/S0025315417001643.

496 Öndes, F., Ünal, V., Özbilgin, Y., Deval C. & Turan, C. (2018). By-catch and monetary loss of pufferfish in  
497 Turkey, the Eastern Mediterranean. *Ege Journal of Fisheries and Aquatic Sciences*, 35, 361-372.

498 Pienaar, E.F., Lew, D.K., & Wallmo, K. (2017). Intention to pay for the protection of threatened and  
499 endangered marine species: Implications for conservation program design. *Ocean Coastal*  
500 *Management*, 138, 170-180.

501 Piroddi, C., Coll, M., Liqueste, C., Macias, D., & Greer, K. (2017). Historical changes of the Mediterranean  
502 Sea ecosystem: modelling the role and impact of primary productivity and fisheries changes over  
503 time. *Scientific Reports*, 7, 44491. doi:10.1038/srep44491.

504 Prado, P., Caiola, N., & Ibáñez, C. (2014). Habitat use by a large population of *Pinna nobilis* in shallow  
505 waters. *Scientia Marina*, 78, 555–565.

506 Rabaoui, L., Tlig-zouari, S., Katsanevakis, S., Belgacem, W., & Ben Hassine, K. (2011). Differences in  
507 absolute and relative growth between two shell forms of *Pinna nobilis* (Mollusca: Bivalvia) along the  
508 Tunisian coastline. *Journal of Sea Research*, 66, 95-103.

509 Rabaoui, L., Tlig-Zouari, S., Katsanevakis, S., & Ben Hassine, O. K. (2010). Modelling population density  
510 of *Pinna nobilis* (Bivalvia) on the eastern and southeastern coast of Tunisia. *Journal of Molluscan*  
511 *Studies*, 76, 340-347.

512 Richardson, C. A., Kennedy, H. A., Duarte, C. M., & Proud, S. V. P. (1999). Age and growth of the fan  
513 mussel *Pinna nobilis* from S.E. Spanish Mediterranean seagrass *Posidonia oceanica* meadows.  
514 *Marine Biology*, 133, 205 – 212.

515 Richardson, C. A., Peharda, M., Kennedy, H., Kennedy, P., & Onofri, V. (2004). Age, growth rate and season  
516 of recruitment of *Pinna nobilis* (L) in the Croatian Adriatic determined from Mg:Ca and Sr:Ca shell  
517 profiles. *Journal of Experimental Marine Biology and Ecology*, 299, 1-16.

518 Rouanet, E., Trigos, S. & Vicente, N., 2015. From youth to death of old age: the 50-year story of a *Pinna*  
519 *nobilis* fan mussel population at Port-Cros Island (Port-Cros National Park, Provence, Mediterranean  
520 Sea). *Sci. Reports Port-Cros Natl. Park* 29, 209–222.

521 Sánchez-Jerez, P., & Ramos-Esplà, A. A. 1996. Detection of environmental impacts by bottom trawling on  
522 *Posidonia oceanica* (L.) Delile meadows: sensitivity of fish and macrobenthic communities. *Journal*  
523 *of Aquatic Ecosystem Health*, 5: 239–253

524 Shepperson, J., Murray, L. G., Cook, S., Whiteley, H., Kaiser, M. J. 2014. Methodological considerations  
525 when using local knowledge to infer spatial patterns of resource exploitation. *Biological*  
526 *Conservation*, 180, 214-223.

527 Taylor, R.B., Morrison, M.A., Shears, N.T., 2011. Establishing baselines for recovery in a marine reserve  
528 (poor Knights Islands, New Zealand) using local ecological knowledge. *Biol. Conserv.* 144, 3038–  
529 3046.

530 Turvey, S. T., Fernández-Secades, C., Nuñez-Miño, J. M., Hart, T., Martinez, P., Brocca, J.L., & Young, R.  
531 P. (2014). Is local ecological knowledge a useful conservation tool for small mammals in a Caribbean  
532 multicultural landscape? *Biological Conservation*, 169, 189–197.

533 Turvey, S. T., Risley, C. L., Moore, J. E., Barrett, L. A., Hao, Y., Zhao, X., Zhou, K., & Wang, D.  
534 (2013). Can local ecological knowledge be used to assess status and extinction drivers in a threatened  
535 freshwater cetacean? *Biological Conservation*, 157, 352–360.

536 UNEP-MAP, 2012 — “State of the Mediterranean Marine and Coastal Environment.” (United Nations  
537 Environment Programme/Mediterranean Action Plan (UNEP/MAP) — Barcelona Convention:  
538 Athens. Athens, Greece), 96 p.

- 539 Vafidis, D., Antoniadou, C., Voultziadou, E., & Chintiroglou, C. (2014). Population structure of the protected  
540 fan mussel *Pinna nobilis* in the south Aegean Sea (eastern Mediterranean). *Journal of Experimental*  
541 *Marine Biology and Ecology*, *94*, 787–796.
- 542 Vázquez-Luis, M., Álvarez, E., Barraón, A., García-March, J. R., Grau, A., Hendriks, I. E., Jiménez, S.,  
543 Kersting, D., Moreno, D., Pérez, M., Ruiz, J. M., Sánchez, J., Villalba, A., & Deudero, S. (2017).  
544 S.O.S. *Pinna nobilis*: A mass mortality event in Western Mediterranean Sea. *Frontiers in Marine*  
545 *Science*, *4*, 220.
- 546 Vázquez-Luis, M., Borg, J. A., Morell, C., Banach-Esteve, G., & Deudero, S. (2015). Influence of boat  
547 anchoring on *Pinna nobilis*: a field experiment using mimic units. *Marine Freshwater Research*, *66*,  
548 786–794.
- 549 Vázquez-Luis, M., March, D., Alvarez, E., Alvarez-Berastegui, D., & Deudero, S. (2014). Spatial  
550 distribution modelling of the endangered bivalve *Pinna nobilis* in a Marine Protected  
551 Area. *Mediterranean Marine Science*, *15*, 626–634.
- 552 Voultziadou, E., Koutsoubas, D., & Achparaki, M. (2010). Bivalve mollusc exploitation in Mediterranean  
553 coastal communities: an historical approach. *Journal of Biological Research*, *13*, 35-45.



## Tables

**Table 1**

Content of the questionnaires related to the local ecological knowledge (LEK)

Category of collected evidence	Specific information collected
1. The bio-ecological characteristics of fan mussel	<ul style="list-style-type: none"><li>- Spatial distribution</li><li>- Depth and habitat</li><li>- Current status of density in different locations</li></ul>
2. Historical changes in density	<ul style="list-style-type: none"><li>- Decrease or increase of density in the last 10 years</li><li>- Habitat change in term of seagrass presence/absence</li></ul>
3. Impacts of fisheries	<ul style="list-style-type: none"><li>- Estimated by-catch quantities of <i>P. nobilis</i> in different fishing gears (e.g. trawl, purse seine, set net, and longline)</li><li>- Illegal fisheries status (illegal collection and illegal trawl operations occurred in the shallow waters and fishing within the 1.5 nautical mile trawl limit)</li><li>- Estimated use by recreational fishers (e.g. bait)</li></ul>
4. Status of consumption	<ul style="list-style-type: none"><li>- Whether restaurants sell <i>P. nobilis</i> or not</li><li>- Whether <i>P. nobilis</i> are consumed by fishers and scuba divers</li></ul>
5. Awareness on the conservation status	<ul style="list-style-type: none"><li>- Whether local people and fishers know this species is endangered</li><li>- Whether fishers know this species is protected</li><li>- Awareness of the conservation status and source of knowledge (Social media, newspaper, legislation, education, etc.)</li></ul>

**Table 2**

Summary of fitting a general linear model (GLM) using data from the diving surveys (direct observations) in the Aegean Sea, Turkey

Source	Type III Sum of Squares	Mean Square	F-ratio	P-value
Corrected model	2291.90 <sup>a</sup>	29.01	4.141	<0.001
Intercept	1204.62	1204.62	171.94	<0.001
Depth	166.40	41.60	5.94	<0.001
Habitat	47.22	47.22	6.74	0.010
Area	472.99	52.55	7.50	<0.001
Depth*habitat*area	1044.03	16.06	2.30	<0.001
Error	1191.00	7.01		
Total	5471.00			
Corrected total	3482.90			

---

Dependent variable, density; fixed factor, area; covariates, habitat and depth.

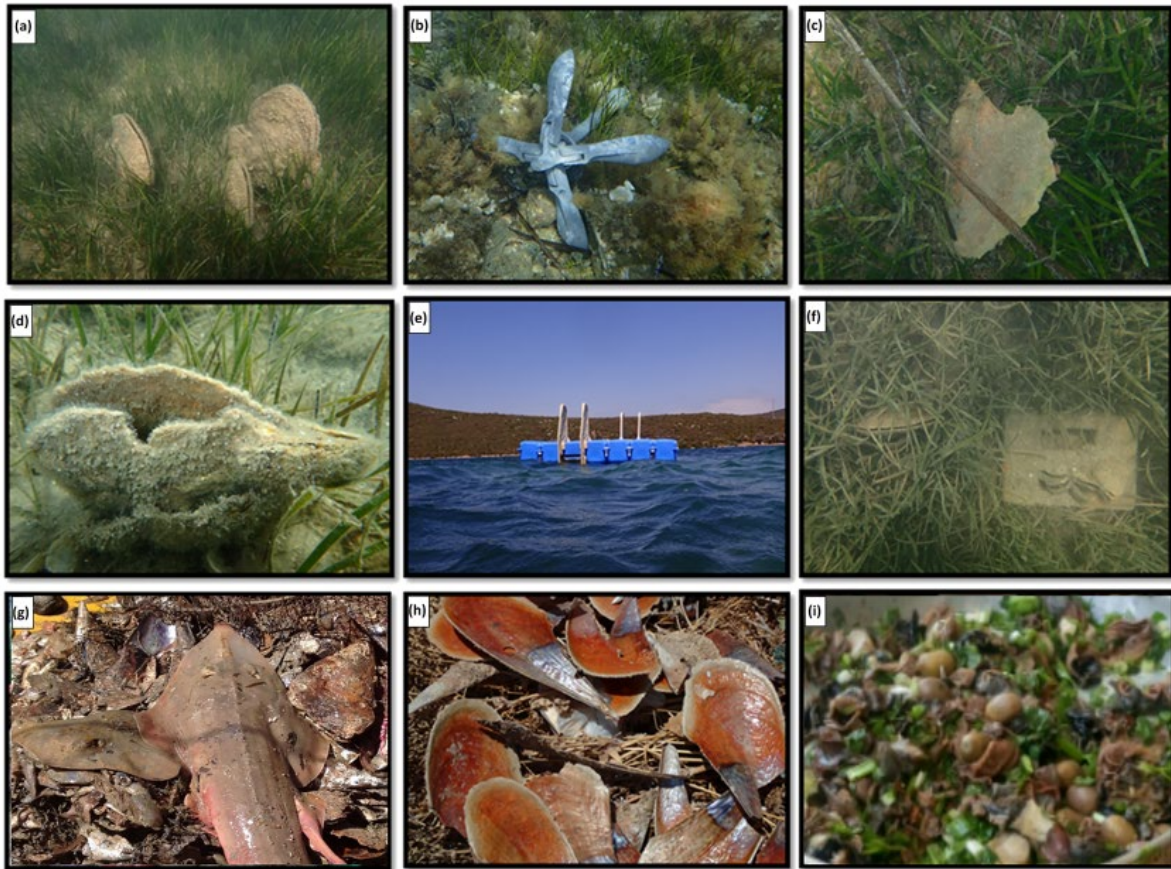
<sup>a</sup>R<sup>2</sup> = 0.66 (adjusted R<sup>2</sup> = 0.50).

**Table 3**

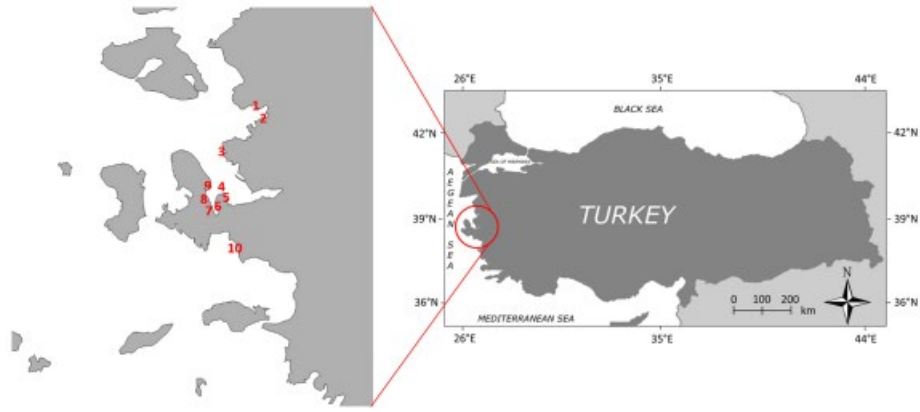
The percentage of stakeholders who provided information on the endangered status of the species, their collection and consumption rates, and whether observed any collection by other people

<b>Groups</b>	<b>Awareness on endangered status (%)</b>	<b>Collection rate (%)</b>	<b>Consume rate (%)</b>	<b>Collection by others (%)</b>
Commercial fishers (n = 120)	3	27	25	38
Spear fishers (n = 35)	3	40	37	63
SCUBA divers (n = 87)	21	7	6	36
<b>Total (n = 242)</b>	<b>9</b>	<b>22</b>	<b>20</b>	<b>41</b>

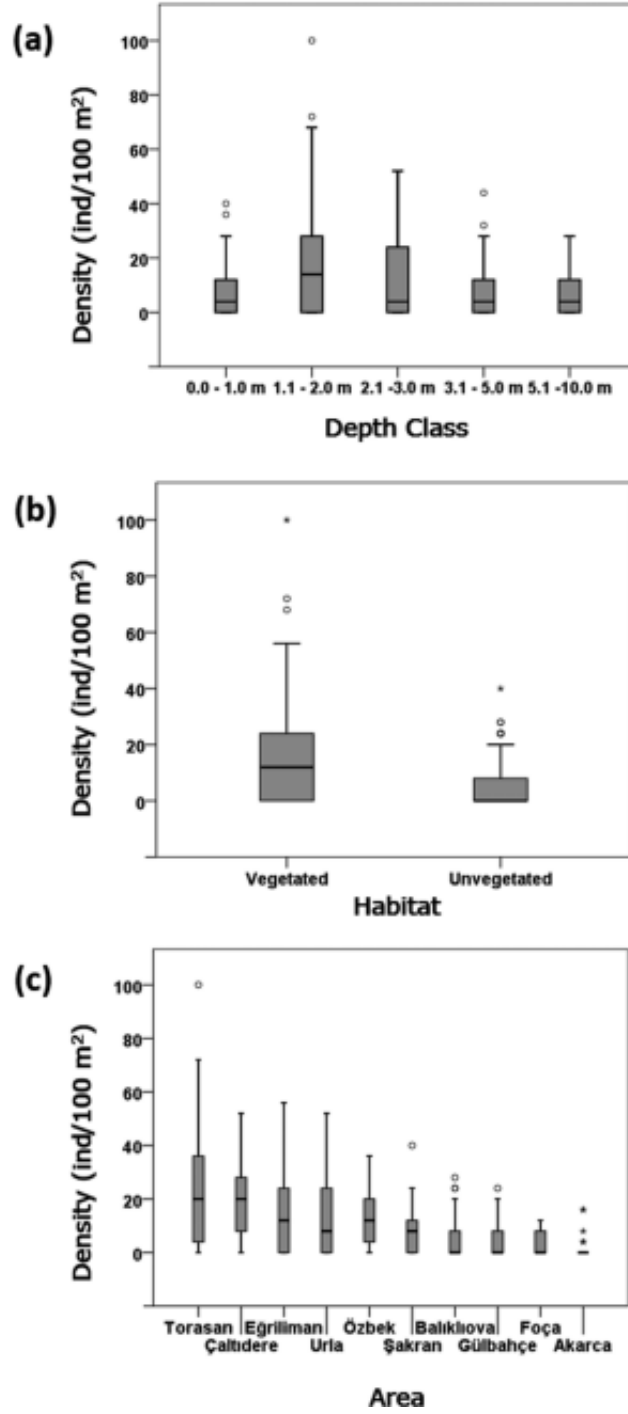
## FIGURES



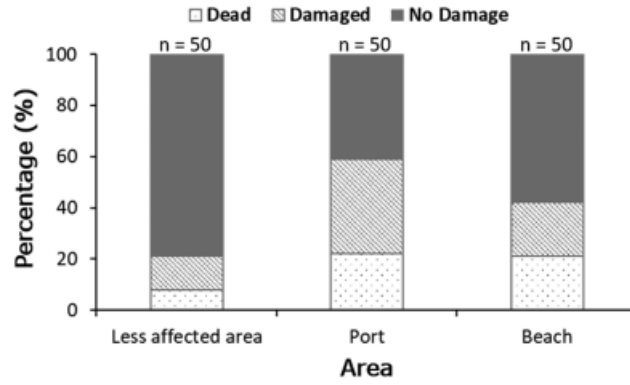
**FIGURE 1** (a) Fan mussel (*Pinna nobilis*) beds in the Aegean Sea. (b) Habitats threatened by boat anchorage in one of the sampling sites at a fishing port. (c) Damaged fan mussel shell in a port. (d) Damaged fan mussel specimen at a beach. (e) A buoy at one of the sampling sites. (f) View of the anchor of a buoy near a fan mussel. (g) Fan mussels as by - catch from a bottom trawl in 2017. (h) Broken fan mussel shells from local collectors. (i) A dish of fan mussels. The photo for (g) was obtained from the Dokuz Eylül University Archive, whereas all other photos were taken by the first author at the sampling sites



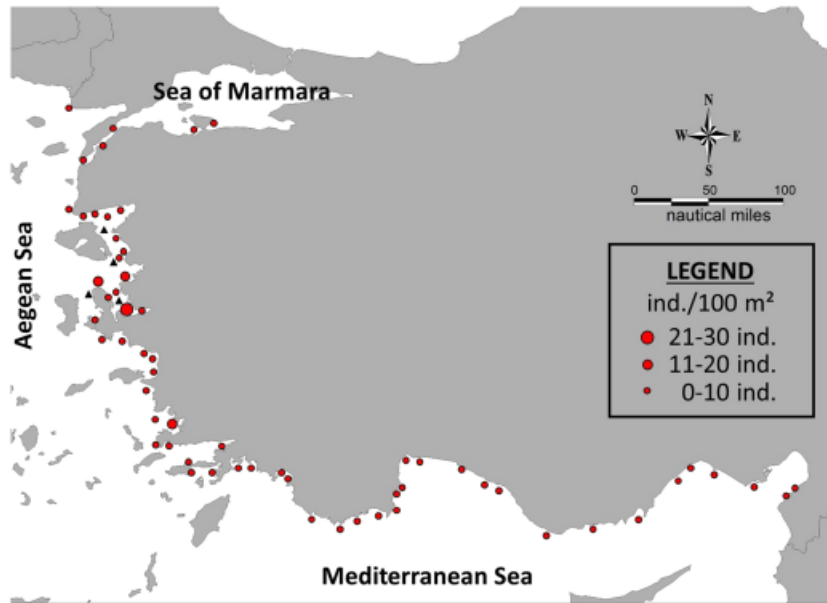
**FIGURE 2** The map of the study area includes the diving surveys in the Aegean Sea (Turkey). Sampling station codes: 1, Şakran; 2, Çaltıdere; 3, Foça; 4, Urla; 5, Özbek; 6, Eğriliman; 7, Torasan; 8, Gülbahçe; 9, Balıklıova; 10, Akarca



**FIGURE 3** The mean values of *Pinna nobilis* density (individuals per 100 m<sup>2</sup>) depending on: (a) depth class (0.0 – 1.0, 1.2. – 2.0, 2.1 – 3.0, 3.1 – 5.0, and 5.1 – 10.0 m); (b) habitat (vegetated and unvegetated); and (c) sampling area (Torasan, Çaltıdere, Egriliman, Urla, Özbek, Şakran, Balıklıova, Gülbahçe, Foça, and Akarca)

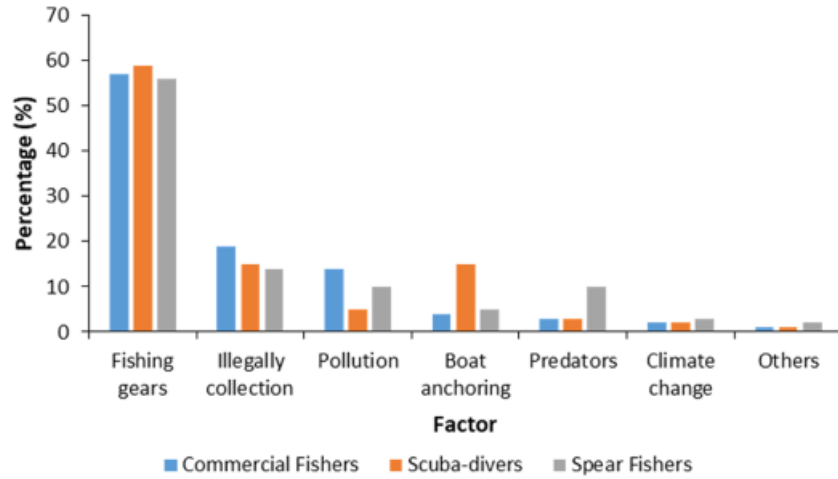


**FIGURE 4** Comparison of different areas (port, beach, and less affected area, LAA) in terms of the percentage of damage to *Pinna nobilis*. Damage scale: 1, no damage; 2, damaged individuals; 3, dead individuals (individuals were counted)



**FIGURE 5** The map of the mean density estimations of *Pinna nobilis* based on the scuba - divers ' ecological knowledge and the locations of the highest *P. nobilis* fields based on trawlers ' knowledge in Turkey. Red circles include the density classes (0 – 10, 11 – 20, and 21 – 30 individuals per 100 m<sup>2</sup>) of *P. nobilis* based on divers ' information; black triangles show the locations where fan mussels are common (where at least one - third of the catch was fan mussels) according to trawlers' information.





**FIGURE 6** The main perceived and reported threats that can influence a local decrease of the fan mussel population, based on the responses of the stakeholders (i.e. commercial fishers, scuba - divers, and spear fishers)