





Article

The Willingness to Assess and Contribute to Pinna-SOS Recovery Actions of Marine Fishers/Farmers and Stakeholders

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Abstract: The present study aimed to address the issue of pressure on the remaining populations of the critical endangered species, fan mussel, *Pinna nobilis*, in the Eastern Mediterranean. Marine professional (shell/fish farmers, divers, fishers, administrators, etc.) stakeholders' knowledge ($n = 151$) in Greece reports that there was a reduction (81.6%) of the *P. nobilis* individuals during the last 15 years, especially in the years 2010–2012 and 2017–2018. Species' abundance decline is significantly ($\rho = 0.293$, $p < 0.05$) correlated over the last 5 years with the observed natural ecosystem degradation. Participants also stated that the main cause was pathogens alone (28.8%) or in combination with (illegal) fishing (17.1%) or pollution (14.4%). Additionally, 88% of them supported a total prohibition on the use of fan mussels for commercial purposes in order to restore stock levels.; 72.4% stated claimed that no appropriate control was in place and that they (>59.4%) were unsure if this monitoring control is carried out by the competent authorities. Marine stakeholders consider the importance of the species for biodiversity preservation (56.1%), environmental education (35.1%), and diving parks (29.7%). They declared that it is important to record-observe *P. nobilis* conservation reserves regions (42.6%), monitor areas of responsibility (39.9%), participate in the information society / use of social networks (38.5%), and participate in informational meetings (37.9%). The lack of interest among shell/fish farmers to contribute to *P. nobilis* on-growing farming indicates the ignorance to the potential benefits of the valuable ecosystem services provided by aquaculture through biodiversity conservation. Nevertheless, there is a demand for promoting the "conservation aquaculture" concept through its incorporation into marine farming activities supplementary to their core business in "production".

Keywords: aquaculture conservation; illegal fisheries; *Pinna nobilis* restoration; ecosystem services; mass mortalities; Greece

Key Contribution: This article provides Greek marine professional stakeholders' (fishers; aquaculture, authorities, and others) observations for the decline of *P. nobilis* and their willingness to contribute to the species' recovering restoration actions.



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1. Introduction

Fan mussel, *Pinna nobilis* (Linnaeus, 1758), is the Mediterranean Sea's biggest endemic Pteriomorphian bivalve, with lengths of up to 120 cm. This species is protected under the Mediterranean Specially Protected Areas Protocol (95/96 SPA ANNEX II) and European legislation (92/43 EEC). *P. nobilis* was recently classified as critically endangered on the IUCN Red List of Threatened Species [1]. One of the most significant issues that *P. nobilis*

populations confront is the influence of multipathogen infections and multifactorial pathogenesis (protozoan parasite *Haplosporidium pinnae*, bacteria from within the *Mycobacterium simiae* complex, and those similar to *Vibrio mediterranei*) [2,3]. This synergism with multipathogen presence has caused enormous death episodes and raised the possibility of extinction in many of the areas where this species lives [4–6]. The parasite's disastrous consequences have been recorded in a number of Mediterranean countries, including France, Italy, Tunisia, Turkey, Greece, and even one of the last remaining safe shelters for the fan mussel in Croatia [7,8].

The ecological services that the fan mussel delivers to the environment have received little (if any) attention. Shellfish farm producers treat these organisms collectively as biodepositors, regardless of species [9–11]. Given that there is no applicable legislative directive to provide practical direction for this issue, problems like the recruitment of the species and what a responsible producer should do must be addressed [12]. It is true that standards for appropriate environmental practice based on the biology of the species must be developed, made available, and conveyed to shellfish producers. Fan mussels' food has received little attention [12,13], even though as a mollusk bivalve, it provides crucial ecosystem functions. Furthermore, more information is needed in the "conservation aquaculture" of vulnerable species. Projecting producers' contributions to the public as "environmental guardian angels" of endangered species is now critical [12,14,15]. This promotion may encourage shellfish farmers to "adopt" the protection of endangered species, providing, in addition to their main production operations, species protection through collection and protection of young individuals through pre-growing, with the ultimate goal of enriching wild stocks. The cost and results of this species-protection endeavor should be evaluated both in terms of ecosystem services and in terms of the societal approach.

Synergies between different sectors that operate primarily in the same sector of a region, such as the Natura 2000 network, will contribute to the conservation and enhancement of endangered species such as finches, offsetting some of the above costs while creating new added value using existing infrastructures and knowledge. Assessing the ecosystem services provided by such an intervention will help to quantify previously unknown ecosystem values. Fisheries research is becoming more and more integrated with the quantification of the fisher's expertise, a contemporary method for gathering data on fisheries [16]. The aforementioned information is especially helpful when incorporating fishery production data into ecosystem fisheries models (Ecopath with Ecosim: [17]) to define reference limits and exploitation indicators as well as to comprehend the structure and function of ecosystems [18,19]. To systematically document unlawful, unrecorded, and unregulated fishing, the European Union has established a community system for recording fishing productivity and effort statistics [20].

The present study aimed to address the issue of pressure on the remaining populations of the endangered species. More specifically, the purpose is to (i) determine which environmental (depth and habitat features) and anthropogenic factors may be related to the occurrence and density of fan mussels; (ii) evaluate the effects of fisheries on fan mussels, such as illegal collection and bycatch associated with various fishing gears; and (iii) assess the stakeholders' knowledge of the conservation status of this endangered species [16]. The methodology for the bivalves developed by [21] will be applied to the ecological services that the fan mussel offers.

2. Materials and Methods

2.1. Survey Design

A variety of stakeholders, including coastal fishers, mussel/oyster and fish farmers, other marine professionals, public fisheries offices, local bodies, recreational fishers and divers, as well as organizers of other marine recreational activities within Greek territory (Figure 1), participated in the survey. In specific, almost a third of participants (29.6%) were derived from Central Aegean, whereas 21.0% were derived from North and South Aegean areas and 19.8% from Ionian Sea and to a lesser extent by the Korinthiakos and Pagasitikos

gulfs (6.2% and 2.5%, respectively). To determine the sample from the target groups to complete the questionnaires, official updated data were recorded following the official data from the Fisheries Departments of the Regional Agriculture and Veterinary Directorates of the respective regions, as well as the updated contact details of the relevant collective bodies [22]. The respondents that participated in the survey and were located within the Greek territories that were chosen represented at least 30% of the total allowed capacity or 30% of the total number of shellfish farming units [23]. All participants completed a single questionnaire that captured their perspectives.

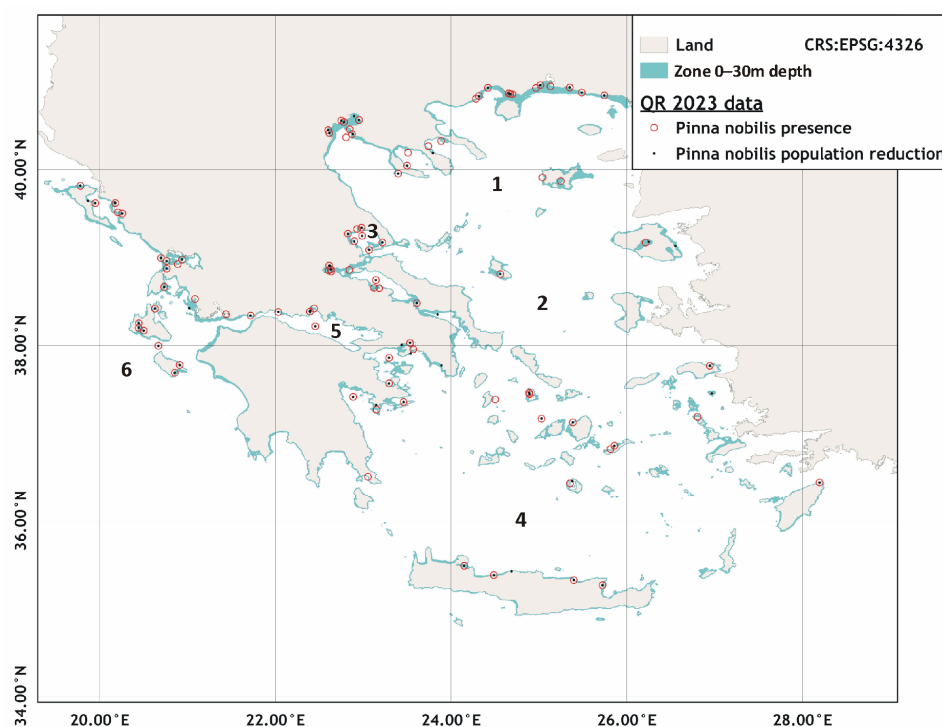


Figure 1. Fan mussel's presence and areas of significant reduction of abundance. 1: North Aegean; 2: Central Aegean; 3: Pagasitikos Gulf; 4: South Aegean; 5: Korinthiakos Gulf; and 6: Ionian.

The two most widely used techniques for gathering data for the study were telephone interviews and in-person interviews. While the second way is less expensive and combines the instability of a direct interview with the affordability of emailing, the first option is more dependable but more costly. It should be mentioned that direct interviews were used to get the majority of the necessary data. The study was conducted in February and June of 2022; before completing the questionnaires, the mussel farmers were informed that participation in the survey was voluntary and that the survey was impersonal. In order to reduce the possibility of bias, the same individual conducted each interview, guaranteeing that questions were asked in the same way and that responses were given voluntarily and without coercion.

The questionnaire consisted of two sections (Appendix A), the first one with 26 questions focusing the area of expertise of the participants and their status of knowledge on fan mussel abundance, protection, historical trends, causes of decline and threats. This section also included proposals for protection and suggested ecosystem services that would safeguard the studied species. The second section included the demographic features of the samples. Certain questions were dichotomous (YES or NO) and others were multi-thematic, for example, there were nine topics for question A22 "To what extent do you think the fan mussel contributes to the following services?" and seven topics for question A24 "How can you contribute to the protection of *Pinna nobilis*?". The first question is based on a 5-point

Likert ranking (0 = I do not know; 1 = None; 2 = Less; 3 = Much; 4 = Very much), and the second one on a 3-point Likert ranking (1 = None; 2 = Less; 3 = Much).

2.2. Data Analysis

The frequency of statements from the entire sample was estimated at the level of the independent variables described above, and they were shown using correlation tables as well as diagrammatic presentation. An independence test was conducted using the χ^2 distribution (likelihood ratio χ^2) for each preference question and respondents' independent ranking variables [24]. A non-parametric correlation analysis (Spearman's rank correlation coefficient ρ) on the values of the questions on the self-efficacy scale was also carried out to determine whether any correlations existed and to assess the strength of the relationships [25].

A reliability examination of the multi-thematic question A22 "To what extent do you think the fan mussel contributes to the following services?" was carried out. This analysis refers to a measurement's property of producing similar results for similar inputs. Cronbach's alpha coefficient is a measure of reliability, which is defined as the fraction of variability in the responses to a survey that is caused by differences in the respondents. [25].

Multivariate analyses were also applied to the multi-thematic question A22. The categorical regression method with optimal scaling constitutes an improvement and extension of the classic linear regression method, which quantifies the data on categorical variables by attributing numerical values to the categories, resulting in an optimal linear regression equation of the converted variables. This method also allows forecasts of the values of a dependent variable for any combination of a set of independent (classification) variables to be made [26]. The effect of each of the classification variables on the dependent variable is described with the corresponding regression coefficient. To test the collinearity in the model, Pratt's measures of relative importance and tolerance were used. A variable with a very low tolerance contributes little information to a model and can cause computational problems. Thus, it should be removed from the categorical regression.

All the analyses were carried out using the statistical package IBM SPSS Statistics 27.0.1.0 [27].

3. Results

3.1. Descriptive Analysis

Of the total 151 participants, the majority (83.4%) were men, with a mean age of 50 years (standard deviation of 11.6 years), with the largest proportion of participants in the 45 to 50 years age group. More than half of the participants had graduated from university (52.3%) and to a lesser extent from Lycée (21.2%) or Technical Colleges (15.2%), while the rest of them had a lower educational level (11.3%). More than a third of the participants were marine fishers—shell fishers and shellfish farmers (46.2%) and to a lesser extent were public (15.2%) or private (13.1%) officers, divers (11.0%) or freelancers (6.2%). The rest of the participants (8.3%) were members of Non-Governmental Organizations (NGOs), retired, students, or unemployed.

Regarding the purpose of the participants' activity, the largest percentage (29.8%) were coastal fishers, followed by fish farmers (23.2%), fisheries department staff (15.2%), diving center personnel (14.6%), and shellfish farmers and fishers (11.9%), and the rest of participants were members of NGOs (3.3%) and scientists (2.0%). An overwhelming majority of the participants (94.0%) were aware of fan mussel and had seen more than 10 individuals (71.0%), while 17.0% had not ever seen any fan mussel and 11.7% had seen up to 10 individuals. According to the statements, a significant presence of the fan mussel was observed in most coastal areas of Greece (Figure 1), with a third of them (32.3%) belonging to the North Aegean sea (No 1 in Figure 1), followed to a lesser extent by areas in Ionian (19.7%), Evvoikos Gulf (13.4%), South Aegean (13.4%), and Central Aegean (10.2%) seas. Areas with minor occurrence of fan mussel's presence were Korinthiakos and Pagasitikos gulfs (both with 5.5%). The same pattern was also observed for the areas

with significant reduction of fan mussel; North Aegean (27.0%) > Ionian (24.3%) > South Aegean (15.3%) > Central Aegean (11.7%) > Evvoikos gulf (9.9%) > Pagasitikos gulf (7.2%) > Korinthiakos gulf (4.5%).

In most of the areas, a high percentage of participants (81.6%) observed a significant decrease of fan mussels during the last 40 years, especially during the last decade (Figure 2a). Cumulatively, 28.8% of the participants stated that the main cause for the decline in fan mussel abundance was pests alone or in combination with fishing or pollution. Separately, pollution was blamed as a cause of fan mussel decline by 17.1% of participants and fishing by 14.4% (Figure 2b). Regarding participants' views on fan mussel's abundance in past years, an overwhelming percentage of participants stated that fan mussel decline was 100% regardless of the historical period (10, 20, or 30 years ago) (Figure 2c). Although half of the participants declared ignorance about the time of the year with the greatest intensity of fishing activity of the species, the remaining participants (29.6%) stated that it takes place in the summer and in a much smaller percentage in the spring (8.6%). Regarding the benefits of the fan mussel to the ecosystem, 46.1% consider water filtering as the most important benefit, followed by biodiversity conservation (19.1%) (Figure 2d).

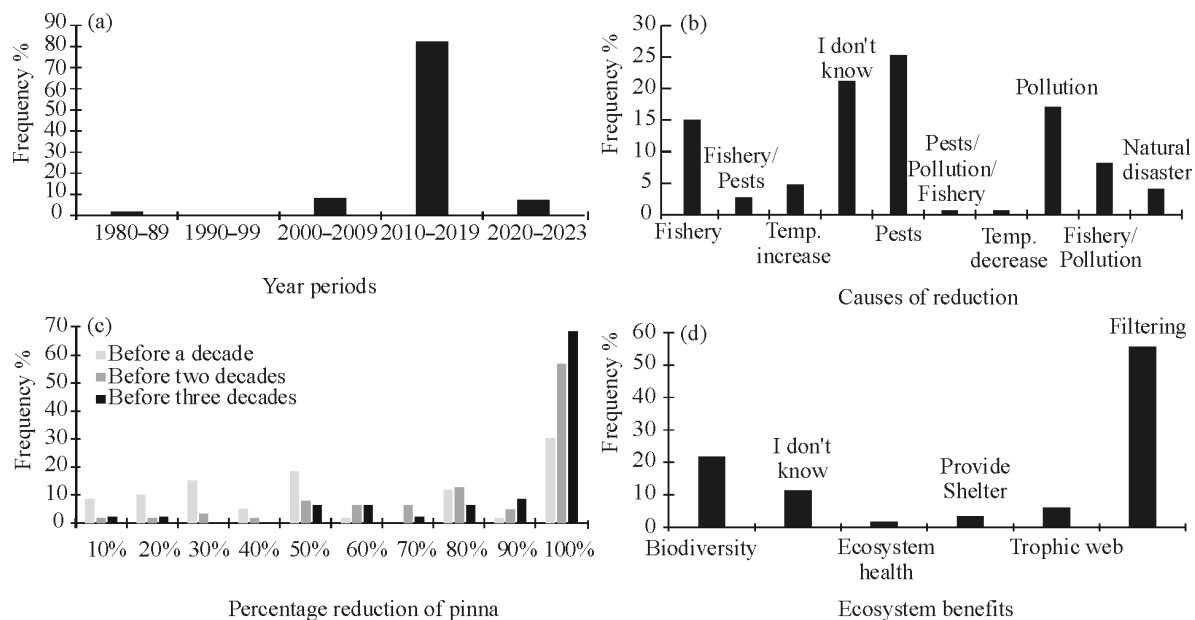


Figure 2. (a) Year period of fan mussel's reduction; (b) main cause of the reduction; (c) percentage reduction through years; and (d) ecosystem benefits due to fan mussel's presence.

A third of participants (33.0%) stated that trawling was the fishing gear with the highest bycatch quantities of fan mussel, followed by nets (18.8%) and diving (17.0%), whereas a 18.8% were not aware and the remaining participants (12.5%) stated that other fishing gears exhibited bycatch on fan mussel. Regarding the fate of the bycatch, more than half of the participants (54.2%) stated that they were not aware of the final fate of the bycatches, with a third (32.6%) retaining the bycatch, whereas 12.5% released these quantities to the sea. More than half of the participants (52.1%) were not aware whether the average size of fan mussels had decreased. Regarding a year with a significant decrease in fan mussel size, 27.5% declared the year of 2012, while 20% declared the year 2017. More than two-thirds of the survey participants (68.1%) do not agree with setting a minimum allowable catch size for fan mussels, while the rest of the participants (31.2%) believed the opposite. Regarding the proposed minimum allowable catch size of fan mussel, 38.0% stated between 40 and 50 cm, 22.2% at 20 cm, and 8.4% more than 70 cm. An overwhelming percentage of participants (88.0%) agree with the measure of a complete ban on fan mussel fishing to replenish stocks. More than two-thirds of the participants (69.4%) have observed a degradation of the natural ecosystem and 39.5% associated this situation with a decrease

in the abundance of fan mussels. In this context, there was a significant ($\rho = 0.293$, $p < 0.05$) correlation between the positive statement on the decline of fan mussel abundance over the last 5 years with the observed ecosystem degradation.

Regarding the ecosystem benefits of preserving *P. nobilis* (Figure 3), more than half of the participants (56.1%) considered the importance of species to the preservation of biodiversity, followed by the importance of environmental education (35.1%) and diving parks (29.7%). Conversely, a large percentage of the participants did not consider *P. nobilis* conservation important to CO₂ sequestration (56.1%), reduction of eutrophication (49.3%), and touristic activities (33.1%) (Figure 3). Regarding the participatory actions towards the conservation of the fan mussel (Figure 4), the highest percentage of the participants declared that it is important (value 3 and 4 in Figure 4) to record-observe in activity areas (42.6%), to monitor the areas of responsibility (39.9%), participate in the information society and the use of social networks (38.5%), and participate in informational meetings (37.9%) (Figure 4). Regarding the inspection conducted by the services for the purpose of protecting the fan mussel, 72.4% of participants said that the relevant inspection is not conducted. The majority of participants (>59.4%) said they were unsure of which agencies—fisheries, veterinary, or port authority—were in charge of this control.

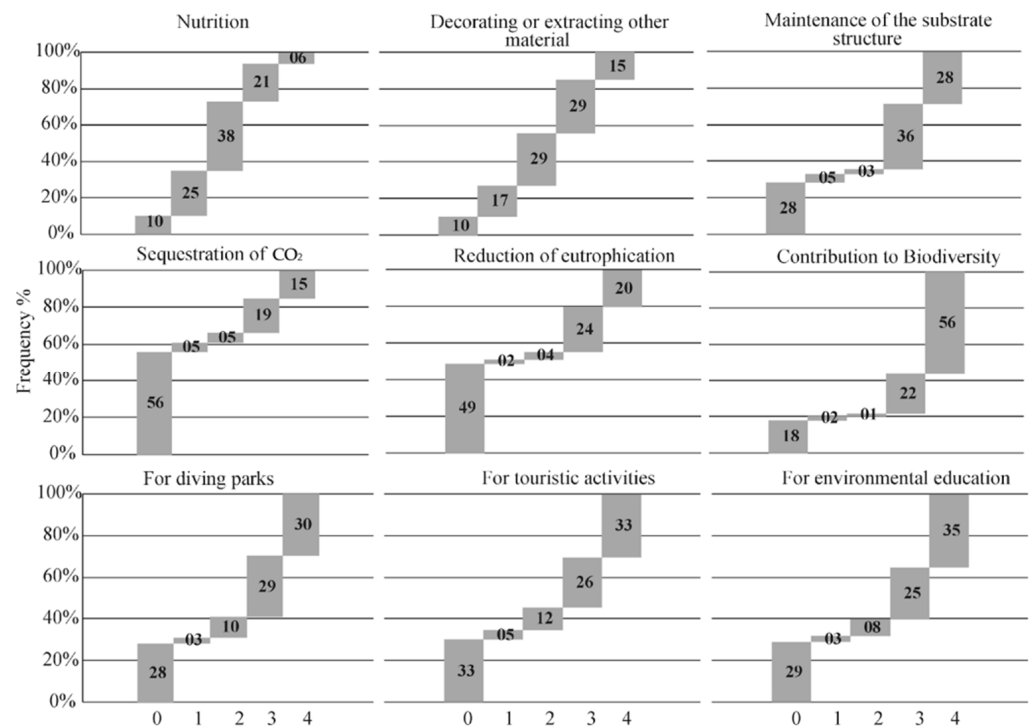


Figure 3. The frequency (% , numbers) of occurrence of the ecosystem services provided by the presence of *P. nobilis*. I do not know: 0; None: 1; Less: 2; Much: 3; Very much: 4.

3.2. Modeling Approach

The internal reliability, measured by Cronbach's alpha coefficient, for the multi-thematic question regarding contributions of fan mussel to the ecosystem exhibited that all criteria were considered in the analysis. Cronbach's alpha was high ($=0.818$), indicating, thus, a strong coherence between the statements of participants among the different topics of this question.

Optimal scaling analysis was further applied between the (dependent variable) above-mentioned question and the (independent variables) demographic features sex, age, profession, knowledge regarding fan mussel, and the opinions of the participants regarding (a) the presence or not of a decline of fan mussel during the last 5 years, (b) a decrease in the observed average size, (c) the potential complete ban of harvest, (d) the setting of a

minimum allowable catch size, and (e) a potential habitat degradation that is related to fan mussel abundance decline. The independent variables left in the final model produced a significant ($p < 0.01$) model with the largest importance for the predictability and a good value for the coefficient of determination ($R^2 = 0.356$) (Table 1). The tolerance values of the regression model were very high, indicating a lack of multicollinearity among the corresponding independent variables (Table 1). The quantitative categorical values of the independent variables and the signs of beta values exhibited that the explained initial variance of the model was 84.7%, indicating that the participants marked high scores (=much importance) to all the topics of the multi-thematic questions in relation to the independent variables left in the final model. Thus, much importance was given by those participants who (Table 1; Figure 5) (a) were well-educated persons (54.8% of the explained variance), (b) proposed a minimum allowable catch size of fan mussel (13.6% of the explained variance), and (c) considered that the degradation of the natural ecosystem might be related to the decline of the abundance of fan mussel.

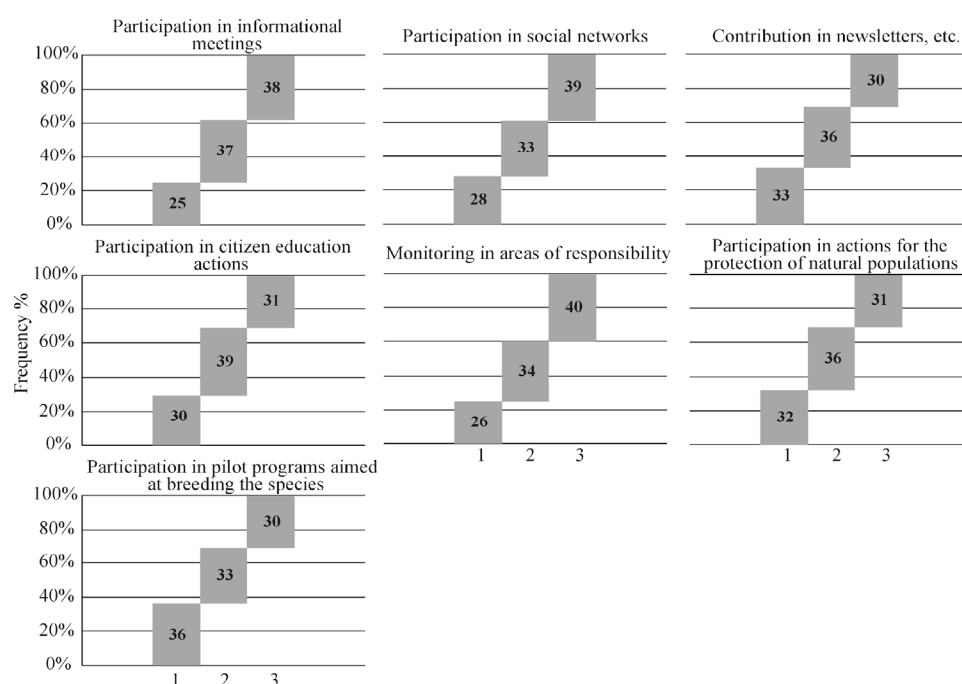


Figure 4. The frequency (% , numbers) of occurrence of issues contributing to the protection of *P. nobilis*. None: 1; Less: 2; Much: 3.

Table 1. Optimal scaling analysis model between the multi-thematic topics of the contribution of fan mussel to the ecosystem services with independent variables. Beta indicates the standardized coefficients of the regression, S.E. is the standard error, F is the ANOVA test value, Importance is the % contribution of the independent variable, and Tolerance is the collinearity tolerance.

Independent Variables	Standardized Coefficients		F Values	Importance	Tolerance
	Beta	S.E.			
Education	0.414	0.130	10.066	0.548	0.881
Set a minimum allowable catch size	0.204	0.106	3.713	0.136	0.974
Degradation of the ecosystem in relation to the decline in fan mussel abundance	0.220	0.116	3.595	0.163	0.959
R ² value	0.356		3.632		

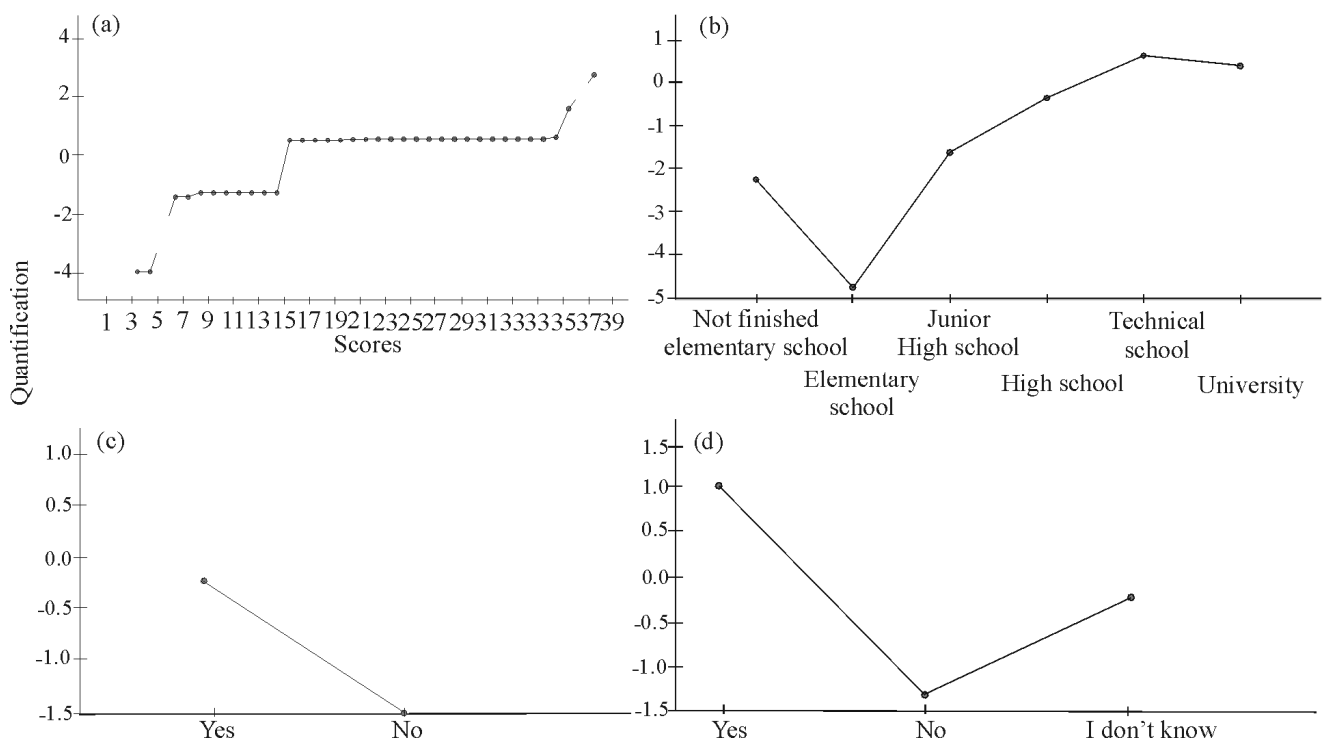


Figure 5. Categorical regression quantification plots of the question on the contribution of fan mussel *P. nobilis* to the ecosystem services in relation to the independent variables: (a) quantification plot (axis x: scores from 1, low, to 39, more intense), (b) educational level, (c) Set a minimum allowable catch size, (d) degradation of the ecosystem in relation to the decline in fan mussel abundance. The scale levels of the dependent variable are derived from the sum of the scores marked to all themes of this question (see in Appendix A).

4. Discussion

The fan mussel (*P. nobilis*) is an endangered bivalve mollusc species that is found in the Mediterranean Sea and has faced the threat of extinction in the wild since 2016, as it is severely impacted by various factors, including overfishing, habitat degradation and disease. As most Mediterranean populations have collapsed, the species has been declared as Critically Endangered in the IUCN Red List of threatened species. It is also listed in the Protocol on Biological Diversity of Special Protected Areas (Annex II) and is included in Annex IV of the Barcelona Convention (UNEP) (1996). The ecological services that the *P. nobilis* delivers to the environment have received limited attention. Synergies between different sectors including coastal fishers, mussel/oyster and fish farmers, other marine professionals, public fisheries offices, local bodies, recreational fishers and divers as well as organizers of other marine recreational activities within Greek territory will contribute to the conservation and enhancement of this endangered species.

Most of the participants consider that there is a reduction of the fan mussel especially in the years 2010–2012 and 2017–2018. This is in accordance with the appearance of the mass mortalities events in Mediterranean in the past decade and especially since 2018 where the first pathogens were detected as causal etiology in Greek coastal waters [3–6]. Environmental degradation has been associated with the decrease in the abundance of fan mussel, especially over the last 5 years, as demonstrated by the *P. nobilis* mass mortalities in relation to marine heatwaves frequency and its consequences at that time [28–30]. However, fishing (illegal, especially during the summer) and pollution have aggregated effects to the fan mussel decline due to pathogens. Illegal harvest is also well documented in earlier observations [15,16]. Trawling is the fishing gear with the highest frequency of bycatch of fan mussel. An overwhelming percentage of participants agreed with the measure of a

complete ban on fan mussel fishing to replenish stocks. Indeed *P. nobilis* is characterized as a critical endangered species in IUCN red list and its capture is illegal and prohibited [31].

More than half of shellfish farmers and divers considered that the average size of *P. nobilis* has been decreased [23], in contrast with most of the NGO workers, marine fishers, public officers, who were not aware of this issue. Most of the different professional categories of the participants considered that the pathogens are the main cause of the decline of *P. nobilis*, with the exception of fish farmers and marine fishers who perceived those fisheries and pollution, respectively were the main causes of the *P. nobilis* decline abundance. Greek mussel farming offers a range of environmental advantages, varying in scope and with varying degrees of supporting data. Nutrient treatment and improved water quality stand out among these advantages due to their high size and solid proof. Large quantities of water may be effectively filtered by mussels, which also remove nutrients like phosphate and nitrogen and reduce eutrophication. This enhances the overall quality of the water.

Marine fishers were also the only professional category which perceived in higher percentages compared with the rest categories that there is not any relation between the habitat degradation and the decline in abundance.

In contrast, most of the participants agreed, independently of the category of the profession, on the complete ban on *P. nobilis* fishing to replenish stocks and on an establishment of a minimum allowable catch of *P. nobilis* for restocking. This is an important issue that has not previously been reported in transplanting studies prior to the mass mortality events [1,32] as the need for “broodstock” in the habitat sites 0–30 m depth was of minor interest since there were high disturbance areas for the species [33,34].

However, the majority of the survey participants stated that the relevant control is not carried out, with the largest percentage of participants stating that they were not aware if this control is carried out by the competent services, fisheries, veterinary service, port authority. Multivariate analysis exhibited that high scores to ecosystem services topics were given by those who (a) have noticed a decrease in the average size of fan mussel, (b) were well-educated persons, (c) were aware about a decline in fan mussel abundance over the last 5 years, and (d) considered that the degradation of the natural ecosystem might be related to the decline in fan mussel abundance. This is in accordance with the recent finding regarding the population renewal [8,23]. Majority of participants consider it to contribute to the preservation of biodiversity, followed by the importance of environmental education and diving parks.

There is lack of interest of mussel and fish farmers to contribute to *P. nobilis* on-growing aquaculture. This can be explained through the lack of or limited knowledge regarding the potential ecosystem services provided by conservation-based aquaculture, including the biodiversity enhancement as in the present case of *P. nobilis* [35–37]. There is a demand for promoting these positive options of aquaculture that could give another more value to the business through building their sustainable and socially responsible image [38–41]. This gap could be easily covered by promoting this “new option” of “conservation” aquaculture, for restoration—rebuilding of the marine “wild” life, through its incorporation into their field activities supplementary to their core business in “production”.

5. Conclusions

The present study aimed to address the issue of pressure on the remaining populations of the endangered species of *P. nobilis*. Illegal fishing and pollution over the past decade have had detrimental effects on the decline of the fan mussel population, exacerbating the issue with pathogens. To address this concerning trend, there is a strong call for a complete ban on fan mussel harvesting as a necessary step to allow *P. nobilis*'s stocks to replenish. However, stakeholders have raised concerns about the lack of relevant control measures being implemented and voiced uncertainty regarding the oversight by competent services. In response to these challenges, marine professionals are considering various initiatives to contribute to the preservation of biodiversity. These include activities such as recording

and observing in designated areas, monitoring their responsibilities diligently, engaging in the information society, and utilizing social networks and informational meetings to enhance awareness and cooperation. Furthermore, it has been noted that the ecosystem services provided by aquaculture, particularly in the conservation of marine biodiversity like *P. nobilis*, are not effectively communicated to shell and fish farmers. To capitalize on the potential benefits of aquaculture-based conservation efforts, there is a critical need to efficiently promote the new opportunities arising from marine wildlife restoration. This entails raising awareness among stakeholders and ensuring that the benefits and importance of these initiatives are effectively conveyed to all relevant parties. By fostering better communication and cooperation among stakeholders, there is a greater likelihood of achieving successful conservation and restoration outcomes for marine biodiversity.

Author Contributions: Conceptualization, J.A.T., B.M. and D.K.M.; methodology, J.A.T., G.K. and D.K.M.; software, D.K.M.; validation, J.A.T., G.K. and D.K.M.; formal analysis, D.K.M.; investigation, O.A. and N.B.; resources, J.A.T., O.A. and N.B.; data curation, D.K.M.; writing—original draft preparation, D.K.M.; writing—review and editing, J.A.T., G.K. and B.M.; visualization, D.K.M.; supervision, J.A.T. and B.M.; project administration, J.A.T.; funding acquisition, J.A.T. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: The manuscript does not describe research on humans or animals, because this is an interview study on the marine professionals and stakeholders working in the field of marine biology and shell/fish aquaculture.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data are available upon request to the first author.

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Conflicts of Interest: Authors Orestis Anagnopoulos and Nikos Bourdaniotis were employed by the company Advanced Planning & Consulting SA. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Appendix A. Questionnaire

Questionnaire for the ecosystem services of *Pinna nobilis*.

This research is carried out for the monitoring of the endangered *Pinna nobilis*. The questionnaire is ANONYMOUS and does not contain any information that leads to the identification of the respondent. Your answers will be evaluated to serve the purpose mentioned above.

- Date of interview
- Questionnaire number

A1. Area of activity.

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A2. Purpose of your professional activity:

Scientific research	<input checked="" type="checkbox"/>
Underwater photography	<input type="checkbox"/>
Recreational fishery	<input type="checkbox"/>
Shellfish fishery	<input type="checkbox"/>
Fisheries control	<input type="checkbox"/>
Shellfish farming	<input type="checkbox"/>
Fish farming	<input type="checkbox"/>
Other activity	

A3. Are you aware of *Pinna nobilis*?

YES [1]	NO [2]
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A4. During your professional activity, how many *Pinna nobilis* have you seen;

None	1 to 3	4 to 10	More than 10
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A5. In which areas have you noticed a significant presence of *Pinna nobilis*?

A6. In your opinion, has there been a decline in *Pinna nobilis* abundance over the last 5 years? If you answered YES, from which year did you notice this decrease?

YES [1]	Year:	NO [2]	I do not know [3]
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A7. In which area have you noticed a decrease in the abundance of *Pinna nobilis*?

A8. Which of the following do you think is the main cause of the decline in *Pinna nobilis* abundance? One answer only.

Pollution	<input type="checkbox"/>
Fishery	<input type="checkbox"/>
Natural disaster	<input type="checkbox"/>
Other cause (Describe)	<input type="checkbox"/>
I do not know	<input type="checkbox"/>

A9. By what percentage do you think <i>Pinna nobilis</i> was more abundant 10, 20 and 30 years ago?			
Before 10 years: %	Before 20 years: %	Before 30 years: %	I do not know
A10. Have you observed any fishing activity for <i>Pinna nobilis</i> in the area you operate?			
YES [1] Year/s:	NO [2]	I do not know [3]	
A11. At what time of the year is the intensity of fishing activity on <i>Pinna nobilis</i> greater? One answer only.			
Spring: →	Summer:	Autumn:	Winter: I do not know:
A12. What do you think are the benefits of the presence of <i>Pinna nobilis</i> in the ecosystem?			
A13. With which fishing technique/fishing gear is there by-catch of <i>Pinna nobilis</i> ?			
A14. When the <i>Pinna nobilis</i> is caught by the side which of the following happens?;			
Release [1]	Retain [2]	I do not know [3]	
A16. Have you noticed a decrease in the average size of <i>Pinna nobilis</i> caught? If you answered YES, from which year did you notice this decrease?			
YES [1] Year:	NO [2]	I do not know [3]	
A17. Do you agree with the measure of a complete ban on <i>Pinna nobilis</i> fishing to replenish stocks?			
YES [1]	NO [2]		
A18. Do you agree with the measure to set the minimum allowable catch of <i>Pinna nobilis</i> for restocking? If YES, what minimum catch size do you recommend?			
YES [1] Size (cm):	NO [2]		
A19. State any point of view you wish to be considered in the survey:			
A20. Have you noticed a degradation of the natural ecosystem?			
YES [1]	NO [2]	I do not know [3]	
A21. Is the degradation of the natural ecosystem believed to be related to the decline in pinna abundance ?			
YES [1]	NO [2]	I do not know [3]	

A22. To what extent do you think the <i>Pinna nobilis</i> contributes to the following services?					
Ecosystem services	None	Less	Much	Very much	I do not know
Collection of the species for nutrition	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Collection of Shells for decorating or extracting other material	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Maintenance of the substrate structure	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Sequestration of CO ₂	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Reduction of eutrophication intensity	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Contribution to Biodiversity	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Contribution to the biological composition of diving parks	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Connection of the species with tourist areas	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
An important species in environmental education	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other (Describe)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

A23. Rank the following categories of agencies in relation to the initiative to highlight the need to protect *Pinna nobilis*? (from 1-not at all important to 7 very important)

Official bodies (public services)	
NGOs	
Producers— Producer organizations/Cooperatives	
Educational institutions	
Research bodies	
Civic associations/groups	
Other (Describe)	

A24. How can you contribute to the protection of <i>Pinna nobilis</i> ?			
Cases	None	Less	Much
Participation in informational meetings	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Participation in social networks	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Contribution in newsletters, etc.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Participation in citizen education actions	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Monitoring in areas of responsibility	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Participation in actions for the protection of natural populations	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Participation in pilot programs aimed at breeding the species	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other (Describe)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

A26. It is checked by the services regarding <i>Pinna nobilis</i> fishery;				
YES [1] <input type="checkbox"/>	NO [2] <input type="checkbox"/>			
If YES....				
Fishery services [1]	Rare <input type="checkbox"/>	Not very often <input type="checkbox"/>	Often <input type="checkbox"/>	I do not know <input type="checkbox"/>
Veterinary services [2]	Rare <input type="checkbox"/>	Not very often <input type="checkbox"/>	Often <input type="checkbox"/>	I do not know <input type="checkbox"/>
Coast guard [3]	Rare <input type="checkbox"/>	Not very often <input type="checkbox"/>	Often <input type="checkbox"/>	I do not know <input type="checkbox"/>

B. DEMOGRAPHIC CHARACTERISTICS

B1. Sex: Male [1] <input type="checkbox"/>	Female [2] <input type="checkbox"/>	Other [3] <input type="checkbox"/>
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B2-3. Age:

Unmarried [1] <input type="checkbox"/>	Married [2] <input type="checkbox"/>	Divorced/Seperated/Widowed [3] <input type="checkbox"/>
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B4. Education:

I have not finihsed elementary school [1] <input type="checkbox"/>	High School Diploma [4] <input type="checkbox"/>
Elementary Diploma [2] <input type="checkbox"/>	Technical School [5] <input type="checkbox"/>
Junior High School Diploma [3] <input type="checkbox"/>	University [6] <input type="checkbox"/>

B5. Profession:

References

1. Katsanevakis, S. Transplantation as a conservation action to protect the Mediterranean fan mussel *Pinna nobilis*. *Mar. Ecol. Progr. Ser.* **2016**, *546*, 113–122. [[CrossRef](#)]
2. Coupé, S.; Giantsis, I.A.; Vázquez Luis, M.; Scarpa, F.; Foulquié, M.; Prévot, J.M.; Casu, M.; Lattos, A.; Michaelidis, B.; Sanna, D.; et al. The characterization of toll-like receptor repertoire in *Pinna nobilis* after mass mortality events suggests adaptive introgression. *Ecol. Evol.* **2023**, *13*, e10383. [[CrossRef](#)] [[PubMed](#)]
3. Carella, F.; Palić, D.; Šarić, T.; Župan, I.; Gorgoglione, B.; Prado, P.; Andree, K.B.; Giantsis, I.A.; Michaelidis, B.; Lattos, A.; et al. Multipathogen infections and multifactorial pathogenesis involved in noble pen shell (*Pinna nobilis*) mass mortality events: Background and current pathologic approaches. *Vet. Pathol.* **2023**, *60*, 560–577. [[CrossRef](#)]

4. Lattos, A.; Feidantsis, K.; Giantsis, I.A.; Theodorou, J.A.; Michaelidis, B. Seasonality in Synergism with Multi-Pathogen Presence Leads to Mass Mortalities of the Highly Endangered *Pinna nobilis* in Greek Coastlines: A Pathophysiological Approach. *Microorganisms* **2023**, *11*, 1117. [CrossRef]
5. Lattos, A.; Feidantsis, K.; Georgoulis, I.; Giantsis, I.A.; Karagiannis, D.; Theodorou, J.A.; Staikou, A.; Michaelidis, B. Pathophysiological Responses of *Pinna nobilis* Individuals Enlightens the Etiology of Mass Mortality Situation in the Mediterranean Populations. *Cells* **2021**, *10*, 2838. [CrossRef]
6. Lattos, A.; Bitchava, K.; Giantsis, I.A.; Theodorou, J.A.; Batargias, C.; Michaelidis, B. The Implication of *Vibrio* Bacteria in the Winter Mortalities of the Critically Endangered *Pinna nobilis*. *Microorganisms* **2021**, *9*, 922. [CrossRef]
7. Čižmek, H.; Čolić, B.; Gračan, R.; Grau, A.; Catanese, G. An emergency for pen shells in the Mediterranean: The Adriatic Sea, one of the last *Pinna nobilis* shelters, is now affected by a mass mortality event. *J. Invertebr. Pathol.* **2020**, *173*, 107388. [CrossRef]
8. Papadakis, P.; Mamoutos, I.; Ramfos, A.; Catanese, G.; Papadimitriou, E.; Theodorou, J.A.; Batargias, C.; Papaioannou, C.; Kamilari, M.; Tragou, E.; et al. Status, distribution, and threats of the last surviving fan mussel populations in Greece. *Mediterr. Mar. Sci.* **2023**, *24*, 679–708. [CrossRef]
9. Tsotsios, D.; Papadopoulos, D.K.; Alvanou, M.V.; Georgoulis, I.; Lattos, A.; Michaelidis, B.; Feidantsis, K.; Giantsis, I.A.; Theodorou, J.A. Environmentally Friendly and Efficient Methods for Mitigating the Density of Ascidian Fouling in Mediterranean Mussel Farming. *Fishes* **2024**, *9*, 135. [CrossRef]
10. Papadopoulos, D.K.; Lattos, A.; Giantsis, I.A.; Theodorou, J.A.; Michaelidis, B.; Feidantsis, K. The impact of ascidian biofouling on the farmed Mediterranean mussel *Mytilus galloprovincialis* physiology and welfare, revealed by stress biomarkers. *Biofouling* **2023**, *39*, 271–288. [CrossRef]
11. Tsotsios, D.; Moutopoulos, D.K.; Lattos, A.; Michaelidis, B.; Theodorou, J.A. Impacts of the Establishment of Biofoulants on Greek Aquaculture: Farmers' Expert Knowledge. *J. Mar. Sci. Eng.* **2023**, *11*, 1077. [CrossRef]
12. Theodorou, J.A.; James, R.; Tzovenis, I.; Hellio, C. The recruitment of the endangered fan mussel (*Pinna nobilis*, Linnaeus 1758) on the ropes of a Mediterranean mussel long line farm. *J. Shell. Res.* **2015**, *34*, 409–414. [CrossRef]
13. Trigos, S.; García-March, J.; Vicente, N.; Tena, J.; Torres, J. Utilization of muddy detritus as organic matter source by the fan mussel *Pinna nobilis*. *Mediterr. Mar. Sci.* **2014**, *15*, 667–674. [CrossRef]
14. Alleway, H.K.; Waters, T.J.; Brummett, R.; Cai, J.; Cao, L.; Cayten, M.R.; Costa-Pierce, B.A.; Dong, Y.-W.; Brandstrup Hansen, S.C.; Liu, S.; et al. Global principles for restorative aquaculture to foster aquaculture practices that benefit the environment. *Conserv. Sci. Pract.* **2023**, *5*, e12982. [CrossRef]
15. Katsanevakis, S.; Poursanidis, D.; Issaris, Y.; Panou, A.; Petza, D.; Vassilopoulou, V.; Chalداiou, I.; Sini, M. Protected marine shelled molluscs: Thriving in Greek seafood restaurants. *Mediterr. Mar. Sci.* **2011**, *12*, 429–438. [CrossRef]
16. Theodorou, J.A.; Akrivos, V.; Katselis, G.; Moutopoulos, D.K. Use of Local Ecological Knowledge on the Natural Recruitment of Bivalve Species of Commercial Exploitation in a Natura Area. *J. Mar. Sci. Eng.* **2022**, *10*, 125. [CrossRef]
17. Pauly, D.; Christensen, V.; Walters, C. Ecopath, Ecosim, and Ecospace as tools for evaluating ecosystem impact of fisheries. *ICES J. Mar. Sci.* **2000**, *57*, 697–706. [CrossRef]
18. Libralato, S.; Coll, M.; Tudela, S.; Palomera, I.; Pranovi, F. Novel index for quantification of ecosystem effects of fishing as removal of secondary production. *Mar. Ecol. Prog. Ser.* **2008**, *355*, 107–129. [CrossRef]
19. Heymans, J.J.; Coll, M.; Libralato, S.; Morissette, L.; Christensen, V. Global Patterns in Ecological Indicators of Marine Food Webs: A Modelling Approach. *PLoS ONE* **2014**, *9*, e95845. [CrossRef]
20. Council Regulation (EC) No 1005/2008 of 29 September 2008 Establishing a Community System to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing, Amending Regulations (EEC) No 2847/93, (EC) No 1936/2001 and (EC) No 601/2004 and repealing Regulations (EC) No 1093/94 and (EC) No 1447/1999. Available online: <https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex:32008R1005> (accessed on 25 April 2024).
21. Rullens, V.; Lohrer, A.M.; Townsend, M.; Pilditch, C.A. Ecological Mechanisms Underpinning Ecosystem Service Bundles in Marine Environments—A Case Study for Shellfish. *Front. Mar. Sci.* **2019**, *6*, 409. [CrossRef]
22. Theodorou, J.A.; Tzovenis, I.; Katselis, G. Empirical approach to risk management strategies of Mediterranean mussel farmers in Greece. *Oceanol. Hydrobiol. Stud.* **2021**, *50*, 455–472. [CrossRef]
23. Nebot-Colomer, E.; Hernandis, S.; Mourre, B.; Fraile-Nuez, E.; Álvarez, E.; Deudero, S.; Albentosa Maite Vázquez-Luis, M. No recruits for an ageing population: First signs of probable population extinction in one of the last reservoirs of the Critically Endangered species *Pinna nobilis*. *J. Nat. Conserv.* **2024**, *79*, 126600. [CrossRef]
24. Zar, J.H. *Biostatistical Analysis*, 5th ed.; Prentice-Hall/Pearson: Upper Saddle River, NJ, USA, 2010; p. 944.
25. Cronbach, L.J. Coefficient alpha and the internal structure of tests. *Psychometrika* **1951**, *16*, 297–334. Available online: <https://link.springer.com/article/10.1007/BF02310555> (accessed on 1 April 2024).
26. Batzios, C.; Moutopoulos, D.K.; Arampatzis, G.; Siardos, G. Understanding Consumer's Attitude on Fish Quality and Marketing Aspects in the Greek Market. *Agric. Econ. Rev.* **2005**, *6*, 18–30.
27. SPSS. SPSS BASE 27.0.1.0. In *Applications Guide*; SPSS Inc.: Chicago, IL, USA, 2020.
28. Lattos, A.; Papadopoulos, D.K.; Feidantsis, K.; Karagiannis, D.; Giantsis, I.A.; Michaelidis, B. Are Marine Heatwaves Responsible for Mortalities of Farmed *Mytilus galloprovincialis*? A Pathophysiological Analysis of *Marteilia* Infected Mussels from Thermaikos Gulf, Greece. *Animals* **2022**, *12*, 2805. [CrossRef]

29. Theodorou, J.A.; Leech, B.S.; Perdikaris, C.; Hellio, C.; Katselis, G. Performance of the cultured Mediterranean mussel *Mytilus galloprovincialis* Lamark, 1819 after summer post-harvest re-immersion. *Turk. J. Fish. Aquat. Sci.* **2019**, *19*, 221–229. [[CrossRef](#)] [[PubMed](#)]
30. Rodrigues, L.C.; van den Bergh, J.C.J.M.; Massa, F.; Theodorou, J.A.; Ziveri, P.; Gazeau, F. Sensitivity of Mediterranean Bivalve Mollusc Aquaculture to Climate Change and Ocean Acidification: Results from a producers' survey. *J. Shellfish Res.* **2015**, *34*, 1161–1176. [[CrossRef](#)]
31. Kersting, D.; Benabdi, M.; Čižmek, H.; Grau, A.; Jimenez, C.; Katsanevakis, S.; Öztürk, B.; Tuncer, S.; Tunesi, L.; Vázquez-Luis, M.; et al. *Pinna nobilis*. In *The IUCN Red List of Threatened Species*; IUCN: Gland, Switzerland, 2019.
32. Tsamadias, I.E.; Rizou, D.D.; Moutopoulos, D.K.; Lattos, A.; Giantsis, I.A.; Michaelidis, B.; Theodorou, J.A. Morphometric Analysis of the Critically Endangered Fan Mussel (*Pinna nobilis* L.) in Maliakos Gulf (Central Aegean). *Diversity* **2023**, *15*, 948. [[CrossRef](#)]
33. Acarli, S. Population, aquaculture and transplantation applications of critically endangered species *Pinna nobilis* (Linnaeus 1758) in the Mediterranean Sea. *Mar. Sci. Technol. Bull.* **2021**, *10*, 350–369. [[CrossRef](#)]
34. Bottari, T.; Spinelli, A.; Busalacchi, B.; Rinelli, P.; Giacobbe, S. Transplant Trials of the Fan Mussel *Pinna nobilis* Inside the Coastal Lagoon of Capo Peloro (Central Mediterranean, Italy). *J. Shellfish Res.* **2017**, *36*, 3–8. [[CrossRef](#)]
35. Alleway, H.K.; Gillies, C.L.; Bishop, M.J.; Gentry, R.R.; Theuerkauf, S.J.; Jones, R. The Ecosystem Services of Marine Aquaculture: Valuing Benefits to People and Nature. *BioScience* **2019**, *69*, 59–68. [[CrossRef](#)]
36. Gentry, R.R.; Alleway, H.K.; Bishop, M.J.; Gillies, C.L.; Waters, T.; Jones, R. Exploring the potential for marine aquaculture to contribute to ecosystem services. *Rev. Aquac.* **2020**, *12*, 499–512. [[CrossRef](#)]
37. Froehlich, H.E.; Gentry, R.R.; Halpern, B.S. Conservation aquaculture: Shifting the narrative and paradigm of aquaculture's role in resource management. *Biol. Conserv.* **2017**, *215*, 162–168. [[CrossRef](#)]
38. Gkikas, D.C.; Gkikas, M.C.; Theodorou, J.A. A Comprehensive Marketing and Diffusion Strategy Protocol for Marine Life Protection, Restoration and Conservation, the Case of Endangered *Pinna nobilis*. In *Strategic Innovative Marketing and Tourism*; Springer Nature: Cham, Switzerland, 2024; pp. 641–649. [[CrossRef](#)]
39. Lacoste, É.; McKindsey, C.W.; Archambault, P. Biodiversity–Ecosystem Functioning (BEF) approach to further understanding aquaculture–environment interactions with application to bivalve culture and benthic ecosystems. *Rev. Aquac.* **2020**, *12*, 2027–2041. [[CrossRef](#)]
40. Overton, K.; Dempster, T.; Swearer, S.E.; Morris, R.L.; Barrett, L.T. Achieving conservation and restoration outcomes through ecologically beneficial aquaculture. *Conserv. Biol.* **2024**, *38*, e14065. [[CrossRef](#)]
41. Mizuta, D.D.; Froehlich, H.E.; Wilson, J.R. The changing role and definitions of aquaculture for environmental purposes. *Rev. Aquac.* **2023**, *15*, 130–141. [[CrossRef](#)]

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