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An Economic View on the Effects of Invasive Rabbitfishes Based on Fishers' Perspectives: The Case of the Parrotfish Métier in the South Ionian Sea

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Abstract: The effect of thermophilic species invasion in the eastern Mediterranean is well-noted in the literature. During the last decade in western Greek waters, small-scale fisheries (SSF) catches exhibit increased relative contribution of rabbitfishes, which have originated from the Red Sea and inhabited the country's southeastern part since the Second World War. This study has used quantitative and qualitative information to assess the short-term economic effect of the rabbitfishes' expansion in the SSF métier targeting the indigenous thermophilic parrotfish in the South Ionian Sea. The short-term micro-level negative economic effects of the rabbitfishes' invasion and the corresponding adverse effects on fishers' economic wealth have been estimated. The results indicate attitudinal differences among fishers, although their local ecological knowledge may enable them to avoid rabbitfishes' hot spots and mitigate the respective economic losses, that particularly for smaller SSF vessels already seem to be quite important. As climate warming may further facilitate the expansion of rabbitfishes, outcompeting parrotfish, the latter métier may eventually become economically unsustainable. Fine-scale analysis at the métier level enables addressing the specificities of social-ecological systems and can contribute to informed and more effective decision making related to SSF, which is an important building block of Mediterranean coastal communities.

Keywords: climate change; thermophilic species; rabbitfishes; parrotfish; fishers' income; fishing cost; fisher behavior; métier-level analysis; Ionian Sea

Key Contribution: Even though the negative economic consequences of thermophilic alien invaders have been well-noted in the relevant literature, there is no quantification of those effects on the short-term micro-level in the Mediterranean SSF sector. This study reveals the importance of conducting fine-scale analysis at the métier level that provides a more realistic assessment of the effects of climate change on SSF catches. Based on a South Ionian Sea case study that aims to evaluate the economic impacts of the highly invasive rabbitfishes on the parrotfish métier, our outcomes indicate the behavioral differences among fishers operating this métier, shedding light on features affecting métier sustainability that should be considered in order to provide improved advice for effective SSF management aiming towards coastal communities resilience.

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1. Introduction

Rising seawater temperatures affect all marine organisms' living conditions and spatial allocation [1]. In the Mediterranean, which has experienced a critical temperature rise attributed to climate change during the last couple of decades, [2], many species of Red Sea origin have entered through the Suez Canal and are currently established in several locations in the eastern part of the region [3]. In the latter area, bioinvasions result in considerable ecosystem regime shifts and multi-species collapses [2,4,5].

The speed of invasion through the Suez Canal and the range of Lessepsian invasive species have followed an increasing trend lately [6]. The Suez Canal, built in 1869, has been expanded by widening and deepening the old canal to increase its traffic capacity [7] and by introducing the 'New Suez Canal' in 2016 [5]. Although the expansion of the Suez Canal may further facilitate the introduction of alien species, the successful invasion of aliens also seems to be related to other important factors, such as climate change and the alien species' dominance over native ones [8–10], certain of which may potentially constitute fishery targets [11,12]. It is indicative that the number of species introduced into the Mediterranean Sea significantly exceeds numbers in other European seas [13], with most of them (about 70%) having established permanent populations [14]. As the number of published records shows a dramatic increase with time, researchers have highlighted the urgent need for immediate proactive management actions and scientifically informed control measures [15], specifically by tackling ecosystem sustainability issues that are further complicated due to bioinvasions [16–21].

The tendency of Red Sea fish species to prefer shallow coastal habitats in the Mediterranean [18] suggests that small-scale fisheries (SSF) is the fishery sector mainly impacted by bioinvasions. The Mediterranean SSF, which comprises more than 80% of the fishing fleet, using multi-gears for targeting multi-species with SSF catches showing a marked seasonality (i.e., different métiers prevail during different times of the year), has already been affected by bioinvasions particularly in the southeastern part of the region; following the prevailing scenarios of climate change, SSF of the whole Mediterranean basin are considered highly vulnerable to shifts in resource abundance and availability [22]. The latter is particularly important for the Greek SSF as they constitute the vast majority of the country's fisheries and support the livelihoods of coastal fishery communities and mainly those on remote islands [23,24].

Despite this fact, there is a remarkable shortage of socioeconomic cost estimation throughout the literature (not only for Mediterranean SSF) regarding invasive species and a lack of understanding of those costs [8] at the local scale, specific species, and fishing métiers. While the socioeconomic effects of invasive species are mentioned in several studies in the relevant literature (see for example [5,8,17,25–29]), the direct (e.g., gear damages, injuries, reduced catch) and indirect (e.g., ecosystem degradation, competition for food and space) adverse economic effects of the various marine invaders, including the rabbitfishes, have not yet been quantified [8]. However, the above constitute necessary inputs to design effective policy measures and management interventions at the appropriate spatial scale.

In Greece nowadays, particularly in the southern part of Greek waters, certain Lessepsian migrants constitute a non-negligible part of the coastal fishery catches [30]. Among them, the rabbitfishes, *Siganus luridus* and *S. rivulatus,* were the first ones to appear in the Dodecanese islands (southeastern Greek waters) during the Second World War, and they have been established there ever since (see also [31–33]). The two rabbitfishes have quite similar densities and responses to environmental factors in Greek waters [32,34]. Solanou et al. [35] mention that apart from their geographical expansion, the two rabbitfishes have also rapidly increased their abundance, highlighting that their density in SSF catches from the area of Kas in southwestern Turkey, has risen to 90% [36], comparing it to that reported in a 10-year-old article in the nearby area of Rhodes, where the average density was about 13% of the catch at the time [32].

It is noteworthy that the two rabbitfishes are included in the blacklist of marine invasive species produced by Otero et al. [37] and are considered a priority species for the UNEP MAP and GFCM joint study in the eastern Mediterranean [38] and for sustainable management concern under ecosystem-based approach concepts [39]. Indeed, rabbitfishes compete with other native herbivores (such as parrotfishes) for common feeding grounds, and they seem to control algae habitats, degrading them to barrens [16,40]. What is more, the increase of the two herbivorous rabbitfishes and their potential impact on seagrass meadows, a priority conservation and essential fish habitat linked mainly to the early life history stages of numerous commercial species in Mediterranean waters, as well as having an important blue carbon potential and contributing thus to the mitigation of climate change effects, has been underlined in recent studies [41].

In general, most Greek fishery sector stakeholders' perception of the two rabbitfishes is highly negative [36], aligning with the above studies and reports. However, it should be noted that there are also studies reporting positive stakeholders' perceptions regarding rabbitfishes, such as Kleitou et al. [42]. According to the latter study, various fishery sector stakeholders in Cyprus consider rabbitfishes beneficial because of their commercial value in local markets. Similar evidence is provided from the southeastern Aegean Sea and, in particular the Dodecanese Islands in Greece, where consumers are familiar with rabbitfishes, which have constituted a commodity for half a century [43]. In fact, a recent study has shown that Greek consumers have a positive attitude towards the consumption of alien species as long as they are fresh, tasty and safe to eat [21]. Building a well-established market for edible invasive alien species needs targeted, well-organized efforts, including increasing consumer awareness (e.g., the project "Pick the alien"; see https://isea.com.gr/pick-the-alien-eng/?lang=en (accessed on 5 August 2023)). In any case, it should be highlighted that efforts related to controlling invasives through human consumption should thoroughly examine the potential production of opposite results than those expected [44]. For example, Nunez et al. [45] mention that a market for invasive species could encourage local communities to protect those harmful species, and Meadows and Sims [46] emphasize that the invasive species' potential dual role (as both a pest and a commodity) may alter incentives to eradicate or exacerbate an invasion.

Given the expansion trend of invasive thermophilic species from the eastern to the western Mediterranean [47], the spatial expansion of thermophilic species at the westernmost area of Greek waters (i.e., the Ionian Sea) seems inevitable. Rabbitfishes are already found in the Ionian Sea (see Figure 1), and there are significant indications, particularly through fishers' Local Ecological Knowledge (LEK), that they are mainly located over rocky substrates inhabited by macroalgae, such as *Cystoseira* spp. and *Posidonia oceanica* in depths shallower than 20m. Unlike the southeastern Aegean, where, as already mentioned above, there are local markets for rabbitfishes [42], in the case of the Ionian Sea, rabbitfishes are totally discarded, as consumers are still not familiar with them and hence there is not an established market [29,48]. In addition, based on feedback from fishers, rabbitfishes are a clearly unwanted bycatch in the Ionian Sea due to their time-consuming disentanglement from fishing nets.

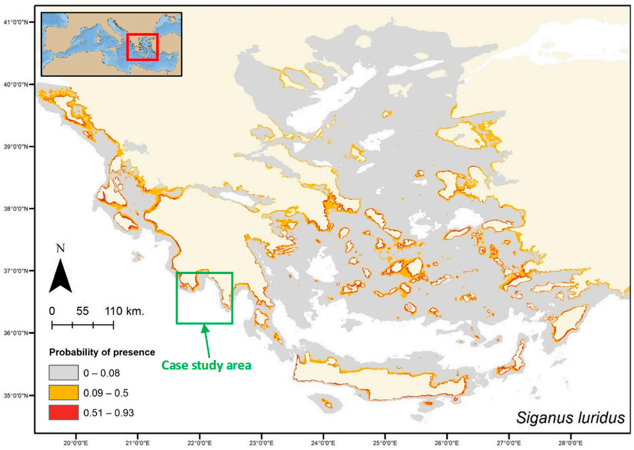

Figure 1. The case study area (green box) in the south Ionian Sea indicated on a map that visualizes the probability of occurrence of the rabbitfish *S. luridus* in Greek waters (reproduced based on Solanou et al. [35]).

Aside from thermophilic alien species, native ones, such as the Mediterranean parrotfish (*Sparisoma cretense*), a species of important commercial value in Greece, have also expanded their distribution reaching the South Ionian Sea. At the same time, they have also appeared in the even more northwestern waters of the Adriatic and the Tyrrhenian Seas [49]. The Mediterranean parrotfish feed primarily upon coralline algae but may also consume epiphytic algae (growing on seagrass) and small invertebrates [50]. Due to this fact, this species competes to large extent with rabbitfishes for food resources and habitat [51].

This study aims to analyze the economic consequences of rabbitfishes expansion in the South Ionian Sea on the métier for parrotfish; the latter is operated using trammel nets and has been mainly established in the last decade, also following the distributional expansion of parrotfish to the west, being another effect of climate change. By focusing on the local context and a specific métier, the study aspires to provide a starting point for addressing the existing quantitative gap in assessments related to impacts of non-native fishes on specific SSF métiers. In addition, the fact that economic consequences are provided at the micro-level shed light on socio-economic aspects related to fishers' real-life experience. By doing so, the analysis can provide additional insights into how proper management regarding alien invasive species can be designed based on the cost parameters implicated in catches of the different invasive species. Finally, outcomes from interviews with local fishers have revealed behavioral aspects related to their attitudes and perceptions towards selecting fishing grounds for catching or avoiding rabbitfishes while operating the parrotfish métier, conveying that individual decisions are governed by each fisher's goals and/or constraints.

2. Materials and Methods

To gather information regarding the economic effects of rabbitfishes invasion on the parrotfish métier in the South Ionian Sea, two sources of data have been used. The first refers to secondary data, including quantitative information regarding catches and their composition at the métier under study, gathered during monitoring activities by observers onboard commercial vessels and conducted under the Greek Data Collection Framework (DCF) program. As there were fragmentations in this dataset, mainly due to interruptions in the implementation of the Greek National DCF program, the data used referred to two time periods with adequate information: 2014–2016 and 2019–2021. Data were extracted using the IMAS-fish project tools [52] and included an overall sample of 93 hauls of the parrotfish métier in the South Ionian Sea, conducted by five vessels (four belonging to the size category 6–12m, and one being smaller than 6m), providing information regarding catches, landings, the surface of the seabed, bottom depth, period of the year (in quarters), vessel length category (0–6m or 6–12m) and vessel port [52].

To further explore the socioeconomic effects of alien species invasion in the area under study, field research has been carried out, including fifteen face-to-face interviews with fishers using semi-structured questionnaires and three open interviews with local stakeholders (local administration representatives and Fisheries Local Action Groups (FLAG) representatives). During face-to-face interviews, the fishers were also asked to indicate hot and cold spots of rabbitfish spatial distribution.

Overall, the main information provided by the fishers included the following:

- Their perception regarding the parrotfish population, spatial distribution, and its evolution during the last decade;
- The main problems arising from the presence of rabbitfishes in the fishing grounds they used to fish, and their main impacts (e.g., degradation of fishing grounds, interaction with of commercial species);
- If/how they adapt their fishing habits based on the presence of rabbitfishes;
- How much additional workload is needed to disentangle rabbitfish from the nets, based on different catch shares (10%, 25%, 50%, 75%, or 100%);
- Identification of hot and cold spots of rabbitfishes using area maps;
- Fuel costs related to the parrotfish métier and whether they increase in case they try to avoid the rabbitfishes' areas of distribution;
- Average wages in the area (hourly rate);
- Prices of parrotfish and other commercial species identified by the fishers operating the parrotfish métier considering also potential prices for rabbitfishes in local markets.

Regarding the open interviews with other stakeholders, their main feedback referred to potential market opportunities for rabbitfishes and potential ways to overcome problems arising from their expansion.

The parrotfish métier in the area under study (see Figure 1) operates using trammel nets, with rabbitfishes being an important discarded bycatch. It is a summer-intensive métier, as the June to September catches get the lion's share of the total catch (Figure 2). The métier in the South Ionian Sea is operated by SSF vessels, mainly utilizing trammel nets of mesh size 34mm in shallow waters with sea beds covered by epilithic and coralline algae. Apart from parrotfish catches, the métier has a mix of other fish species catches with various commercial values, such as the grey mullet (*Mugil cephalus*), the common cuttlefish (*Sepia officinalis*), and the dreamfish (*Sarpa salpa*).

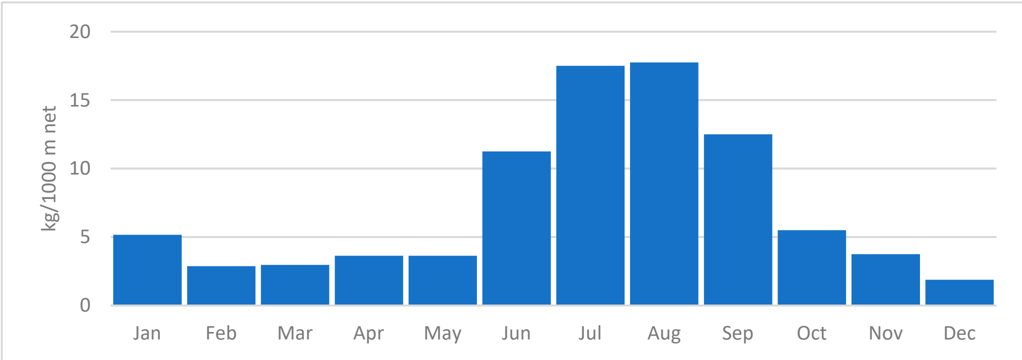

Figure 2. Average monthly catch distribution of parrotfish per vessel during the period 2014–2021 (Source: authors' processing of data collected under the Greek Data Collection Framework (DCF) program).

The rationale behind modeling and estimating the short-term economic cost from the fishers' (micro-level) perspective is that the rabbitfishes' invasion is a driver for economic losses for the parrotfish métier for a number of reasons. Firstly, in line with other studies in the field (e.g., [14,36,53]), the expansion and establishment of rabbitfishes have a direct negative impact on the catch and value of landings of the main targeted commercial species (per unit of effort). The information provided by the field research (i.e., the interviews with the fishers and the mapping exercise) is used to approach sources of additional cost. To accommodate the results regarding the share of parrotfish and rabbitfishes and their evolution between the two periods under consideration, the Probability Density Functions (PDF) (using Simetar^{TM} [54]) and the Kolmogorov–Smirnov (KS) tests have been applied. The KS test is a non-parametric test of the equality of continuous probability distributions that quantifies the distance between the empirical distribution functions of two samples, assuming under the null hypothesis (H_0) that the samples are drawn from a population with the same distribution [55].

Another critical cost source is related to the additional labor needed due to the presence of rabbitfishes in the catch. Indeed, catching rabbitfishes drastically affects the time needed to clean the net. Following the field research, special attention is needed to avoid their thorns, and according to the fishers interviewed, this time is directly related to the share of those species in the catch. Based on the fact that disentanglement time appeared to be equiproportional to the share of rabbitfishes in the catch, the relationship between the share of rabbitfishes in the catch and the additional labor cost $\Delta(l\_c)$ has been described as follows:

$$\Delta(l\_c) = AHN \times WR \times ShR \quad (1)$$

where $\Delta(l\_c)$: Additional labor cost

AHN: Additional hours needed

WR: Hourly wage rate

ShR: Share of rabbitfish in the catch.

The economic losses can then be calculated based on the following equation:

$$\text{Econ\_Losses} = \Delta(p\_v) + \Delta(o\_v) + \Delta(e\_c) + \Delta(L\_c) \quad (2)$$

where

$\Delta(p\_v)$ and $\Delta(o\_v)$ are the decreased landing values (landing weight multiplied by price) of parrotfish and other commercial species' catch, respectively.

$\Delta(e\_c)$ is the increased energy cost caused by the increased fuel consumption stemming from the fact that some fishers are more selective about fishing grounds to avoid rabbitfishes. This cost will increase further as the rabbitfishes' population continues to grow.

Equation (2) implicitly assumes that the remaining types of cost categories, i.e., fixed costs, the other variable costs, the capital costs, and the interest costs (see STECF [56]), remain unaffected by the rabbitfishes' invasion in the métier. This seems to be a rational assumption, as none of those categories are, at least directly, affected by the rabbitfishes. At this point, it should be mentioned that in cases where other invasive alien species, such as *Lagocephalus spp.*, are also included in fish catches, there may be additional costs stemming from greater damage to the nets; however, this was not the case in the present study.

Finally, the assumption that the market value of rabbitfishes is negligible in the south Ionian coastal areas and will continue to be so in the near future has been adopted. Even though there are ongoing campaigns in Greece to raise awareness of alien invasions, familiarizing people with those species in order to promote their consumption, currently there is no market for rabbitfishes in the area under study and, on the basis of our interactions with local stakeholder, its establishment seems to be highly improbable in the near future.

To assess how the level of economic losses affects the wealth of the fishers of this métier, the study estimates the economic effects of the rabbitfishes' invasion on the Fishing Family Income (FFI). The FFI index can be considered the most representative index of the wealth of a family engaged in fishing and represents the reward of the production factors that belong to the family [57]. Differently defined, it is the total amount of money a family can spend without compromising the operation of the family fishing enterprise [58]. Similar family wealth indices have been widely used in agriculture studies (e.g., [59–62]) and recently they are also used in fisheries (see [57,58]). Although other financial indices are commonly applied to evaluate a firm's economic performance, they make less sense in the primary sector as, unlike FFI, they do not consider the unique characteristics of small-scale enterprises, such as the family contribution to labor and family ownership.

The FFI is estimated as follows:

$$\text{Fishing Family Income (FFI)} = \text{Net profit} + \text{value of unpaid labor} + \text{opportunity cost of family-owned capital} \quad (3)$$

and its change, Δ(FFI), can be directly estimated as:

$$\Delta(\text{FFI}) = \text{FFI} - \text{Econ\_losses} \quad (4)$$

Finally, a sensitivity analysis has been applied to account for the inherited uncertainty of the short-term future density levels of parrotfish in the catches. The share of parrotfish in the short-term future scenario is based on the relative change in parrotfish numbers during the two periods under consideration (2014–2016 and 2019–2021). Then, the optimistic and pessimistic scenarios include a $\pm 10\%$ relative difference in the projected share in the catch. Through the same procedure the other species' share and the share of rabbitfishes have been assessed respectively.

3. Results

Table 1 provides descriptive statistics of the hauls conducted by five vessels operating the parrotfish métier (93 hauls in total). The catch of each haul of the parrotfish métier has been divided into three parts: "the parrotfish catch", the "rabbitfishes catch", and "the catch of other commercial species". Rabbitfishes are a bycatch of this specific métier and they are subsequently discarded. According to Table 1, there are important differences between the two periods considered. The share of rabbitfishes weights almost tripled in the second period, mainly due to the expansion of *S. rivulatus*. At the same time, the share of parrotfish has decreased by seven percentage units while the total catch has also decreased (by about five percentage units).

Table 1. Descriptive statistics from an average haul of the "Parrotfish métier" utilizing trammel nets in the sample during 2014–2016 and 2019–2021(all parameters have been standardized to 1000 m net).

	Parrotfish	**Rabbitfish**	***Siganus luridus***	***Siganus rivulatus***	**Other Commercial Species**	**Total**
			2019–2021			
Catch (gr)	1528	969	438	531	3125	5622
Catch share (%)	27	17	8	9	56	
Share of hauls (%) that include the species *	87	14	10	10	100	
			2014–2016			
Catch (gr)	2078	324	273	51	3503	5937
Catch share (%)	35	6	5	1	59	
Share of hauls (%) that include the species *	88	44	42	9	100	

* (No. of hauls including the species)/(total no. of hauls) (%). Source: authors' processing of data collected under the Greek DCF program.

Table 1 also reveals that the cases in which rabbitfishes appear in the catch are fewer in 2019–2021 compared to 2014–2016 (14% and 44%, respectively). On the other hand, there are cases of zero catches of parrotfish (about 12% of hauls in both periods) but a significant share of rabbitfishes, although fishers have declared beforehand to observers recording their operations that parrotfish was the target species of their specific trips. The latter was also confirmed during the interviews, when all fishers have agreed that, even when trying to avoid rabbitfishes while targeting parrotfish, there is always the possibility of a school of those species being trapped in their nets, increasing thus the share of rabbitfishes in the total catch. Overall, the data have revealed a clear and statistically significant negative relationship between the share of rabbitfishes and parrotfish in the catches as indicated by the value of the Spearman rank correlation coefficient that equals -0.3276 (p-value = 0.0016).

Data on the catches per haul have fed into two empirical distributions (one for each period: 2014–2016 and 2019–2021) for the share of rabbitfishes, shedding more light on the share of catches in each haul (Figure 3). The Probability Density Function (PDF) for 2014–2016 indicates a more considerable variation in the percentage share of rabbitfishes in the catch. In 2019–2021, the relative PDF curve was more concentrated (it did not exceed 60%), while there are much higher probabilities for zero or a meager share of rabbitfish catches. Therefore, even if the LEK of fishers may have increased, totally avoiding rabbitfishes still remained very difficult. Interestingly, the PDF curve is multimodal; besides the peak of the distribution in the 0% share of rabbitfishes, there are also two smaller peaks, around 8% and 25%, indicating that there are fishers who cannot avoid hauls where parrotfish and rabbitfishes coexisted in the catch although they may have been aware of their potential coexistence.

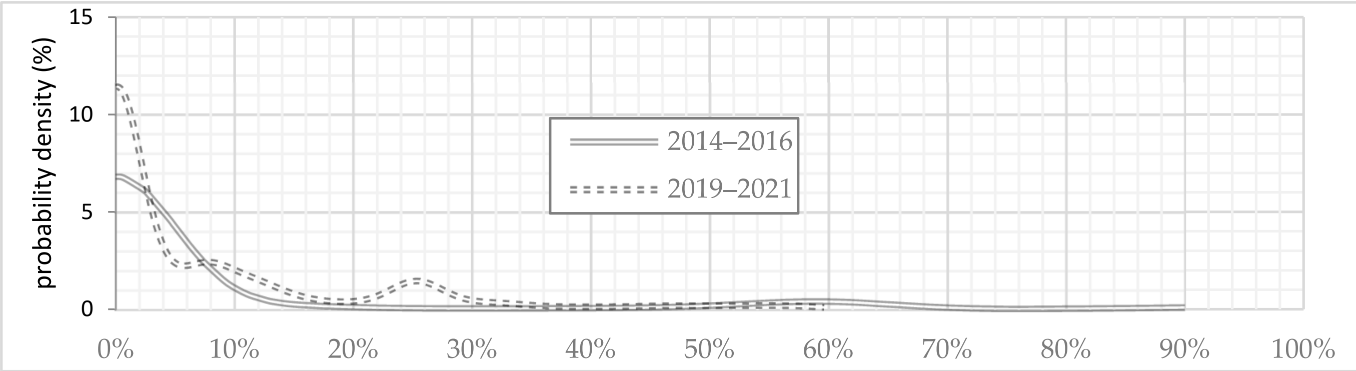

Figure 3. The probability distribution function of the share of rabbitfishes in the total catch (Source: authors' processing of data collected under the Greek DCF program).

In addition, the results of the Kolmogorov–Smirnov tests (KS tests) and the associated *p*-values (Table 2) verify a statistically significant increase in rabbitfishes catches from 2014–2016 to 2019–2021. At the same time, the KS test has also indicated a statistically significant reduction in the share of hauls that include rabbitfishes; the latter is probably due to experience gained by certain fishers, who may move to areas that according to their LEK are not suitable for rabbitfishes in order to avoid them where, however, parrotfish exist.

Table 2. Kolmogorov–Smirnov equality-of-distributions tests between the periods 2014–2016 and 2019–2021 for the variables (a) share of hauls including rabbitfishes and (b) share of rabbitfishes in the catch.

Share of Hauls, including Rabbitfishes	D	*p*-Value	Exact
2014–2016	0.0169	0.989	
2019–2021	−0.3011	0.026	0.042 *
Combined K-S	0.3011	0.052	
% weight share of rabbitfishes in the catch (gr)	**D**	***p*-value**	**Exact**
2014–2016	0.0714	0.795	
2019–2021	−0.3117	0.013	0.019 **
Combined K-S	0.3117	0.026	

* statistically significant at the 0.05 level; ** statistically significant at the 0.01 level. Source: authors' processing of data collected under the Greek DCF program.

Indeed, during the field research (interviews and mapping exercise), most of the fishers have reported that there are hot and cold spots for rabbitfish spatial distribution, as the species seem to prefer warm waters over coastal reefs covered with algae [63] in areas shallower than 20m. More specifically, 20% of fishers (3 out of the 15 fishers) could not identify specific hot spots in the map; however, they agreed that after a specific depth—which they were not able to identify accurately—rabbitfishes were absent. The rest of the fishers have mentioned a threshold for the presence of rabbitfishes at the depth of 20 m, and they have also indicated on maps specific hot spots of rabbitfishes occurrence at certain near shore sites. Then, 67% of the fishers (10 out of 15) have underlined that rabbitfishes' spatial distribution only partly coincides with parrotfish distribution which appears to extend to deeper waters down to 40 m. Therefore, outcomes from the interviews imply that depending on fishers' capacities (including their vessel's power), and their LEK and gained experience (regarding rabbitfishes' favorable habitats), they may avoid them (or not). On the other hand, moving to deeper areas suggests that fishers need to increase fuel consumption per fishing trip; thus, energy costs $\Delta(e\_c)$ are higher by approximately 10% on the average. It should be noted, however, that the latter applies only partially to the SSF fishers operating this métier, as only half of them (8 out of 15) have responded that they have the adequate capacity and/or the necessary cash flow to move to more distant fishing grounds and thus tactually choose to follow a so-called 'avoidance' strategy.

The field research also provides evidence for the time needed for disentangling rabbitfishes in relation to their respective share in the catch. Figure 4 graphically presents the relationship between the rabbitfishes catch share and the percentage time increase for disentangling them based on fishers' responses to different rabbitfishes catch scenarios. Given this figure, a catch full of rabbitfishes may take five times as long, or even more, to clean the nets compared to the required time for no rabbitfishes in the catch. As the trend line in Figure 4 indicates, the relationship between the share of rabbitfishes in the catch and the additional time (in relative terms) needed for cleaning the net is approximately linear. Applying an hourly wage rate (WR), the additional cost can be estimated; following the field research, the WR in the area was estimated to be approximately 4.5 EUR/h.

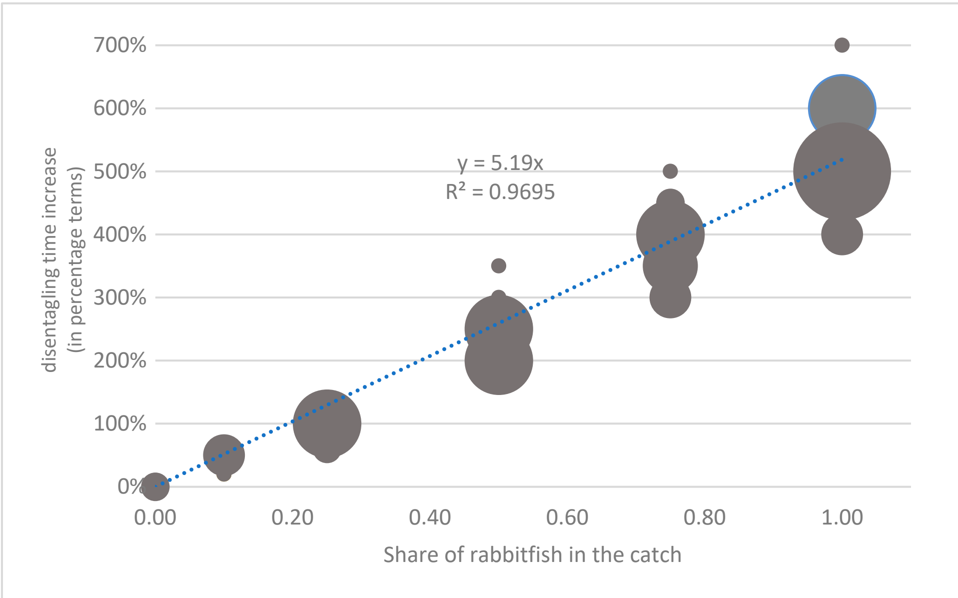

Figure 4. The relationship between the rabbitfish catch share and the percentage of disentangling time increase is based on fishers' responses to different rabbitfish catch share scenarios. The size of the bubbles reflects the frequency of each response. The dashed line represents the linear trend of this relationship.

In the revenue part of Equation (2), i.e., the variables $\Delta(p\_v)$ and $\Delta(o\_v)$, the price of parrotfish in the area is 10 EUR/kg, on average. For the catch that corresponds to "other commercial catch", we consider a weighted average of 7.5 EUR/kg as it includes a mix of species with significant market value, such as the grey mullet (*Mugil cephalus*), the common cuttlefish (*Sepia officinalis*), the dreamfish (*Sarpa salpa*), as well as other species of lower commercial interest like the stargazer (*Uranoscopus scaber*).

Table 3 provides the cost structure for the parrotfish métier, per vessel and trip, for two vessel size groups: less than 6 m and 6 to 12 m. It is constructed based on the cost structure for the vessels belonging to the fleet segments DFN0006 (vessels using nets, with a size smaller than 6 m) and DFN0612 (vessels using nets, with a size larger than 6 m and smaller than 12 m) of the Greek fishing fleet for the year 2019, following the STECF fleet segmentation and Annual Economic Report methodology [12] (extracted from the AER database, available at https://stecf.jrc.ec.europa.eu/reports/economic (accessed on 5 July 2023). In this study, we decided not to include the year 2020, also available in the database, due to the significant distortions in the socioeconomic cost and revenue structure caused by the COVID-19 pandemic. The adjusted cost structure for the parrotfish métier is based on the increased energy cost, the increased labor cost for disentangling them from the nets, and the adjustment on the hourly wage rate, as estimated using data from the field research. According to outcomes of the FFI for the parrotfish métier, in smaller vessels it is well below the DFN value, while in larger vessels it is slightly higher.

Table 3. Economic parameters (in EUR) for the parrotfish métier and SSF vessels using nets (DFN), with sizes smaller than 6 m (DFN0006) and larger than 6 m (DFN0612) (per fishing trip and vessel).

	Vessels Smaller than 6 Meters		**Vessels Larger than 6 Meters**	
	DFN0006	**Parrotfish Métier**	**DFN0612**	**Parrotfish Métier**
Gross value of landings	86.65	53.55	125.94	133.88
Other sources of income and operating subsidies	6.53	6.53	9.98	9.98
Total Revenues	93.18	60.08	135.92	143.85
Cost structure				
Energy costs	11.08	11.08	19.93	19.93
Personnel costs *	14.73	0	6.33	10.01
Value of unpaid labor	33.02	26.59	29.52	46.70
Other cost categories **	23.79	23.79	63.69	63.69
Family Fishing Income (FFI)	43.58	25.21	45.97	50.22

Source: Authors' processing of data included in the Annual Economic Report for the Greek fishing fleet and the period 2019–2021 [12], which was collected under the Greek DCF program * In the case of vessels smaller than 6 m, operating the parrotfish métier in the South Ionian, there is no evidence of paid personnel; therefore, the whole labor is considered unpaid (related to family members' work). ** Includes: "Other variable costs"; "Other non-variable costs"; "Repair & maintenance costs"; "Consumption of fixed capital". These cost categories are not métier-specific and are not, at least directly, associated with the invasion of rabbitfishes in the métier under study.

Table 4 presents the analysis outcomes regarding the effect of the rabbitfishes' expansion in the following years, according to which there may be a higher overlap of areas where parrotfish and rabbitfishes coexist, and hence, fewer options for fishers to avoid rabbitfishes. The results indicate expected economic losses of 6.14 EUR/trip and 18.82 EUR/trip for vessels smaller than 6 m and larger than 6 m, respectively. Those losses correspond respectively to a decrease of 24% and 37% in the FFI. Overall, the FFI index is estimated as 19.06 EUR/trip and 31.41 EUR/trip for the smaller and larger vessels of the parrotfish métier, respectively, showing an important decrease particularly in larger vessels.

Table 4. Sensitivity analysis scenarios of changes in the catch share of parrotfish, rabbitfishes, and other species in the next 5-year period.

	Status Quo	**Optimistic**	**Expected**	**Pessimistic**
Share of parrotfish (%)	27	24	22	20
Share of rabbitfish (%)	17	20	23	26
Share of other species (%)	56	56	55	54
Vessels < 6 m				
Economic losses (in EUR)		3.51	6.14	8.78
Fishing Family Income (in EUR)		21.70	19.06	16.43
%Δ (Fishing Family Income)		−14	−24	−35
Vessels 6–12 m				
Economic losses (in EUR)		13.57	18.82	24.08
Fishing Family Income (in EUR)		36.66	31.41	26.15
% Δ (Fishing Family Income)		−27	−37	−48

Finally, the sensitivity analysis is based on a 20% relative change in the share of parrotfish in the catches in the short-term future (5-year period), corresponding to the relative change during the periods under consideration (2014–2016 and 2019–2021). Thus, the expected share of parrotfish will be 22%. Similarly, using the relative change of rabbitfishes, the share of rabbitfishes is equal to 23%, and consequently, the share of other species is 55%. The optimistic and the pessimistic scenarios are based on a ±10% of the share of parrotfish and rabbitfishes, while the share of other species rises accordingly. Therefore, given that in the expected scenario the share of parrotfish is 22%, the 10% relative difference that is used in the optimistic and pessimistic scenario is equal to 22+2.2% and 22−2.2%, respectively. Therefore, in the pessimistic scenario, the share of parrotfish is 19.8% while in the optimistic one it is 24.2% (expressed in rounded terms in Table 4).

The results of the sensitivity analysis indicate that, even in the optimistic scenario, significant economic losses further deteriorate fishers' income by 14% and 27% for smaller and larger vessel groups respectively, and the parrotfish métier appears to be much worse in the pessimistic scenario. In this case, the economic losses are much larger and significantly hinder the sustainability of this métier, even in the near future, by reducing the FFI index by 35% or 48%, depending on the vessel size group.

4. Discussion

Climate change and the corresponding critical rise of seawater temperature in the Mediterranean Sea have already affected the living conditions and spatial allocation of marine organisms. During the last decades, many species of Red Sea origin have invaded Mediterranean waters through the Suez Canal, resulting in considerable ecosystem regime shifts [64,65] and multi-species collapses, thus affecting economic and societal integrity in multiple ways [8]. Of the thermophilic Red Sea species that have invaded eastern Mediterranean waters, the rabbitfishes are among the first invaders. The relevant literature accuses them of having significant economic, social, and environmental effects. Indeed, they are included in the species with the most negative impacts, causing dramatic losses to Mediterranean macroalgal communities through intense algal grazing [33,35,51]. Their population is constantly increasing in the invaded areas, while they have also expanded to the west, now reaching sites of the central Mediterranean as far as the Adriatic-Ionian Region [22,35].

According to this study, the relative contribution of rabbitfishes in SSF catches in western Greek waters has significantly increased during the last decade. Unlike other areas of the southeastern part of Greece, where rabbitfishes have a medium but still significant market value [43], this was not the case for the Cyclades archipelago of the Aegean Sea [49], nor for the Ionian Sea (present study), where there is no market value for the two species. Indeed, the latter two areas have been invaded by rabbitfishes relatively recently and hence consumers are not familiar with them, and therefore, according to the outcomes of this study's interviews, locals are very reluctant to consume them, or even try to taste them, as long as they can find the fish products they are familiar with and they thus prefer to purchase.

As the invasion rate through the Suez Canal and the range of Lessepsian invasive species follow an increasing trend, there is an urgent need for immediate proactive management actions and scientifically informed control measures. The increase in the abundance of rabbitfishes and their expansion from the east to the west of the Mediterranean have resulted in a considerable increase in their share in SSF catches in shallow coastal waters of the central Mediterranean/South Ionian Sea. This may be related to the fact that those herbivores compete for similar fishing grounds with native herbivores [51], but rabbitfishes seem to have a much more invasive attitude that may facilitate their more successful establishment.

Given that rabbitfishes, but also other thermophilic alien invaders, will remain a dominant feature as climate warms, native biodiversity will be altered by the development of novel communities. Therefore, management realism dictates the need to adapt to the new conditions rather than concentrating on efforts to preserve native biodiversity features [66] that may be potentially outcompeted by bioinvaders, also considering that thermophilic invaders possibly replace ecosystem functions lost due to the loss of certain native species [40,67]. Understanding and quantifying the effects of alien invaders on the ecosystem and the impacted maritime activities is of utmost importance to minimize potential economic impacts on fisheries and particularly SSF, a sector highly vulnerable to thermophilic and herbivorous coastal invaders. Studying the effects on the métiers mainly affected by those species is the only way to ensure meaningful results that may provide solid advice for effective and adaptive management.

However, up to now, there is a remarkable shortage of socioeconomic cost estimation in the literature as well as a lack of understanding how these costs are generated and assessed, even at the local scale or for specific species and fishing métiers [8]. Indeed, even though the socioeconomic effects of invasive species are highly recognized throughout the relevant literature, no direct assessment and quantification at the métier level have been provided so far.

This study has used quantitative and qualitative information to understand the economic effects of the rabbitfishes' expansion in a specific SSF métier that targets the indigenous thermophilic parrotfish in the South Ionian coastal waters. Unlike other studies in the field, the current study has focused on the short-term micro-level economic effects and the effects on fishers' wealth using the FFI index. Also, the study has a vessel segment and spatially explicit focus, highlighting that economic consequences are métier-dependent, linked with characteristics of the distinct ecosystems and fishers' attitudes and capacities.

Aligned with outcomes from other studies (e.g., [14,36,53]), our results have revealed an increasing trend in the share of rabbitfishes in the parrotfish métier catches and, accordingly, a decreasing trend in the share of parrotfishes, the main target of the métier, as well as in other commercial species in the study area in recent years. This fact, as already mentioned, may arise due to interspecific competition between them [55]; as seawater temperatures are expected to rise further in the near future, rabbitfishes are also expected to increase their abundance and expand their distribution in coastal areas of the Mediterranean [35], suggesting a potentially increased competition with parrotfish in more areas and depth zones than those where the species coexist today.

Our analysis has revealed that the FFI of the parrotfish métier operated by smaller vessels is currently well below the DFN value of the respective vessel category, raising economic sustainability questions over the specific métier and vessels group in the study area. What is more, there is an inevitable expected further economic loss in the next short-term period, as most fishers choose to operate in areas where the two species coexist, which however seems to be more pronounced in the larger vessels category, due also to the expansion of rabbitfishes in deeper areas and thus further outcompeting parrotfish. More specifically, the results indicate that, even according to a more optimistic scenario, the métier under study is significantly negatively affected by the expansion of rabbitfishes, experiencing economic losses that correspond to 14% and 27% in their level of wealth (approached by the FFI index) for respectively vessels smaller than 6m, already experiencing significant losses while operating this métier, and larger than 6m, in which this métier will eventually become also economically unsustainable. Thus, there seems to be a red flag warning for the overall sustainability of this métier, revealing the corresponding income deterioration for the fishers who may continue to operate it.

Also, the analysis has shown how LEK may increase certain fishers' capacity and skills to avoid rabbitfishes based on knowing where their distributional hot spots exist. In quantitative terms, this is supported by the fact that the recent distribution of the species' catch share (2019–2021) is less skewed to the right than the previous period (2014–2016). Even though the skewness of this distribution may be reduced even more in the future, many fishers in this métier may not avoid rabbitfishes, which aside to a greater overlap in the spatial distribution between rabbitfishes and parrotfish, may be also linked to choices and norms related to individual fishers' behavior despite the existing LEK. Attitudinal differences of fishers within and between sectors have been well-established in the literature of the last couple of decades, suggesting that they need to be considered in decision making, which should be participatory in order for management measures to be effective [68].

Following the above, further interactions with fishers' associations are needed to disseminate those results and explain the costs and benefits of the different options. Then, such outcomes should also be communicated to regional and central authorities responsible for fisheries policy and management to explain the need for quantifying assessments at the métier level of the appropriate spatial scale of different social-ecological systems (SES), considering at the same time human behavioral diversity among fishers. In the case of unwanted rabbitfish catches, a measure that may seem appropriate may be to subsidize targeted fishing in areas where they exist to control their populations. Hence, those fishers less keen to move to less known fishing grounds, and particularly those having small vessels who already seem to experience economic losses due to rabbitfishes, may serve the goal of controlling the invaders' populations, and by being compensated according to catches and damages to their gears may also improve their resilience. In any case, enhancing our understanding of fishers' behavior while operating specific métiers is a prerequisite for more realistic assessments related to fishery sustainability problems [69–71].

This kind of analysis can be expanded to other métiers for the same and other invasive species to understand the local context of their economic effect and, therefore, to fine-tune a tailor-made policy regime and proper and adaptive fisheries management. Indeed, in the South Ionian waters, two other métiers also seem to be affected by rabbitfishes; they are the striped mullet and the cuttlefish métiers, in which the share of rabbitfishes in the catches has also increased during the last decade. Future research can also focus on analyzing the economic effects of rabbitfishes and other invasive species on the impacted SSF métiers in different marine regions at the appropriate spatial scale and potentially other fishery sectors. To this end, a more exhaustive examination for parameterization fine-tuning, using the next generation of fisheries models that capture more efficiently the complexity of SES [70], is a significant future challenge.

Fine-scale analysis at the métier level, addressing issues of social heterogeneity and fisher motivations, enables us to better comprehend the specificities of SES in each area, ensuring more efficient scientific advice in decision making, to cope with existing challenges such as climate change, which, although imposed at a global scale, should be tackled at appropriate local ones. Such approaches may contribute towards meeting the UN 2030 Agenda of the SDGs while leaving no one behind, particularly small-scale fishers in Mediterranean waters, who constitute a traditional coastal community and should be considered as an important building block of sustainable development in the region [72]. In this direction, the global digital transformation of fisheries is of the utmost importance as it will fill the vast data gaps, particularly related to SSF, that currently constrain the validity of assessments due to the inherited uncertainty in assumptions made. Digital tools and technologies will not only provide integrated information on exploited resources and challenges incurred in the different fishing practices, and on fishers' behavior and motivations, but may also promote collaboration between fishers in existing and potentially new opportunities that may contribute to solutions on important sustainability issues that the SSF sector is facing today both in the Mediterranean and globally.

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References

1. Frazão Santos, C.; Agardy, T.; Andrade, F.; Calado, H.; Crowder, L.B.; Ehler, C.N.; García-Morales, S.; Gissi, E.; Halpern, B.S.; Orbach, M.K.; et al. Integrating climate change in ocean planning. *Nat. Sustain.* **2020**, *3*, 505–516. [CrossRef]
2. Rilov, G. Multi-species collapses at the warm edge of a warming sea. *Sci. Rep.* **2016**, *6*, 36897. [CrossRef]
3. Zenetos, A.; Galanidi, M. Mediterranean non indigenous species at the start of the 2020s: Recent changes. *Mar. Biodivers. Rec.* **2020**, *13*, 10. [CrossRef]
4. Garrabou, J.; Coma, R.; Bensoussan, N.; Bally, M.; Chevaldonné, P.; Cigliano, M.; Diaz, D.; Harmelin, J.G.; Gambi, M.C.; Kersting, D.K.; et al. Mass mortality in Northwestern Mediterranean rocky benthic communities: Effects of the 2003 heat wave. *Glob. Change Biol.* **2009**, *15*, 1090–1103. [CrossRef]
5. Garrabou, J.; Gómez-Gras, D.; Medrano, A.; Cerrano, C.; Ponti, M.; Schlegel, R.; Bensoussan, N.; Turicchia, E.; Sini, M.; Gerovasileiou, V.; et al. Marine heatwaves drive recurrent mass mortalities in the Mediterranean Sea. *Glob. ChangeBiol.* **2022**, *28*, 5708–5725. [CrossRef]
6. Zenetos, A.; Albano, P.G.; Garcia, E.L.; Stern, N.; Tsiamis, K.; Galanidi, M. Established non-indigenous species increased by 40% in 11 years in the Mediterranean Sea. *Mediterr. Mar. Sci.* **2022**, *23*, 196–212. [CrossRef]
7. Balzani, P.; Cuthbert, R.N.; Briski, E.; Galil, B.; Castellanos-Galindo, G.A.; Kouba, A.; Kourantidou, M.; Leung, B.; Soto, I.; Haubrock, P.J. Knowledge needs in economic costs of invasive species facilitated by canalisation. *NeoBiota* **2022**, *78*, 207–223. [CrossRef]
8. Kourantidou, M.; Cuthbert, R.N.; Haubrock, P.J.; Novoa, A.; Taylor, N.G.; Leroy, B.; Capinha, C.; Renault, D.; Angulo, E.; Diagne, C.; et al. Economic costs of invasive alien species in the mediterranean basin. *NeoBiota* **2021**, *67*, 427–458. [CrossRef]
9. Tarkan, A.S.; Yoğurtçuoğlu, B.; Karachle, P.K.; Kalogianni, E.; Top Karakuş, N.; Tricarico, E. Editorial: Understanding the Impact and Invasion Success of Aquatic Non-native Species: How They Interact with Novel Environments and Native Biota. *Front. Ecol. Evol.* **2021**, *9*, 790540. [CrossRef]
10. Giakoumi, S.; Pey, A.; Thiriet, P.; Francour, P.; Guidetti, P. Patterns of predation on native and invasive alien fish in Mediterranean protected and unprotected areas. *Mar. Environ. Res.* **2019**, *150*, 104792. [CrossRef]
11. Cardinale, M.; Scarcella, G. Mediterranean sea: A failure of the European fisheries management system. *Front. Mar. Sci.* **2017**, *4*, 72. [CrossRef]
12. Joint Research Centre; Scientific, Technical and Economic Committee for Fisheries. *The 2021 Annual Economic Report on the EU Fishing Fleet*; Publications Office of the European Union: Luxembourg, 2021; ISBN 978-92-76-40959-5.
13. Tsiamis, K.; Palialexis, A.; Stefanova, K.; Gladan, Ž.N.; Skejić, S.; Despalatović, M.; Cvitković, I.; Dragičević, B.; Dulčić, J.; Vidjak, O.; et al. Non-indigenous species refined national baseline inventories: A synthesis in the context of the European Union's Marine Strategy Framework Directive. *Mar. Pollut. Bull.* **2019**, *145*, 429–435. [CrossRef]
14. Edelist, D.; Rilov, G.; Golani, D.; Carlton, J.T.; Spanier, E. Restructuring the Sea: Profound shifts in the world's most invaded marine ecosystem. *Divers. Distrib.* **2013**, *19*, 69–77. [CrossRef]
15. Ragkousis, M.; Sini, M.; Koukourouvli, N.; Zenetos, A.; Katsanevakis, S. Invading the Greek Seas: Spatiotemporal Patterns of Marine Impactful Alien and Cryptogenic Species. *Diversity* **2023**, *15*, 353. [CrossRef]
16. Giakoumi, S.; Cebrian, E.; Kokkoris, G.D.; Ballesteros, E.; Sala, E. Relationships between fish, sea urchins and macroalgae: The structure of shallow rocky sublittoral communities in the Cyclades, Eastern Mediterranean. *Estuar. Coast. Shelf Sci.* **2012**, *109*, 1–10. [CrossRef]
17. Katsanevakis, S.; Tempera, F.; Teixeira, H. Mapping the impact of alien species on marine ecosystems: The Mediterranean Sea case study. *Divers. Distrib.* **2016**, *22*, 694–707. [CrossRef]
18. van Rijn, I.; Kiflawi, M.; Belmaker, J. Alien species stabilize local fisheries catch in a highly invaded ecosystem. *Can. J. Fish. Aquat. Sci.* **2020**, *77*, 752–761. [CrossRef]
19. Ray, A.; Aswatha, S.M. An analysis of the influence of growth periods on physical appearance, and acemannan and elemental distribution of *Aloe vera* L. gel. *Ind. Crops Prod.* **2013**, *48*, 36–42. [CrossRef]
20. Tsirintanis, K.; Azzurro, E.; Crocetta, F.; Dimiza, M.; Froglia, C.; Gerovasileiou, V.; Langeneck, J.; Mancinelli, G.; Rosso, A.; Stern, N.; et al. Bioinvasion impacts on biodiversity, ecosystem services, and human health in the Mediterranean Sea. *Aquat. Invasions* **2022**, *17*, 308–352. [CrossRef]

21. Minasidis, V.; Doumpas, N.; Giovos, I.; Kleitou, P.; Kaminas, A.; Moutopoulos, D.K. Assessing Consumer Attitude towards Marine Non-Indigenous Fish Species: A Case Study From Greece (Eastern Mediterranean Sea). *Thalassas* **2023**, *39*, 35–53. [CrossRef]
22. Cavraro, F.; Anelli Monti, M.; Matić-Skoko, S.; Caccin, A.; Pranovi, F. Vulnerability of the Small-Scale Fishery to Climate Changes in the Northern-Central Adriatic Sea (Mediterranean Sea). *Fishes* **2023**, *8*, 9. [CrossRef]
23. Tzanatos, E.; Georgiadis, M.; Peristeraki, P. *Small-Scale Fisheries in Greece: Status, Problems, and Management. InSmall-Scale Fisheries in Europe: Status, Resilience and Governance*; Springer: Cham, Switzerland, 2020; pp. 125–150.
24. Liontakis, A.; Tzouramani, I.; Mantziaris, S.; Sintori, A. Unravelling the role of gender in fisheries' socio-economic performance: The case of Greek small-scale fisheries. *Sustainability* **2020**, *12*, 5304. [CrossRef]
25. Katsanevakis, S.; Zenetos, A.; Belchior, C.; Cardoso, A.C. Invading European Seas: Assessing pathways of introduction of marine aliens. *Ocean Coast. Manag.* **2013**, *76*, 64–74. [CrossRef]
26. Zenetos, A.; Gofas, S.; Verlaque, M.; Çinar, M.E.; García Raso, J.G.; Bianchi, C.N.; Morri, C.; Azzurro, E.; Bilecenoglu, M.; Froglia, C.; et al. Alien species in the Mediterranean Sea by 2010. A contribution to the application of European Union's Marine Strategy Framework Directive (MSFD). Part I. Spatial distribution. *Mediterr. Mar. Sci.* **2010**, *11*, 381–493. [CrossRef]
27. Bayram, Ö. *Non-Indigenous Species in the Mediterranean and the Black Sea*; General Fisheries Commission for the Mediterranean: Rome, Italy, 2021.
28. Occhipinti-Ambrogi, A.; Galil, B. Marine alien species as an aspect of global change. *Adv. Oceanogr. Limnol.* **2010**, *1*, 199–218. [CrossRef]
29. Galanidi, M.; Zenetos, A.; Bacher, S. Assessing the socio-economic impacts of priority marine invasive fishes in the Mediterranean with the newly proposed SEICAT methodology. *Mediterr. Mar. Sci.* **2018**, *19*, 107. [CrossRef]
30. Peristeraki, P.; Skarvelis, K.; Giannakaki, A.; Tambakakis, K.; Tserpes, G. Preliminary results on the abundance of alien species in the coastal fisheries catches of Crete. In Proceedings of the 11th Panhellenic Symposium on Oceanography and Fisheries, Mytilene, Lesvos Island, Greece, 13–17 May 2015; pp. 149–152.
31. Kalogirou, S.; Mittermayer, F.; Pihl, L.; Wennhage, H. Feeding ecology of indigenous and non-indigenous fish species within the family Sphyraenidae. *J. Fish Biol.* **2012**, *80*, 2528–2548. [CrossRef]
32. Kalogirou, S. Ecological characteristics of the invasive pufferfish Lagocephalus sceleratus (Gmelin, 1789) in Rhodes, Eastern Mediterranean Sea. A case study. *Mediterr. Mar. Sci.* **2013**, *14*, 251–260. [CrossRef]
33. Kalogirou, S.; Wennhage, H.; Pihl, L. Non-indigenous species in Mediterranean fish assemblages: Contrasting feeding guilds of Posidonia oceanica meadows and sandy habitats. *Estuar. Coast. Shelf Sci.* **2012**, *96*, 209–218. [CrossRef]
34. Bariche, M.; Letourneur, Y.; Harmelin-Vivien, M. Temporal fluctuations and settlement patterns of native and Lessepsian herbivorous fishes on the Lebanese coast (eastern Mediterranean). *Environ. Biol. Fishes* **2004**, *70*, 81–90. [CrossRef]
35. Solanou, M.; Valavanis, V.D.; Karachle, P.K.; Giannoulaki, M. Looking at the Expansion of Three Demersal Lessepsian Fish Immigrants in the Greek Seas: What Can We Get from Spatial Distribution Modeling? *Diversity* **2023**, *15*, 776. [CrossRef]
36. Öndes, F.; Ünal, V. The dominance of non-indigenous species in the catch composition of small-scale fisheries: A case study from the Kaş–Kekova Special Environmental Protection Area, Türkiye, Eastern Mediterranean. *Acta Ichthyol. Piscat.* **2023**, *53*, 27–35. [CrossRef]
37. Otero, M.; Cebrian, E.; Francour, P.; Galil, B.; Savini, D. *Monitoring Marine Invasive Species in Mediterranean Marine Protected Areas (MPAs): A Strategy and Practical Guide for Managers*; IUCN: Malaga, Spain, 2013.
38. GFCM-UNEP/MAP. *Report of the Joint GFCM-UN Environment/MAP Subregional Pilot Study for the Eastern Mediterranean on Non-Indigenous Species in Relation to Fisheries UNEP(DEPI)/MED WG.445/4*; UNEP: Geneva, Swotzerland, 2018.
39. WWF. Fishing in the Tine of Climate Change: The Economy and Biodiversity of the Mediterranean Are Being Threatened by New Invaders. Available online: https://wwf.exposure.co/fishing-at-the-time-of-climate-change (accessed on 7 August 2023).
40. Giakoumi, S.; Katsanevakis, S.; Albano, P.G.; Azzurro, E.; Cardoso, A.C.; Cebrian, E.; Deidun, A.; Edelist, D.; Francour, P.; Jimenez, C.; et al. Management priorities for marine invasive species. *Sci. Total Environ.* **2019**, *688*, 976–982. [CrossRef] [PubMed]
41. Magneville, C.; Leréec Le Bricquir, M.L.; Dailianis, T.; Skouradakis, G.; Claverie, T.; Villéger, S. Long-duration remote underwater videos reveal that grazing by fishes is highly variable through time and dominated by non-indigenous species. *Remote Sens. Ecol. Conserv.* **2023**, *9*, 311–322. [CrossRef]
42. Kleitou, P.; Moutopoulos, D.K.; Giovos, I.; Kletou, D.; Savva, I.; Cai, L.L.; Hall-Spencer, J.M.; Charitou, A.; Elia, M.; Katselis, G.; et al. Conflicting interests and growing importance of non-indigenous species in commercial and recreational fisheries of the Mediterranean Sea. *Fish. Manag. Ecol.* **2022**, *29*, 169–182. [CrossRef]
43. Corsini, M.; Stamatellos, S. Information collected at the Hydrobiological Station of Rhodes (Greece) on Lessepsian migrant fishes. In Proceedings of the 16th European Union of Aquarium Curators Symposium, Barcelona, Spain, 25–29 September 1998; pp. 35–40.
44. Quintana, A.; Marcos, S.; Malpica-Cruz, L.; Tamayo, L.; CantoNoh, J.Á.; Fernández-RiveraMelo, F.; Fulton, S. Socioeconomic dilemmas of commercial markets for invasive species: Lessons from lionfish in Mexico. *ICES J. Mar. Sci.* **2023**, *80*, 31–39. [CrossRef]
45. Nuñez, M.A.; Kuebbing, S.; Dimarco, R.D.; Simberloff, D. Invasive Species: To eat or not to eat, that is the question. *Conserv. Lett.* **2012**, *5*, 334–341. [CrossRef]
46. Meadows, B.; Sims, C. Can We Love Invasive Species to Death? Creating Efficient Markets for Invasive Species Harvests. *Environ. Resour. Econ.* **2023**, *85*, 443–477. [CrossRef]

47. Arianoutsou, M.; Adamopoulou, C.; Andriopoulos, P.; Bazos, I.; Christopoulou, A.; Galanidis, A.; Kalogianni, E.; Karachle, P.K.; Kokkoris, Y.; Martinou, A.F. HELLAS-ALIENS. The invasive alien species of Greece: Time trends, origin and pathways. *NeoBiota* **2023**, *86*, 45–79. [CrossRef]
48. Tsagarakis, K.; Palialexis, A.; Vassilopoulou, V. Mediterranean fishery discards: Review of the existing knowledge. *ICES J. Mar. Sci.* **2014**, *71*, 1219–1234. [CrossRef]
49. Esposito, G.; Prearo, M.; Menconi, V.; Mugetti, D.; Meloni, D.; Tomasoni, M.; Pizzul, E.; Piras, P.; Renzi, M.; Gaspa, D.; et al. Northward spread of the parrotfish *Sparisoma cretense* (Teleostei: Scaridae) in the mediterranean sea: An update on current distribution with two new records from Sardinia. *J. Mar. Sci. Eng.* **2021**, *9*, 536. [CrossRef]
50. Papoutsoglou, E.S.; Lyndon, A.R. Distribution of α-amylase along the alimentary tract of two Mediterranean fish species, the parrotfish *Sparisoma cretense* L. and the stargazer, *Uranoscopus scaber* L. *Mediterr. Mar. Sci.* **2003**, *4*, 115–124. [CrossRef]
51. Giakoumi, S. Distribution patterns of the invasive herbivore Siganus luridus (Rüppell, 1829) and its relation to native benthic communities in the central Aegean Sea, Northeastern Mediterranean. *Mar. Ecol.* **2014**, *35*, 96–105. [CrossRef]
52. Kavvadas, S.; Damalas, D.; Georgakarakos, S.; Maravelias, C.; Tserpes, G.; Papaconstantinou, C.; Bazigos, G. IMAS-Fish: Integrated MAnagement System to support the sustainability of Greek Fisheries resources. A multidisciplinary web-based database management system: Implementation, capabilities, utilization and future prospects for fisheries stakeholde. *Mediterr. Mar. Sci.* **2013**, *14*, 109–114. [CrossRef]
53. Kalogirou, S.; Corsini-Foka, M.; Sioulas, A.; Wennhage, H.; Pihl, L. Diversity, structure and function of fish assemblages associated with Posidonia oceanica beds in an area of the eastern Mediterranean Sea and the role of non-indigenous species. *J. Fish Biol.* **2010**, *77*, 2338–2357. [CrossRef] [PubMed]
54. Richardson, J.W.; Feldman, P.; Schuemann, K. *Simetar*™; Department of Agricultural Economics, Texas A&M University: College Station, TX, USA, 2003.
55. Concu, G.B.; Atzeni, G.; Meleddu, M.; Vannini, M. Policy design for climate change mitigation and adaptation in sheep farming: Insights from a study of the knowledge transfer chain. *Environ. Sci. Policy* **2020**, *107*, 99–113. [CrossRef]
56. Scientific Technical and Economic Committee for Fisheries (STECF). *Scientific, Technical and Economic Committee for Fisheries (STECF): The 2019 Annual Economic Report on the EU Fishing Fleet (STECF 19-06)*; Publications Office of the European Union: Luxembourg, 2019; Volume JRC 97371, ISBN 9789276095170.
57. Sgardeli, V.; Damalas, D.; Liontakis, A.; Maravelias, C.D.; Mantopoulou-Palouka, D.; Tserpes, G. The Aegean Sea demersal fishery under four climatic and socio-political futures. *Mar. Policy* **2022**, *144*, 105194. [CrossRef]
58. Liontakis, A.; Vassilopoulou, V. Exploring fishing tourism sustainability in North-Eastern Mediterranean waters, through a stochastic modelling analysis: An opportunity for the few or a viable option for coastal communities? *Ocean Coast. Manag.* **2022**, *221*, 106118. [CrossRef]
59. Liontakis, A.; Tzouramani, I. Economic sustainability of organic aloe vera farming in Greece under risk and uncertainty. *Sustainability* **2016**, *8*, 338. [CrossRef]
60. Rozakis, S.; Tsiboukas, K.; Petsakos, A. Greek Cotton Farmers' Supply Response to Partial Decoupling of Subsidies. In Proceedings of the 2008 International Congress, Ghent, Belgium, 26–29 August 2008. [CrossRef]
61. Sintori, A.; Tsiboukas, K.; Zervas, G. Evaluating Socio-economic and Environmental Sustainability of the Sheep Farming Activity in Greece: A Whole-Farm Mathematical Programming Approach. In *Methods and Procedures for Building Sustainable Farming Systems*; Springer: Dordrecht, The Netherlands, 2013; pp. 219–235.
62. Vallerand, F.; Dubeuf, J.P.; Tsiboukas, K. Le lait de brebis et de chèvre en méditerranée et dans les balkans: Diversité des situations locales et des perspectives sectorielles. *Cah. Agric.* **2007**, *16*, 258–264. [CrossRef]
63. Vergés, A.; Tomas, F.; Cebrian, E.; Ballesteros, E.; Kizilkaya, Z.; Dendrinos, P.; Karamanlidis, A.A.; Spiegel, D.; Sala, E. Tropical rabbitfish and the deforestation of a warming temperate sea. *J. Ecol.* **2014**, *102*, 1518–1527. [CrossRef]
64. Buonocore, E.; Grande, U.; Franzese, P.P.; Russo, G.F. Trends and evolution in the concept of marine ecosystem services: An overview. *Water* **2021**, *13*, 2060. [CrossRef]
65. Saygu, İ.; Heymans, J.J.; Fox, C.J.; Özbilgin, H.; Eryaşar, A.R.; Gökçe, G. The importance of alien species to the food web and bottom trawl fisheries of the Northeastern Mediterranean, a modelling approach. *J. Mar. Syst.* **2020**, *202*, 103253. [CrossRef]
66. Rilov, G.; Peleg, O.; Yeruham, E.; Garval, T.; Vichik, A.; Raveh, O. Alien turf: Overfishing, overgrazing and invader domination in south-eastern Levant reef ecosystems. *Aquat. Conserv. Mar. Freshw. Ecosyst.* **2018**, *28*, 351–369. [CrossRef]
67. Rilov, G.; Mazaris, A.D.; Stelzenmüller, V.; Helmuth, B.; Wahl, M.; Guy-Haim, T.; Mieszkowska, N.; Ledoux, J.B.; Katsanevakis, S. Adaptive marine conservation planning in the face of climate change: What can we learn from physiological, ecological and genetic studies? *Glob. Ecol. Conserv.* **2019**, *17*, e00566. [CrossRef]
68. Richardson, E.A.; Kaiser, M.J.; Edwards-Jones, G. Variation in fishers' attitudes within an inshore fishery: Implications for management. *Environ. Conserv.* **2005**, *32*, 213–225. [CrossRef]
69. Schadeberg, A.; Kraan, M.; Hamon, K.G. Beyond métiers: Social factors influence fisher behaviour. *ICES J. Mar. Sci.* **2021**, *78*, 1530–1541. [CrossRef]
70. Wijermans, N.; Boonstra, W.J.; Orach, K.; Hentati-Sundberg, J.; Schlüter, M. Behavioural diversity in fishing—Towards a next generation of fishery models. *Fish Fish.* **2020**, *21*, 872–890. [CrossRef]

71. Kraan, M.; Bitetto, I.; Bellanger, M.; Brown, E.J.; Depestele, J.; Frangoudes, K.; Hamon, K.; Hegland, T.; Lehuta, S.; Letschert, J.; et al. *SEAwise Report on Fisher Behaviour Submodels*; Technical University of Denmark: Lyngby, Denmark, 2023.
72. Hansen, G.F.; Feiring, B.; Stidsen, S. *Enhancing Accountability for Small-Scale Fishers—Using Human Rights Monitoring to Guide Effective Implementation of SDG Target 14.B*; The Danish Institute for Human Rights: Copenhagen, Denmark, 2021.