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FISHERS PERCEPTIONS ON THE STATUS AND IMPACT OF THE ALIEN FISH *SIGANUS LURIDUS* AND *S. RIVULATUS* IN THE AEGEAN AND IONIAN SEAS

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Abstract

Marine biological invasions are considered as a threat for biodiversity and ecosystem services. The two spinefoot species, *Siganus luridus* and *S. rivulatus* (*Siganus* spp.), are among the dominant alien fish species that have been established in the eastern Mediterranean Sea. In this work we used a questionnaire-based survey addressed to small-scale fishers operating in the Aegean and Ionian Seas, regarding the statuses of these two species and any perceived impact on the environment. Our analyses revealed a positive temporal shift in the frequency of occurrence of the species during 2016 to 2021. Moreover, fishers from the Aegean Sea stated that both species affect the commercially targeted species, a fact that can be attributed to the successful establishment of the species in the region and their impact on the environment.

Keywords: Biological invasions, Small-scale Fisheries, *Siganus* spp., Greece, Mediterranean.

1. Introduction

Marine alien species are considered as one of the most important ecological threats at an international scale since they negatively affect the local biodiversity and ecosystem services. This phenomenon is rapidly expanding in the Mediterranean Sea due to anthropogenic disturbances and activities related to shipping and aquaculture (Katsanevakis *et al.,* 2014). Besides the ecological aspect, there is a huge economic impact caused by biological invasions, which has been estimated at $27.3 billion, or $3.6 billion when only realized costs are considered, over the last three decades for the Mediterranean basin (Kourantidou *et al.,* 2021).

The two herbivore species of the genus *Siganus* (Dusky spinefoot *S. luridus* and Marbled spinefoot *S. rivulatus*; hereafter *Siganus* spp.) have been established in the eastern Mediterranean since the last century (Ben-Tuvia, 1964; Dulčić *et al.,* 2011). During the last decade their distribution has gradually expanded in the Greek coasts of the Aegean and the Ionian Sea (Karachle *et al.*, 2021), and their effects on the environment and ecosystem services have been well documented (Giakoumi 2014; Katsanevakis *et al.,* 2014; 2020). The aim of this study is to record and analyse the perceptions of the Greek fishers on the status and the impacts of *Siganus* spp.

2. Material and Methods

2.1 Data collection

A questionnaire was compiled within 4ALIEN project, and a total of 250 in-person interviews were conducted with professional fishers in 2021 throughout Greece (for details see Margaritis *et al.*, 2021). However, information on the two *Siganus* spp. was extracted only from 93 interviews from the Aegean Sea and 50 from the Ionian Sea. Here we present and analyse responses in six questions focusing on the current status and impact of the species on the ecosystem and commercially exploited species (Table 1).

2.2 Data analysis

The responses in the first four questions concerning the frequency of encounters and the contribution to the catch were classified in ordinal interval classes (IC): "1" (0-5%), "2" (5-20%), "3" (20-50%), "4" (50-75%), "5" (75-100%). The other two questions' replies where of "Yes/No" nature, accompanied by a short free-text reply, and thus quantified accordingly. Initially, bar plots were employed to highlight potential spatial and temporal patterns; however, they did not allow the efficient interpretation of the multi-dimensional features of the data. Moreover, comparisons cannot be implemented based on individual-based changes since the data were pooled. Hence, with the use of the delta difference [Δ_{yi}: frequency of occurrence (Δ_{Freq}); proportion of the catch share (Δ_{Prop})] of each ordinal interval class variable (y) we attempted to highlight the temporal change (c=5 years) based on the individual-based observational shifts of each fisher (i) regarding the past (2016; t) and the present (2021; $t+c$) as follows (Eq.1):

$$\Delta_{yi} = y_{i,t+c} - y_{i,t} \quad [1]$$

$$\Delta_{y\mu} = \frac{\sum_{i}^{n_y} \Delta_{yi}}{n_y} \quad [2]$$

where $\Delta_{y\mu}$ (Eq.2) denotes the mean (μ) value of each variable (y) and n the total number of individuals. As a result, in case of $\Delta_{y\mu} > 0$, the difference exhibits that there is a proportional increase compared to five years before and if $\Delta_{y\mu} < 0$, the opposite. The data have been depicted in a two-dimensional scale with a random local variation assessed to the discrete data points to avoid visually overlapping. Finally, with the use of the non-parametric Kruskal-Wallis (KW) rank sum test we validated if the Boolean answers of the fishers from the two marine regions derived from the same population, while we applied the chi-square test (χ^2) to the yes/no answers against the equal ratio 1:1.

Table 1. List of the questions addressed to fishers from the Aegean and Ionian Seas on the status and the impact of *Siganus luridus* and *S. rivulatus*. IC=interval class. For details see text and Margaritis *et al*. (2021).

A/A	Question	Data type
1	"How often did you catch the species during the last year (i.e., 2021)?"	[Frequency of occurrence: IC]
2	"How often did you catch the species five years ago (i.e., 2016)?"	[Proportion of the catch share: IC]
3	"What was the species' proportional share of the catch during the last year?"	[Frequency of occurrence: IC]
4	"What was the species' proportional share of the catch five years ago?	[Proportion of the catch share: IC]
5	"Have you observed environmental changes due to the presence of the species?"	[Yes | No]
6	"Do you consider that the species affect the commercially targeted species?"	[Yes | No]

3. Results

According to the answers of the fishers, trammel nets (GTR) and gillnets (GNS) were characterized as the predominant fishing gears for the catch of the species in both Seas (GTR: Aegean=72%, Ionian=50%; GNS: Aegean= 22%, Ionian=22.5%) and thus, were included in the analysis (Fig. 1). It appears that there was a temporal increase from 2016 to 2021 in the frequency of occurrence during the use of GTR in the Aegean (red bars) and in the Ionian (blue bars) Sea (Fig. 1), whereas the proportion of catch share exhibited only a relatively minor temporal increase in both seas. In the case of GNS, the pattern is analogous since there was an increase in the frequency of occurrence and in the proportional shift in the Aegean

Sea. However, the proportion of catch share of *Siganus* spp. observed by the fishers in the Ionian Sea indicated a reduction during the period of 2016 to 2021.

The temporal difference of the mean frequency of occurrence ($\Delta_{Freq\mu}$) showed that the $\Delta_{Freq\mu}$ of *Siganus* spp. resulted in a positive mean in both fishing gears in the Aegean ($\Delta_{Freq\mu}$= 0.86 and 0.82, for GTR and GNS respectively) and in the Ionian Sea ($\Delta_{Freq\mu}$= 1.09 and 0.55, for GTR and GNS respectively). On the contrary, the mean values regarding the observation shifts on the proportion of catch share ($\Delta_{Prop\mu}$) were lower compared to the $\Delta_{Freq\mu,}$ in the two marine regions [Aegean: (GTR: $\Delta_{Prop\mu}$= 0.17; GNS: $\Delta_{Prop\mu}$= 0.11); Ionian (GTR: $\Delta_{Prop\mu}$= 0.11; GNS: $\Delta_{Prop\mu}$= -0.5). The calculated positive means (Δ_{Freq}) in the y axis mean (triangles) validated the positive temporal shift detected in the frequency of observation on the species in both fishing gears and marine regions (Aegean: red polygon; Ionian: blue polygon), respectively (Fig. 2). Apparently, there was a higher variance in the values of the x axis (Δ_{Prop}) since the polygons were allocated in both positive and negative values. In the exceptional case of the Δ_{Prop} in the Ionian Sea, there was a general trend towards negative values.

Regarding the observed environmental changes, the majority of the fishers reported that the species do affect the environment (Yes: Aegean = 49, Ionian = 28; No: Aegean = 44, Ionian = 22). However, no statistical difference between the answers of each region (χ^2, $p > 0.05$) was found, neither a statistical difference between the answers of the Aegean and Ionian Seas (KW, $p > 0.05$). Finally, with respect to the effects on targeted species, the same pattern was observed with generally a positive response (Yes: Aegean = 56, Ionian = 29; No: Aegean = 29, Ionian = 31). The positive answer of fishers from the Aegean was statistically significant (χ^2, $p < 0.05$) compared to the Ionian that was not (χ^2, $p > 0.05$), along with a non-statistically significant effect between the two marine regions (KW, $p > 0.05$).

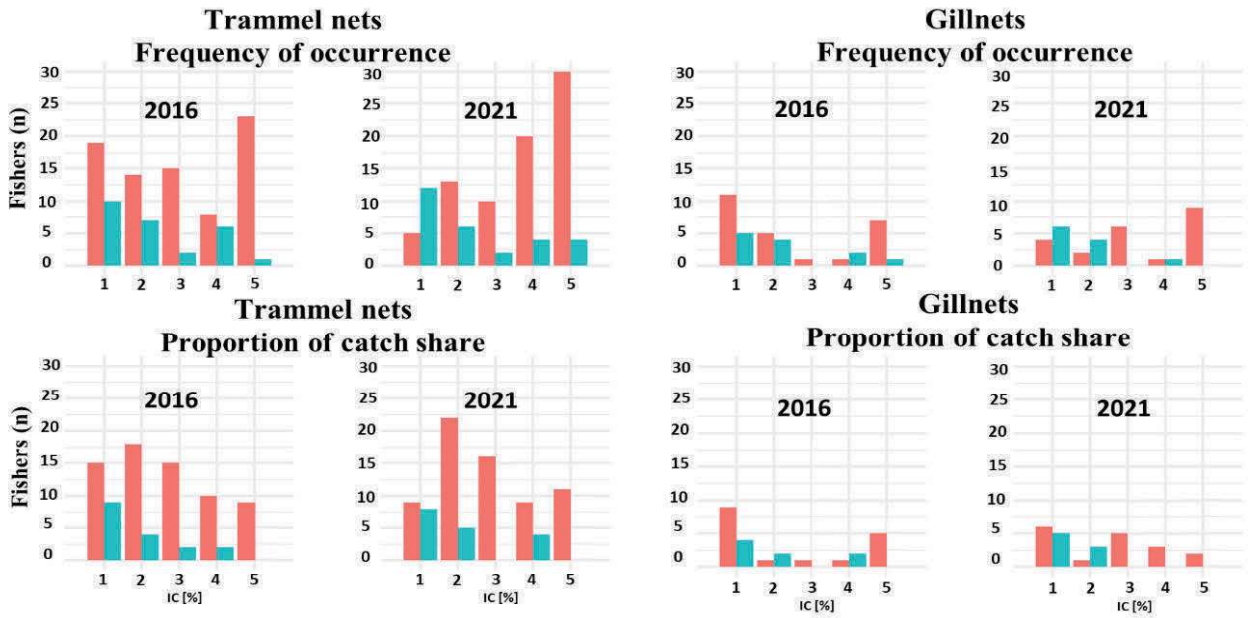

Fig. 1: Bar plots indicating the 5 interval classes (IC; 0-5%, 2: 5-20%, 3: 20-50%, 4: 50-75%, 5: 75-100%) of the frequency of occurrence (top; IC) and the proportion of catch share out the total catch (bottom; IC) of *Siganus luridus and S. rivulatus* with the two major fishing gears (Trammel nets, left; Gillnets, right) based on answers of fishers (n) in the Aegean (red bars) and Ionian (blue bars) Seas.

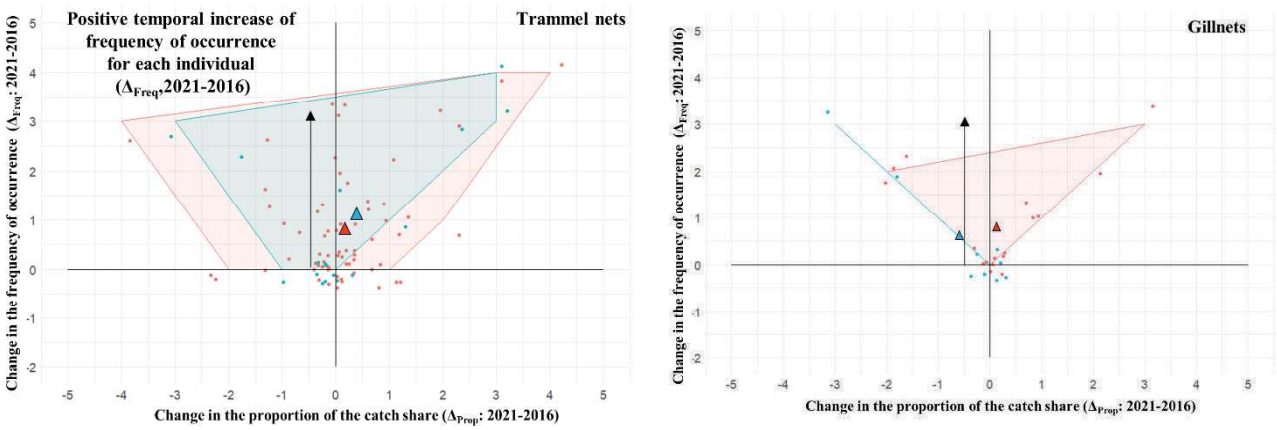

Fig. 2: Two-dimensional depiction of the temporal difference of the frequency of occurrence (Δ_{Freq}; y axis) and the proportion of *Siganus luridus and S. rivulatus* out of the total catch share (Δ_{Prop}; x axis) for both fishing gears (Trammel nets: left; Gillnets: right) based on answers of fishers in the Aegean (red polygon) and Ionian (blue polygon) Seas. The triangles indicate the mean values of each subset (Aegean: red; Ionian: blue).

4. Discussion

The present study recorded and analysed the perceptions of Greek fishers on the current status and the impact of the alien fish species *Siganus luridus* and *S. rivulatus.* Based on their answers, a positive temporal shift (2016-2021) was highlighted in the frequency of occurrence of both species in the Aegean and Ionian Seas, in both trammel nets and gillnets. On the contrary, the distribution of the values regarding the proportion out of the total catch was scattered and a temporal shift was not that clear. In the case of *S. rivulatus*, a possible explanation on the positive temporal shift of the frequency of occurrence can be attributed to the fact that the invasive species has the ability to cover larger distances in the eastern Mediterranean (i.e., larger home range, lower site fidelity), compared to its native range in the Red Sea (Pickholtz *et al.*, 2018).

Fishers' responses regarding whether the species change the marine environment were positive in both marine regions, while in the question on the effect of the species on commercially target species there was a statistically significant positive answer for the Aegean Sea. Indeed, it has been previously recorded that increased abundance of the herbivorous *Siganus* spp. can lead to benthic algal communities with extremely low biomass and the creation of barrens (Sala *et al.*,2011; Giakoumi, 2014), and this was clearly perceived by the fishers. These barrens have multiple effects on the algal communities, the rocky infralittoral food webs, but can also lead to habitat loss for a wide variety of animals, loss of spawning and recruitment grounds for fishes, even extirpation of fish species (e.g., Katsanevakis *et al.*, 2020).

The results of this study further underline the importance of the collaboration between the fishers and the scientific community. These types of collaborations enhance the mutual transfer of ecological information, such as the fundamental fishers ecological knowledge based on their observations (Holm, 2003), which will contribute to practices focusing on the management and the protection of the marine environment.

5. Acknowledgements

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