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ASSESSING THE STATE OF INVASIVE FISHES IN TWO MEDITERRANEAN MARINE PROTECTED AREAS AND ADJACENT UNPROTECTED AREAS

Abstract

*The Mediterranean Sea is the most invaded marine region in the world. Besides their numerous ecological impacts, invasive species also affect the provision of ecosystem services with severe socio-economic consequences for coastal communities. In this study, we conducted underwater visual census inside and outside two Eastern Mediterranean Marine Protected Areas (MPAs), Zakynthos MPA in the Ionian Sea and Kaş-Kekova MPA in the Levantine Sea, to estimate the density and biomass of native and alien fishes. Additionally, we conducted interviews with local fishers to better assess the state of fish populations in the study regions. Fishers were asked about the presence of alien species in their catches, the change observed over the years, and the general state of fish stocks in their area. According to the fish surveys the biomass of alien species corresponded to 19% of total fish biomass in Zakynthos MPA, and 42% in Kaş MPA. In Zakynthos, the species *Siganus luridus* was the only alien visually recorded, whereas in Kaş we recorded six alien species. Interviews revealed that fishers in Kaş perceived biological invasions as the most important reason for the current fish stock depletion whereas overfishing was identified as the most important reason in Zakynthos. The abundance of most invasive fishes caught by fishers in Kaş decreased since the year 2000 whereas in Zakynthos the abundance of invasives increased. In Zakynthos, none of the invasive fishes had a commercial value; conversely, the commercial value of all invasives increased in Kaş, with *Upeneus moluccensis* presenting a 4-fold increase in its price since 2000. In both regions, nearly all fishers stated that the current situation could be improved if overfishing is stopped through the enforcement of existing regulations.*

Key-words: fishers, impacts, invasive fish, Marine Protected Areas, Mediterranean

Introduction

Biological invasions are one of the main components of global change and the second most important driver of biodiversity loss (Bellard *et al.*, 2016). Invasive alien species cause disturbances to native communities in the recipient ecosystem through competition, predation, hybridization, and the displacement of native species (Molnar *et al.*, 2008).

A massive introduction of alien marine organisms into the Mediterranean Sea, known as Lessepsian migration (Por, 1978), occurred after the opening of the Suez Canal in 1869 which eliminated the natural geographical barrier that separated the Indo-Pacific ecosystem from the Mediterranean Sea. Some of these species have become invasive causing severe negative ecological and socio-economic impacts (Katsanevakis *et al.*, 2014). Up to date, more than 100 Lessepsian fishes have been recorded in the Mediterranean Sea (Golani *et al.*, 2013) both in unprotected and protected areas (Galil *et al.*, 2017).

In theory, Marine Protected Areas (MPAs) could host lower abundances of alien/invasive species based on major hypotheses in invasion biology and mechanisms related to the

effects of MPAs on ecosystems. For example, the restoration of top-down regulation processes (e.g., restoration of top predators' populations) in MPAs could help control the population of some alien species inside MPAs. However, relevant evidence is very limited and should be considered with caution (Giakoumi & Pey, 2017).

Herein, we assessed the state of invasive alien fishes in two Mediterranean MPAs, Zakynthos MPA in the Greek Ionian Sea and Kaş-Kekova MPA in the Turkish Levantine Sea, and adjacent unprotected areas by conducting underwater surveys. To have a broader view of the presence and impact of invasive alien fishes in the regions, we complemented the data from fish surveys with local ecological knowledge by performing interviews with local fishers.

Material and methods

Rocky habitats at 6-10 m depth were sampled at 3 replicate stations within each MPA and at another 3 replicate stations in adjacent unprotected areas. We conducted SCUBA surveys of the abundance and size of fishes along 6 replicate 25 m-long and 5 m-wide transects at each station. The diver swam at constant speed, identifying, counting and estimating the size of all individuals within 2.5 m on either side of the transect line. Length estimates of fish from surveys were converted to wet weight by using the length-weight relationship: $W = aL^b$, where W is weight in grams and L is total length in cm. Parameters a and b were obtained from Fishbase (Froese & Pauly, 2016). Alien species were classified according to Zenetos *et al.* (2010).

We then performed a permutational multivariate analysis of variance (PERMANOVA; Anderson, 2001) to detect the effects of protection on the structure of alien species. "Protection" was considered a fixed factor (2 levels: protected vs unprotected), "Site" was a random factor orthogonal to "Protection", and "Station" was a random factor nested in "Site" and "Protection".

A total of 21 small-scale fishers ($n = 13$ in Kaş and $n = 8$ in Zakynthos) were interviewed based on semi-structured questionnaires. All fishers used mainly gill nets and long lines. Fishers were asked about the presence of alien species in their catches, the changes in their abundance observed over the years, and the commercial value (if any) of alien species. They were also questioned on the general state of fish stocks in their area and the reasons associated to the decline or increase of fish stocks. If fishers stated that they have observed decline of fish stocks, they were asked to suggest measures to reverse this negative trend.

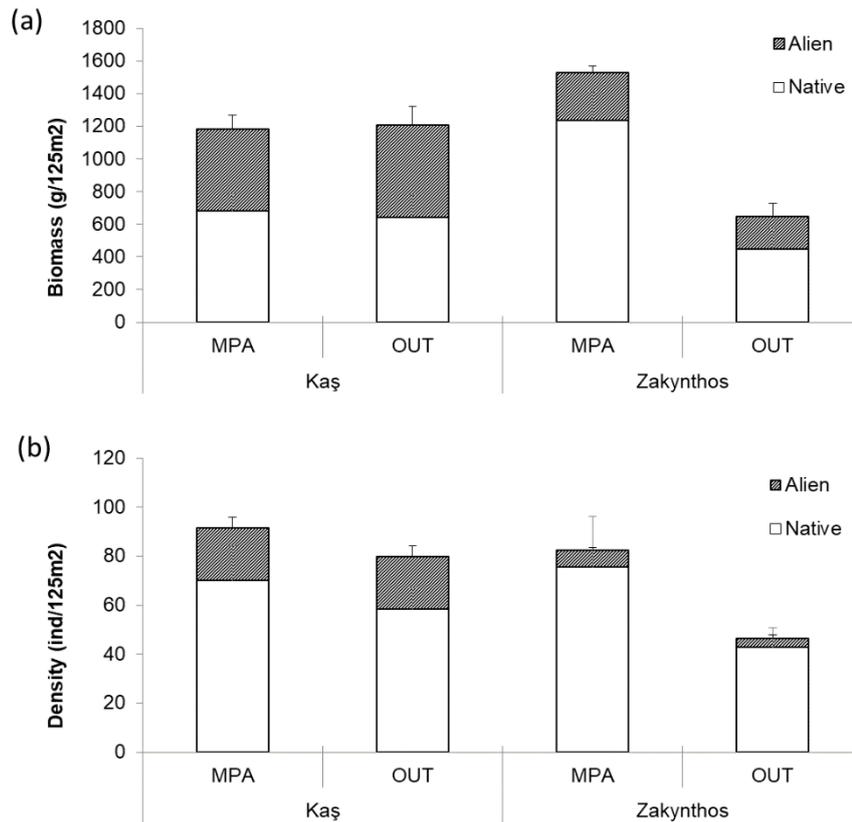
Results

During the visual surveys in Kaş, we recorded six alien species: *Fistularia commersonii*, *Pempheris rhomboidea*, *Sargocentron rubrum*, *Siganus luridus*, *S. rivulatus*, and *Torquigener flavimaculosus* (Tab. 1). In Zakynthos, the only alien species recorded was *S. luridus* (Tab. 1). The mean biomass of alien species in the Kaş and Zakynthos MPAs was 501 (± 87) and 292 (± 41) gr/125 m² respectively (Fig. 1a), corresponding to 42% and 19% of total fish biomass, respectively. In terms of density, the average values were 21 (± 4) in the Kaş-Kekova MPA and 7 (± 1) individuals/125 m² in the Zakynthos MPA (Fig. 1b).

The effect of protection on the overall alien species biomass was significantly different between the protected and unprotected sites only in Zakynthos (pseudo-F = 6.5302, $p = 0.043$). In this MPA, *S. luridus* biomass was significantly higher than in unprotected adjacent areas (see further information in Giakoumi *et al.*, In Press).

Tab. 1: List of alien fishes recorded during visual census surveys in Kaş and Zakynthos and/or present in fishers' catches as reported by small-scale fishers.

| Alien fish species | Kaş visual census | Kaş fishers' catches | Zakynthos visual census | Zakynthos fishers' catches |
|---------------------------------------|----------------------|-------------------------|----------------------------|-------------------------------|
| <i>Fistularia commersonii</i> | ✓ | ✓ | | ✓ |
| <i>Lagocephalus sceleratus</i> | | ✓ | | ✓ |
| <i>Pempheris rhomboidea</i> | ✓ | | | |
| <i>Sargocentron rubrum</i> | ✓ | ✓ | | |
| <i>Siganus luridus</i> | ✓ | ✓ | ✓ | ✓ |
| <i>Siganus rivulatus</i> | ✓ | ✓ | | ✓ |
| <i>Stephanolepis diaspros</i> | | ✓ | | ✓ |
| <i>Torquigener flavimaculosus</i> | ✓ | | | |
| <i>Upeneus moluccensis</i> | | ✓ | | |

**Fig. 1: Composition of native and alien fishes in and out of the Kaş and Zakynthos MPAs in terms of (a) biomass (g/125 m²) and (b) density (individuals/125 m²). The white part of the bar corresponds to native fish and the striped part to aliens.**

In Kaş, fishers reported that the following alien species have occurred in their catches: *Lagocephalus sceleratus*, *F. commersonii*, *Stephanolepis diaspros*, *S. rubrum*, *S. luridus*, *S. rivulatus* and *Upeneus moluccensis* (Tab. 1). When fishers were asked about the change (if any) of alien species abundance in their catches since the year 2000 (year of reference), the majority responded that the abundance of most species decreased except for the abundance of *L. sceleratus* and *U. moluccensis* which increased. Conversely, in

Zakynthos, the abundance of all alien species present in fishers' catches (*L. sceleratus*, *F. commersonii*, *S. diaspros*, *S. luridus* and *S. rivulatus*; Tab. 1) has increased since 2000. In Kaş, all fishers stated that the only discarded alien fish was *L. sceleratus*. Conversely, in Zakynthos all alien fishes were discarded; only one fisher (out of eight) stated that he eats *S. rivulatus* and two that ate *S. diaspros*. In Kaş, all alien species were commercially exploited except for *L. sceleratus*, *F. commersonii*, and *S. diaspros*. In fact, the value of the commercially exploited alien species increased in the past decade with *U. moluccensis* presenting a 4-fold increase in its price since 2000. In Zakyntos, none of the alien species caught had a commercial value.

When fishers were asked about the general state of fish stocks, all fishers in Zakynthos (n=8) stated that fish stocks have been declining whereas in Kaş the opinions were divided, 54% stating that the fish stocks are stable while the rest stating decreasing fish stocks. In Kaş, biological invasions were reported as the main reason for their catches decline whereas in Zakynthos overfishing was identified as the principal cause (Tab. 2). Stopping overfishing and illegal fishing activities by enforcing existing laws was identified as the most important measure to help the recovery of fish stocks by all fishers in both regions. In Kaş, the vast majority of fishers (92%) thought it was equally important to manage and reduce the impacts of invasive alien fishes.

Tab. 2: Reasons explaining the depletion of fish stocks according to fishers' perceptions. Some fishers gave more than one answer.

| Reasons for fish stock depletion | Zakynthos (fishers No) | Kaş (fishers No) |
|---|---------------------------|---------------------|
| Overfishing | 6 | 4 |
| The use of illegal fishing tools by professional fishers (e.g. use of dynamite) | 0 | 2 |
| Recreational fishing - spearfishing | 1 | 4 |
| Illegal fishing practices by recreational fishers | 0 | 0 |
| Large scale fishing (trawlers, purse seiners) | 1 | 0 |
| Pollution | 2 | 4 |
| Climate change | 4 | 1 |
| Lack of law enforcement | 2 | 9 |
| Dolphins, seals, or turtles | 1 | 6 |
| Invasive species | 0 | 13 |

Discussion and conclusions

Invasive alien species are a major threat for Mediterranean marine ecosystems which based on our evidence present equal or greater biomass in MPAs than in unprotected areas. This evidence suggests that additional management actions are required in MPAs for the control of invasive alien fish populations (Giakoumi *et al.*, In Press).

In both MPAs, the biomass of the herbivore alien fish *S. luridus* was particularly high. In the Kaş-Kekova MPA, *S. rivulatus* was also present. Evidence shows that the combined grazing effect of these two herbivore fishes can create barrens (rocky reefs deprived of vegetation) and consequently lead to biodiversity impoverishment (Vergés *et al.*, 2014). Although other factors (abiotic and biotic) can contribute to the creation of barrens,

limiting the grazing activity of these alien fishes in Mediterranean MPAs by controlling their populations should be a management priority.

The region of Kaş in the Levantine Sea has been exposed to biological invasions for a longer period than Zakynthos in the Ionian Sea. This fact has affected the way local fishers perceive the impact of invasive species on marine ecosystems. In highly impacted Mediterranean areas, such as the Levantine and South Aegean Seas, fishers perceive biological invasions as a major reason for the decrease in their catches (see also Panagopoulou *et al.*, 2017). More specifically, the high level predator fish *L. sceleratus* is perceived to cause serious damages to the small-scale fishing gears. At the same time, this fish being extremely poisonous cannot be commercially exploited.

The period of invasion exposure is also related to the commercial value attributed to alien fishes. In Kaş, where currently almost half of the fish biomass corresponds to alien species, most of these species are consumed and their commercial value has been increasing. Conversely, in Zakynthos, where fish invasion is relatively recent, alien species are discarded from fishers' catches and they are not commercially exploited. Increasing the consumption of alien fishes, and particularly of *S. luridus*, through marketing and targeted removal, could benefit substantially native marine communities and increase fishers' income.

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