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## Introduction

Alien species introduction in the Mediterranean Sea is outstanding when compared to other seas and oceanic areas (Galil, 2000; Boudouresque, 2008), harbouring the greatest number of introduced species in the world's oceans (Boudouresque and Verlaque, 2002a). Macroalgae stands as one of the most important groups of alien species and some of them are able to change the seascape and compromise the functioning of marine ecosystems when they become invasive (Boudouresque, 2008). Total number of introduced macrophyte taxa depend on different estimations but should range between 80 and 128 (Boudouresque and Verlaque, 2002a, b; Cormaci *et al.*, 2004; Zenetos *et al.*, 2012), with a high percentage of invasive or potentially invasive species (Boudouresque and Verlaque, 2002b; Zenetos *et al.*, 2010).

A species belonging to the genus *Batophora* J. Agardh and tentatively identified as *Batophora occidentalis* var. *largoensis* (J.S Prince and S. Baker) S. Berger and Kaefer ex M.J. Wynne was found in 2020 in Estany des Peix, a coastal lagoon from Formentera (Balearic Islands) (Fig. 1), when it was already significant (Ballesteros, 2020). The geographical range of the genus *Batophora* includes the tropical and subtropical Atlantic coasts, including the Caribbean and the Gulf of Mexico (Taylor, 1960) and has been recently reported from Tenerife (Canary Islands Eastern Atlantic) (Reyes *et al.*, 1993), Mar



**Fig. 1.** Situation of Estany des Peix and Estany Pudent in Formentera.

**Fig. 1.** Situació de s'Estany des Peix i s'Estany Pudent a Formentera.

Menor (Spain, Mediterranean Sea) (Terradas-Fernández *et al.*, 2022) and Taranto (Italy, Mediterranean Sea) (Cormaci *et al.*, 2004). In its native distribution area *Batophora* grows on quiet waters of lagoons, inlets and estuaries as well as over mangrove roots (Gómez-Poot *et al.*, 2002; Rodríguez-Reyes *et al.*, 2018; Littler and Littler, 2000). The sudden and rapid proliferation of this alga in Estany des Peix, mimicking what it has been observed in Mar Menor (Terradas-Fernández *et al.*, 2022) suggested an aggressive invasive behaviour and it was recommended to monitor the evolution of the invasion in the future (Ballesteros, 2020). Here we follow



**Fig. 2.** Presence of *Batophora* (red dots) along the perimeter of Estany des Peix in november 2020. Aerial picture year 2021.

**Fig. 2.** Presència de *Batophora* (punts vermells) al llarg del perímetre de s'Estany des Peix al novembre de 2020. Ortofoto any 2021.



**Fig. 3.** Presence of *Batophora* (red dots) along the perimeter of Estany des Peix in November 2021. Aerial picture year 2021.

**Fig. 3.** Presència de *Batophora* (punts vermells) al llarg del perímetre de s'Estany des Peix al novembre de 2021. Ortofoto any 2021.



**Fig. 4.** Presence of *Batophora* (red dots) along the perimeter of Estany des Peix in September 2022. Aerial picture year 2021.

**Fig. 4.** Presència de *Batophora* (punts vermells) al llarg del perímetre de s'Estany des Peix al setembre de 2022. Ortofoto any 2021.



**Fig. 5.** Presence of *Batophora* (red dots) along the perimeter of Estany des Peix, at the entrance of Estany des Peix and at the channel connecting the open sea and the Estany Pudent in November 2023. Aerial picture year 2021.

**Fig. 5.** Presència de *Batophora* (punts vermells) al llarg del perímetre de s'Estany des Peix, a l'entrada de s'Estany des Peix i al canal que connecta el mar obert amb s'Estany Pudent al novembre de 2023. Ortofoto any 2021.

this recommendation and present the results of the *Batophora* expansion obtained between 2020 and 2023 in the lagoon of Estany des Peix and surrounding areas.

## Material and Methods

The monitoring of the presence of *Batophora* along the perimeter of Estany des Peix was performed by walking along the la-

goon shore between 0 and 50 cm depth, obtaining the GPS positions of the areas where the alga was found. The open sea area adjacent to the lagoon was also prospected. Monitoring was performed in November 2020, November 2021, September 2022 and November 2023. In October 2022, prospections were made in 369 sites of the

lagoon, at depths higher than 0.5 m, down to the deepest point of the lagoon (4.9 m). The open sea close to the entrance of the lagoon was also surveyed by free diving, as well as the harbour of La Savina and the entrance of the Estany Pudent (Sa Síquia). Habitat classification follows Templado *et al.* (2012), Ballesteros and Cebrian (2015) and Ballesteros (2019).

## Results

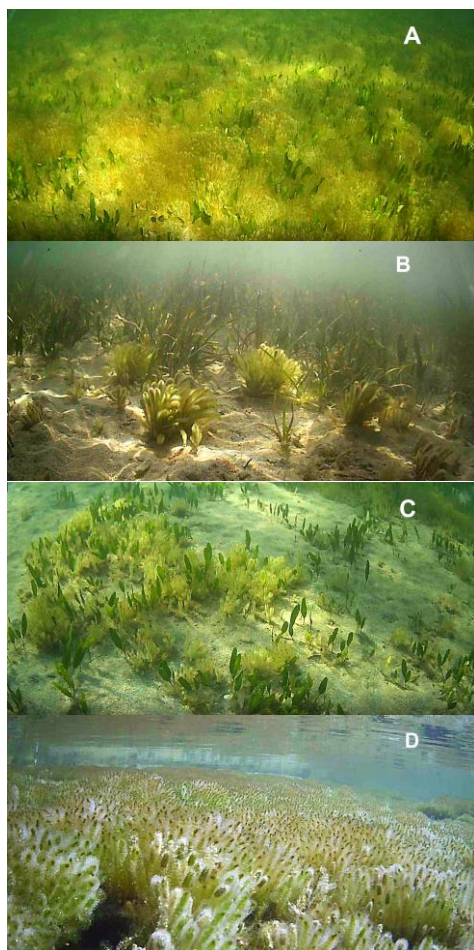
Eighteen percent of the lagoon perimeter showed the presence of *Batophora* in November 2020, with hot spots in the very shallow areas of the Estanyets, small and extremely shallow water bodies situated in the west side, and at the north east side (Fig. 2). This distribution pattern did not change much one year later, in November 2021 (Fig. 3), but increased substantially two years later (September 2022) (Fig. 4), when almost 100% of the perimeter of the lagoon showed the presence of *Batophora*. The same values were reported by November 2023 (Fig. 5). Free diving performed in October 2022 reported presence of *Batophora* in 93% of the 369 sites surveyed below 0.5 m depth, meaning that *Batophora* was already present in most of the lagoon. By the end of year 2023 *Batophora* became the most abundant macrophyte in Estany des Peix, growing over all kind of habitats and substrates (Fig. 6). In fact, not a single habitat was not colonized by *Batophora*, including *Caulerpa prolifera* (Forsskal) Lamouroux beds (LPRE code 0305130201), mixed *Ruppia cirrhosa* (Petagna) Grande, *Zostera noltii* Hornemann and *Cymodocea nodosa* (Ucria) Ascherson meadows (LPRE code 03051301), lagoonal muddy sands (LPRE code 03040217), infralittoral very fine, fine and medium sands (LPRE code 03040220) and sheltered infralittoral rock,

well illuminated, with *Dasycladus vermicularis* (Scopoli) Kraser and *Acetabularia acetabulum* (Linnaeus) P.C. Silva (LPRE code 03010030702). *Batophora* also grew abundantly over dead *Posidonia oceanica* (Linnaeus) Delile leaves and over all man-made structures present in the lagoon, such as boat hulls, jetties, ropes, car wheels and permanent anchorages (Fig. 7).

Surveys in November 2023 also detected the presence of *Batophora* outside the lagoon, in an area situated 100 m west and 50 m east from the entrance of the lagoon to a depth of 3 meters (Fig. 5). In the open sea *Batophora* colonized rocky bottoms, sandy areas and the margins of *Posidonia oceanica* meadows, where dead rhizome was present (LPRE code 03051203). *Batophora* was not found in the harbour of La Savina but it was present along the channel connecting the open sea with the Estany Pudent (Sa Síquia), along a length of 40 m (Fig. 5), over rocky bottom.

## Discussion

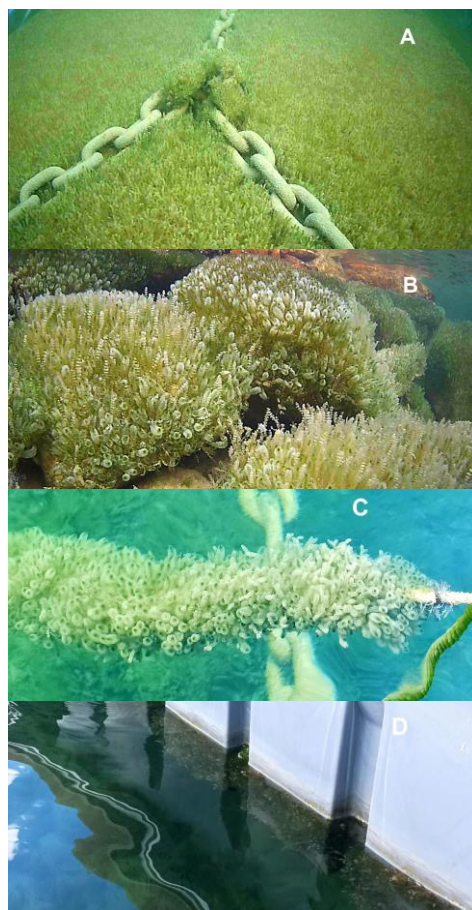
Four years after the first report of *Batophora* in Estany des Peix this tropical alien alga colonized almost all available habitats and substrates in the lagoon, from rocky habitats, sedimentary bottoms, algal beds, seagrass meadows to man-made structures. Not a single habitat was free from colonization, sometimes with astonishing coverage. *Batophora* was already colonizing some areas situated outside the lagoon, in the open sea, as well as at the entrance channel of Estany Pudent, a brackish water lagoon situated close to Estany des Peix. Estany des Peix being an area where a lot of small boats are permanently anchored and, given the high capacity of *Batophora* of growing over any kind of substrate including



**Fig. 6.** Different habitats colonized by *Batophora* in Estany des Peix: A) *Caulerpa prolifera* bed. B) *Cymodocea nodosa* and *Caulerpa prolifera* meadow from Els Estanyets. C) Sandy bottoms with *Caulerpa prolifera*. D) Shallow rocky bottoms.

**Fig. 6.** Hàbitats diferents colonitzats per *Batophora* a l'Estany des Peix: A) Alguer de *Caulerpa prolifera*. B) Alguer de *Cymodocea nodosa* i *Caulerpa prolifera* dels Estanyets. C) Fons sorrencs amb *Caulerpa prolifera*. D) Fons rocósos superficials.

boat hulls, boats whose permanent anchorage is at Estany des Peix can easily spread the alien alga to the rest of Formente-



**Fig. 7.** Colonization of man-made structures by *Batophora* in Estany des Peix: A) Concrete permanent anchorages. B) Blocks deployed to hold the pillars of the new jetties. C) Ropes. D) Floating jetty structures.

**Fig. 7.** Colonització per *Batophora* d'estructures artificials a l'Estany des Peix. A) Morts de formigó. B) Blocs de contenció dels pilars dels molls nous. C) Caps. D) Estructures flotants dels molls.

ra and the neighbouring island of Eivissa. Fortunately, until now, *Batophora* has not been detected in La Savina harbour, the main and only harbour in Formentera which, in case of colonization, could foster its spread across the Balearic Islands. The same

species of *Batophora* has been recently reported from Mar Menor lagoon, situated in the eastern coast of Spain (Terradas-Fernández *et al.*, 2022), at a rough distance of 220 km from Estany des Peix. The fact that this species has not spread out to the open sea in Mar Menor suggests that *Batophora* has probably some trouble in colonizing open sea areas but this possibility cannot be disregarded.

We still do not know the phenological features of *Batophora* in Estany des Peix and how many cohorts are happening during the year. In the tropical Gulf of Mexico, *Batophora* is fertile all over the year (Quan-Young *et al.*, 2006), probably showing several cohorts, which could not be the case in Formentera since the Mediterranean is a warm-temperate sea and temperature decreases down to less than 15°C in winter, probably hampering reproduction. Despite the lack of this information and considering the large extension and cover of *Batophora* in the lagoon, its colonization has profoundly changed the macroalgal composition of the habitats and it may have increased organic matter production, with cascading effects on macroinvertebrate assemblages studied by Ballesteros *et al.* (2008). Quantitative information on the macroalgal and macroinvertebrate assemblages is necessary to know the effect of the invasion on the biodiversity of the lagoon as well as in its biological functionality. It would be also necessary to perform a phenological study focused on the biomass cycle, number of cohorts and reproduction patterns of *Batophora* in Estany des Peix in order to quantify the increase in the yearly organic matter produced in the lagoon, which is now available to consumers and detritivores.

Due to the relevance of Estany des Peix in the Natural Park and Marine Protected Area of "Freus d'Eivissa i Formentera" and

the high value of this area in the context of marine biodiversity protection in the Balearic Islands, we ask for a yearly monitoring of the expansion of *Batophora* inside but also (and mainly) outside the lagoon, especially in La Savina harbour. We also propose some management plan or mechanism that avoid boats permanently anchored in the lagoon and whose hulls are colonized by *Batophora* to leave Estany des Peix and go to other areas of the MPA or to Eivissa, in order to reduce the risks of expansion of the alga outside the lagoon. Otherwise, the probability of finding *Batophora* in other places in the following years will exponentially increase. In the Mediterranean Sea we already have an example of a species previously restricted to a lagoon that has recently spread to open sea areas causing deleterious effects to other macroalgae and changing the infralittoral seascape on wide areas: *Rugulopteryx okamurae* (E.Y. Dawson) I.K. Hwang, W.J. Lee & H.S. Kim (Verlaque *et al.*, 2009; García-Gómez *et al.*, 2020, 2021; Ruitton *et al.*, 2021). Although it is still early to make an adequate assessment of the risks of *Batophora* to behave as *Rugulopteryx okamurae*, to disregard the possibility of this species to widely colonize open sea areas would be naive and irresponsible due to the large threats that such an invasion could pose to marine infralittoral habitats in the Balearic Islands and other warm, sheltered places of the Mediterranean Sea.

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