diversity

MDPI

Interesting Images

Possible Interactions between Invasive *Caulerpa* Taxa and Native Macrozoobenthos: The Case Study of Favignana Island

Anna Maria Mannino [1,2,*] and Paolo Balistreri [3]

[1] Department of Biological, Chemical and Pharmaceutical Sciences and Technologies, University of Palermo, 90123 Palermo, Italy

[2] National Biodiversity Future Center (NBFC), 90133 Palermo, Italy

[3] Independent Researcher, 91100 Trapani, Italy; requin.blanc@hotmail.it

* Correspondence: annamaria.mannino@unipa.it

Abstract: Biological invasions are widely recognized as a major threat to native biodiversity, ecosystem functioning and services. Amongst the NIS recorded in the Mediterranean Sea, Chlorophyta species belonging to the genus *Caulerpa* (*Caulerpa cylindracea*, *C. taxifolia* and *C. taxifolia* var. *distichophylla*) have raised serious concerns due to their potential or ascertained impact on native benthic communities. During surveys carried out to monitor the occurrence and the coverage of *Caulerpa* species along the coasts of Favignana Island (Egadi Islands Marine Protected Area), we observed variations in *C. cylindracea* and *C. taxifolia* coverage and also some large invertebrates overgrown with thalli of both species.

Keywords: camouflage; *Caulerpa cylindracea*; *Caulerpa taxifolia*; *Holothuria* (*Holothuria*) *tubulosa*; secondary spread; Sicily; Egadi Islands

check for updates

Citation: Mannino, A.M.; Balistreri, P. Possible Interactions between Invasive *Caulerpa* Taxa and Native Macrozoobenthos: The Case Study of Favignana Island. *Diversity* **2023**, *15*, 919. https://doi.org/10.3390/d15080919

Academic Editors: Andrea Bonifazi, Emanuele Mancini and Bert W. Hoeksema

Received: 20 July 2023
Revised: 7 August 2023
Accepted: 8 August 2023
Published: 9 August 2023

Non-indigenous species (NIS) are widely recognized as one of the main drivers of global change, threatening native biodiversity, ecosystem functioning and services. Under favorable conditions, NIS may become invasive (Invasive Alien Species "IAS"), causing significant environmental impacts, such as biodiversity loss and ecosystem services degradation. The Mediterranean Sea is particularly vulnerable to NIS introduction [1,2], and in recent decades, there has been a rapid increase (estimated to be eight species per year for the whole Mediterranean basin) of NIS with an expansion of tropical and sub-tropical species. The Sicilian islands (the Central Mediterranean Sea, Italy) and all the Marine Protected Areas (MPAs) they host are notably prone to marine biological invasions, due to their strategic position at the crossroads between the South Western and Eastern Mediterranean Sea, by virtue of the intense maritime traffic skirting the region and Lessepsian migrations [3–8].

Amongst the NIS recorded in the Mediterranean Sea, Chlorophyta species belonging to the *Caulerpa* genus (*Caulerpa cylindracea* Sonder, *Caulerpa taxifolia* (M. Vahl) C. Agardh and *Caulerpa taxifolia* var. *distichophylla* (Sonder) Verlaque, Huisman and Procaccini), which have raised serious concerns due to their potential or ascertained impact on native communities, are actually considered IAS [8–10].

Since 2014, surveys have been regularly carried out in the Egadi Islands MPA to monitor the occurrence and the coverage of green algae belonging to the *Caulerpa* genus [11,12]. The Egadi Islands MPA is the largest Italian MPA, comprising three main islands: Favignana, Marettimo, and Levanzo. The surveys, carried out within the projects *Caulerpa cylindracea*—Egadi Islands and Aliens in the Sea, showed a wide distribution of *C. cylindracea* along the coasts of the MPA. In all probability, anchorage activities, and in general maritime traffic, represent an important pathway for the spread of *C. cylindracea* within the MPA.

On the contrary, the presence of *C. taxifolia* was punctiform, being recorded only at Bue Marino, Cala Fumere, Praia, Punta Marsala, and Arrè Turino till 2018 ([13,14], authors' observations). In 2019, the presence of *C. taxifolia* was observed for the first time at the entrance of Cala San Nicola (37.93012 N, 12.32585 E) (Figure 1).

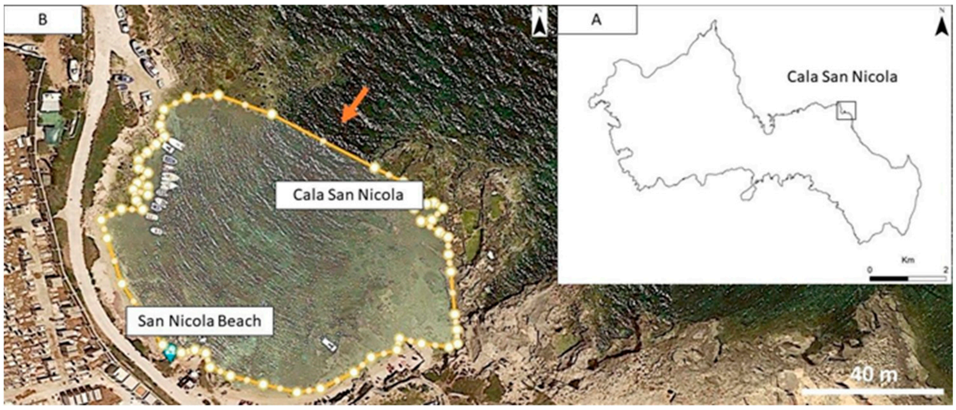

Figure 1. The study area: (**A**) Favignana Island; (**B**) Cala San Nicola (northern coast of Favignana Island) is characterized by a surface of 5.817 m^2 and a perimeter of 330.62 m (from Google Earth). The arrow indicates the entrance to the Cala.

This site presents a sandy bottom inhabited in the central part by a *Posidonia oceanica* (L.) Delile meadow. The coast is characterized by sand, calcarenite and a vermetid reef, a bioconstruction built up mainly by the gastropod mollusc *Dendropoma cristatum* (Biondi, 1859) (Vermetidae) in association with some coralline algae such as *Neogoniolithon brassica-florida* (Harvey) Setchell et Mason. In August 2021 a survey was carried out within the Cala San Nicola to monitor the distribution of both species, *C. cylindracea* and *C. taxifolia* (Figure 2).

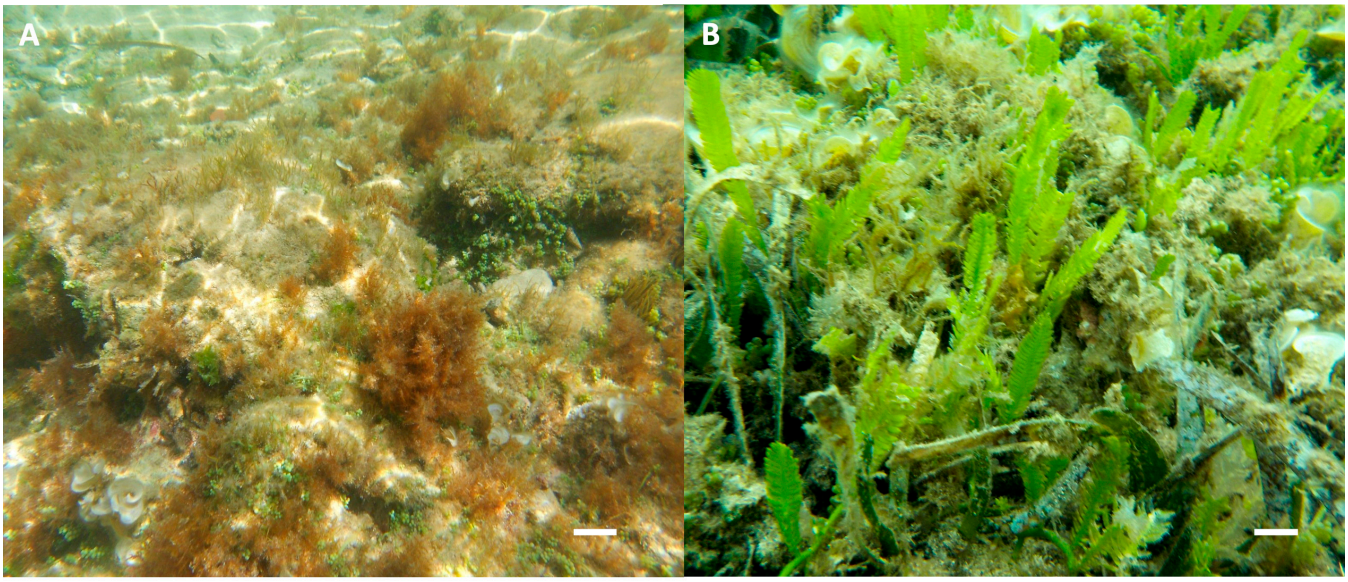

Figure 2. *Caulerpa* species: (**A**) patches of *Caulerpa cylindracea*. Scale bar: 4 cm; (**B**) thalli of *Caulerpa taxifolia*. Scale bar: 3.5 cm. Photo credit: Paolo Balistreri.

Caulerpa cylindracea was observed near the coast, and a decrease in coverage (from values over 50% to a value of about 20%) with respect to previous observations was highlighted [11]. Instead, a significant increase in *C. taxifolia* (whose patches reached a coverage of about 50%) was registered. The patches of *C. taxifolia* covered 30% of the rhizomes of *P. oceanica*, and for the remaining 20%, there was a mixed bottom (sand–

rock). Surveys carried out in July 2023 highlighted a further reduction in the coverage of *C. cylindracea* (from 20% to 5%), which also showed very short thalli (about 2 cm high), together with a consistent reduction in *C. taxifolia* (from 50% to 5–10%). Many vertebrate and invertebrate species are reported to feed on *C. cylindracea*, for instance, *Oxynoe olivacea* (Rafinesque, 1814), *Paracentrotus lividus* (Lamarck, 1816), *Holothuria* (*Roweothuria*) *poli* Delle Chiaje, 1824, *Sarpa salpa* (Linnaeus, 1758) and *Diplodus sargus* (Linnaeus, 1758) [15,16]. It is well known that feeding on *C. cylindracea* may have negative effects as a consequence of the caulerpin it contains [15–18]. However, *C. cylindracea* exhibits great spread and regeneration abilities that allow it to tolerate a wide range of grazing intensities. Indeed, it can easily recover by regenerating from detached fragments of stolons and fronds [19,20].

During the surveys, we also observed several individuals of *Holothuria (Holothuria) tubulosa* Gmelin, 1791 and only one individual of *Holothuria* (*Roweothuria*) *poli* overgrown with a few thalli of *C. cylindracea* and *C. taxifolia* (August 2021, San Nicola, Figures 3 and 4). Both of these holothurians are common and widespread in the coastal areas of the Mediterranean Sea [16], are "continuous" deposit-feeders that can ingest and rework large amounts of sediment, and can have a role in the recycling of seagrass detritus in *P. oceanica* meadows [21,22].

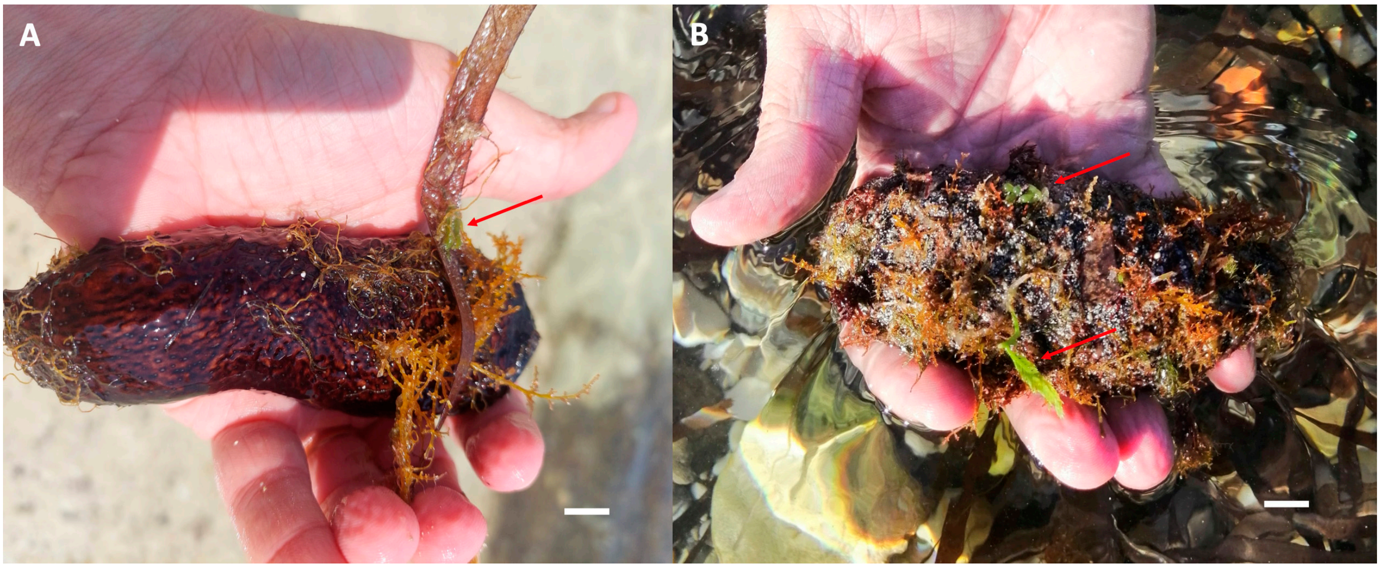

Figure 3. Individuals of *Holothuria* spp.: (**A**) *Holothuria* (*Roweothuria*) *poli* overgrown with *Caulerpa cylindracea* (arrow); (**B**) *Holothuria* (*Holothuria*) *tubulosa* overgrown with *Caulerpa cylindracea* (upper arrow) and *Caulerpa taxifolia* (lower arrow). Scale bar: 1 cm. Photo credit: Paolo Balistreri.

This finding would suggest a possible interaction for the purposes of camouflage, i.e., animals are hidden by decorating themselves with parts of organisms, some of which being algae [23]. This strategy, costly in terms of time and energy, is well known for Decapoda (Crustacea) and Echinodermata to avoid their predators. Indeed, we also observed individuals of the crab *Maja crispata* (Risso, 1827) overgrown with *C. cylindracea* (San Giuseppe, 2017; Figure 4) and individuals of the echinoderm *Sphaerechinus granularis* (Lamarck, 1816) covered by a few thalli of *C. cylindracea* (Figure 5).

Decoration in majid species is well known; some of them showed a preference for macroalgae and also opportunistic behavior by using what is available at the site [24]. Since *Caulerpa* taxa contain toxic substances which discourage predators, we hypothesize that a passive mutualistic interaction may be established between *Caulerpa* taxa and their hosts. In particular, it is possible that the host uses *Caulerpa* both as camouflage and as a deterrent for predators, while *Caulerpa* uses the host as a pathway of secondary spread to invade new areas inhabited by both native macroalgal communities and *P. oceanica* meadows.

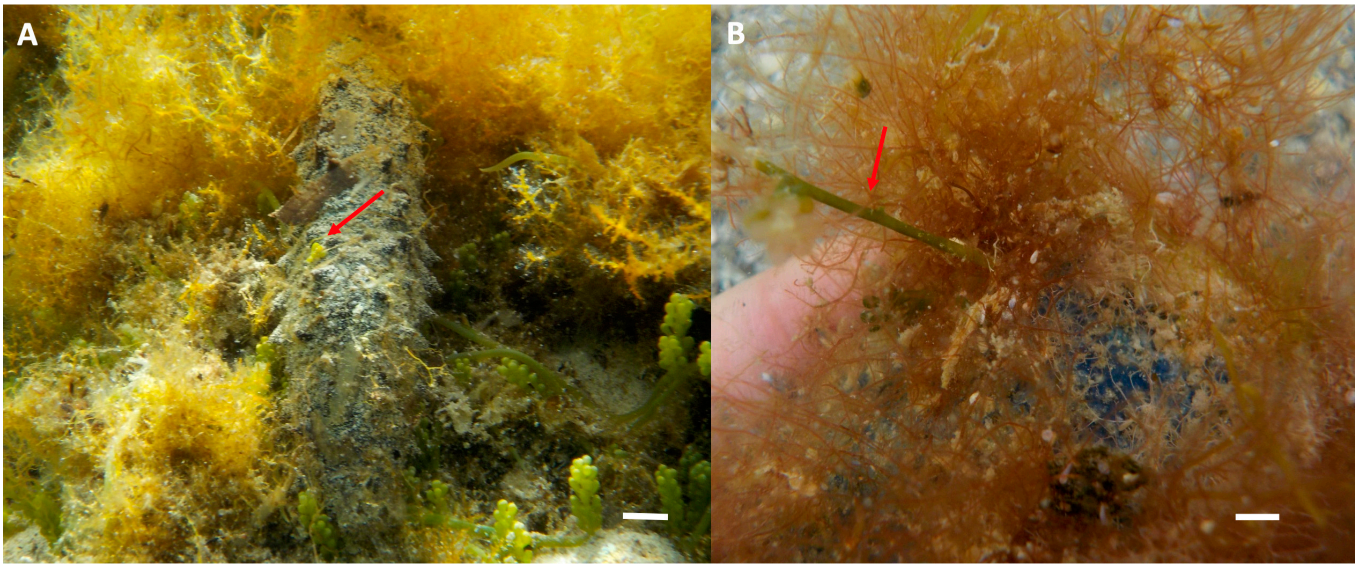

Figure 4. Two examples of camouflage: (**A**) *Holothuria (Holothuria) tubulosa* overgrown with *C. cylindracea* (arrow) moving on the substrate; (**B**) an individual of the crab *Maja crispata* overgrown with *C. cylindracea* (the arrow indicates a long stolon). Scale bar: 1 cm. Photo credit: Paolo Balistreri.

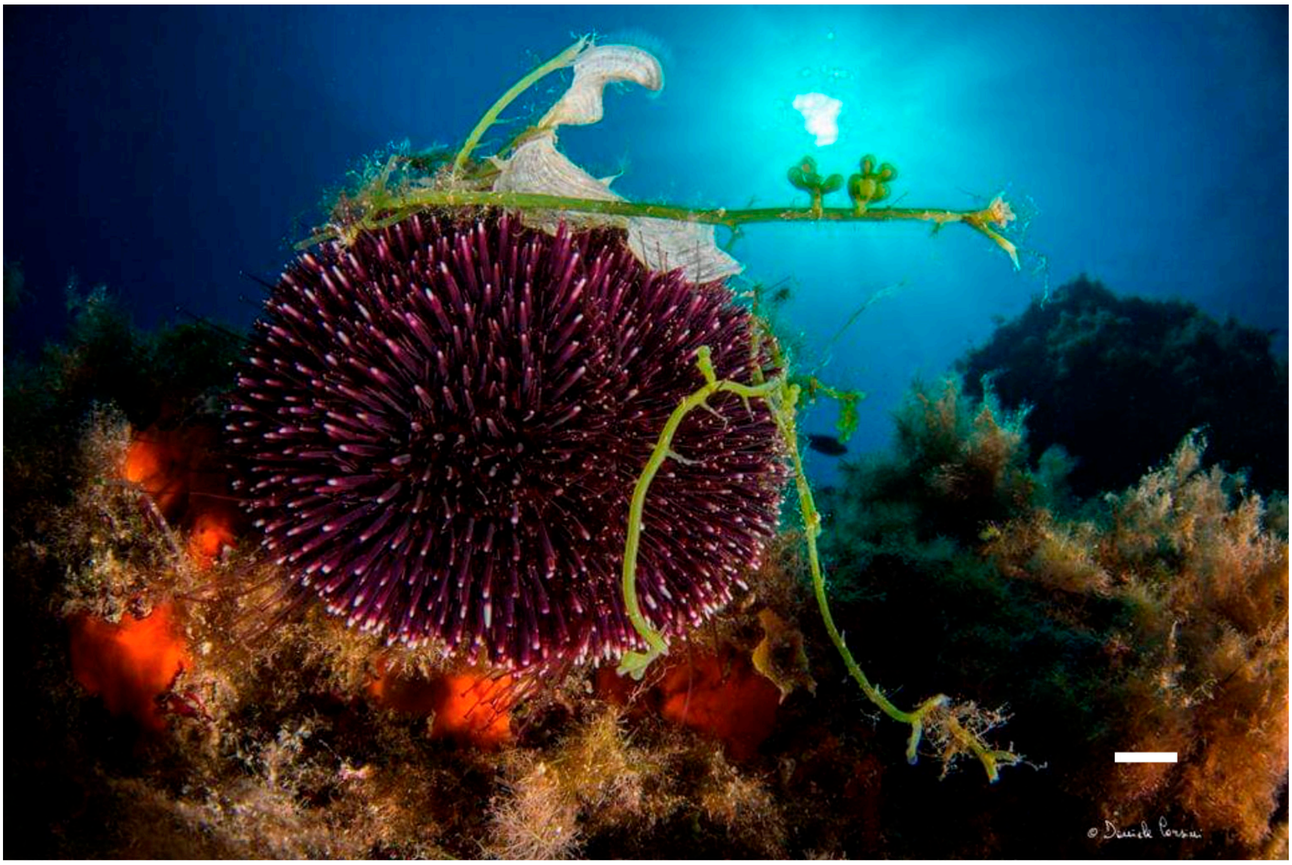

Figure 5. An individual of *Sphaerechinus granularis* covered by *C. cylindracea* (Trapani). Scale bar: 1 cm. Photo credit: Daniele Corsini.

However, selectivity in camouflage has been demonstrated, suggesting that decoration behavior is a more complex process than is generally recognized. Animals that cover themselves with natural substrates can increase their protection by selecting items that are defended against larger omnivorous consumers [25]. McLay (2020) also proposed the hypothesis of the evolution of masking, from passive to active camouflage [26].

Moreover, it is known that some crabs also use organisms decorating their body as a food store, whose ingestion rate is highest when they are deprived of other sources of food [27]. These observations highlight the need for regular monitoring activity on NIS, particularly in MPAs, to have accurate and regularly updated information on their current distribution, spread dynamics and strategies, abundance, and pathways of introduction. In this respect, Citizen Science activities could significantly improve the efficacy of monitoring plans.

Author Contributions: Conceptualization, A.M.M. and P.B.; methodology, A.M.M. and P.B.; formal analysis, A.M.M. and P.B.; writing—original draft preparation, A.M.M. and P.B.; writing—review and editing, A.M.M. and P.B. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: We wish to thank Daniele Corsini for providing the photo.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Streftaris, N.; Zenetos, A. Alien marine species in the Mediterranean—The 100 worst invasives and their impact. *Mediterr. Mar. Sci.* **2006**, *7*, 87–118. [CrossRef]
2. Zenetos, A.; Galanidi, M. Mediterranean non-indigenous species at the start of the 2020s: Recent changes. *Mar. Biodivers. Rec.* **2020**, *13*, 10. [CrossRef]
3. Occhipinti-Ambrogi, A.; Marchini, A.; Cantone, G.; Castelli, A.; Chimenz, C.; Cormaci, M.; Froglia, C.; Furnari, G.; Gambi, M.C.; Giaccone, G.; et al. Alien species along the Italian coasts: An overview. *Biol. Invasions* **2010**, *13*, 215–237, Erratum in *Biol. Invasions* **2010**, *13*, 531–532. [CrossRef]
4. Katsanevakis, S.; Coll, M.; Piroddi, C.; Steenbeek, J.; Lasram, F.B.R.; Zenetos, A.; Cardoso, A.C. Invading the Mediterranean Sea: Biodiversity patterns shaped by human activities. *Front. Mar. Sci.* **2014**, *1*, 32. [CrossRef]
5. Mannino, A.M.; Balistreri, P.; Yokeş, M.B. First record of *Aplysia dactylomela* (Opisthobranchia: Aplysiidae) from the Egadi Islands (western Sicily). *Mar. Biodivers. Rec.* **2014**, *7*, E22. [CrossRef]
6. Mannino, A.M.; Parasporo, M.; Crocetta, F.; Balistreri, P. An updated overview of the marine alien and cryptogenic species from the Egadi Islands Marine Protected Area (Italy). *Mar. Biodivers.* **2016**, *47*, 469–480. [CrossRef]
7. Mannino, A.M.; Gambi, M.C.; Dieli, T.; Gianguzza, P. A new contribution to the alien macroalgal flora of the Ustica Island Marine Protected Area (Tyrrhenian Sea, Italy). *BioInvasions Rec.* **2018**, *7*, 367–373. [CrossRef]
8. Mannino, A.M.; Cicero, F.; Toccaceli, M.; Pinna, M.; Balistreri, P. Distribution of *Caulerpa taxifolia* var. *distichophylla* (Sonder) Verlaque, Huisman & Procaccini in the Mediterranean Sea. *Nat. Conserv.* **2019**, *37*, 17–29. [CrossRef]
9. Boudouresque, C.F.; Meinesz, A.; Ribera, M.A.; Ballesteros, E. Spread of the green alga *Caulerpa taxifolia* (Caulerpales, Chlorophyta) in the Mediterranean: Possible consequences of a major ecological event. *Sci. Mar.* **1995**, *59* (Suppl. S1), 21–29.
10. Klein, J.; Verlaque, M. The *Caulerpa racemosa* invasion: A critical review. *Mar. Pollut. Bull.* **2008**, *56*, 205–225. [CrossRef] [PubMed]
11. Mannino, A.M.; Balistreri, P. Citizen science: A successful tool for monitoring invasive alien species (IAS) in Marine Protected Areas. The case study of the Egadi Islands MPA (Tyrrhenian Sea, Italy). *Biodiversity* **2018**, *19*, 42–48. [CrossRef]
12. Mannino, A.M.; Balistreri, P. Invasive alien species in Mediterranean Marine Protected Areas: The Egadi Islands (Italy) case study. *Biodiversity* **2021**, *22*, 13–23. [CrossRef]
13. Gianguzza, P.; Bonaviri, C.; Zava, B.; Monteverde, G.; Riggio, S. Spread of *Caulerpa taxifolia* (Caulerpales, Ulvophyceae) along the coasts of Favignana Island. *Biol. Mar. Medit.* **2006**, *13*, 182–183.
14. Gianguzza, P.; Zava, B.; Bonaviri, C.; Monteverde, G.; Palmeri, A.; Riggio, S. First record of *Caulerpa taxifolia* (Caulerpales, Ulvophyceae) in the western Sicilian waters (Italy). *Biol. Mar. Medit.* **2006**, *13*, 591–592.
15. Miccoli, A.; Mancini, E.; Boschi, M.; Provenza, F.; Lelli, V.; Tiralongo, F.; Terlizzi, A.; Bonamano, S.; Marcelli, M. Trophic, chemo-ecological and sex-specific insights on the relation between Diplodus sargus (Linnaeus, 1758) and the invasive Caulerpa cylindracea (Sonder, 1845). *Front. Mar. Sci.* **2021**, *8*, 680787. [CrossRef]

16. Rizzo, L.; Vega Fernández, T. Can the invasive seaweed *Caulerpa cylidracea* represent a new trophic resource in the Mediterranean Sea? *Water* **2023**, *15*, 2115. [CrossRef]
17. Terlizzi, A.; Felline, S.; Lionetto, M.G.; Caricato, R.; Perfetti, V.; Cutignano, A.; Mollo, E. Detrimental physiological effects of the invasive alga *Caulerpa racemosa* on the mediterranean white seabream *Diplodus sargus*. *Aquat. Biol.* **2011**, *12*, 109–117. [CrossRef]
18. Felline, S.; Mollo, E.; Cutignano, A.; Grauso, L.; Andaloro, F.; Castriota, L.; Consoli, P.; Falautano, M.; Sinopoli, M.; Terlizzi, A. Preliminary observations of caulerpin accumulation from the invasive *Caulerpa cylindracea* in native Mediterranean fish species. *Aquat. Biol.* **2017**, *26*, 27–31. [CrossRef]
19. Ruitton, S.; Verlaque, M.; Aubin, G.; Boudouresque, C.F. Grazing on *Caulerpa racemosa* var. *cylindracea* (Caulerpales, Chlorophyta) in the Mediterranean Sea by herbivorous fishes and sea urchins. *Vie Milieu-Life Environ.* **2006**, *56*, 33–41.
20. Bulleri, F.; Malquori, F. High tolerance to simulated herbivory in the clonal seaweed, *Caulerpa cylindracea*. *Mar. Environ. Res.* **2015**, *107*, 61–65. [CrossRef] [PubMed]
21. Boncagni, P.; Rakaj, A.; Fianchini, A.; Vizzini, S. Preferential assimilation of seagrass detritus by two coexisting Mediterranean and sea cucumbers: *Holothuria polii* and *Holothuria tubulosa*. *Estuar. Coast.* **2019**, *231*, 106464. [CrossRef]
22. Pasquini, V.; Addis, P.; Giglioli, A.A.; Moccia, D.; Pusceddu, A. Outcomes of feeding activity of the sea cucumber *Holothuria tubulosa* on quantity, biochemical composition, and nutritional quality of sedimentary organic matter. *Front. Mar. Sci.* **2023**, *9*, 1010014. [CrossRef]
23. Bedini, R.; Canali, M.G.; Bedini, A. Use of camouflaging materials in some brachyuran crabs of the Mediterranean infralittoral zone. *Cah. Biol. Mar.* **2003**, *44*, 375–384.
24. Tanduo, V.; Virgili, R.; Osca, D.; Crocetta, F. Hiding in fouling communities: A native spider crab decorating with a cryptogenic bryozoan in a Mediterranean marina. *J. Mar. Sci. Eng.* **2021**, *9*, 495. [CrossRef]
25. Cruz-Rivera, E. Generality and specificity in the feeding and decoration preferences of three Mediterranean crabs. *J. Exp. Mar. Biol. Ecol.* **2001**, *266*, 17–31. [CrossRef]
26. McLay, C.L. Camouflage by the masking crab, *Notomithrax ursus* (Herbst, 1788) (Decapoda: Brachyura: Majidae): Is it a decorator or a dressmaker? *J. Crust. Biol.* **2020**, *40*, 673–683. [CrossRef]
27. Woods, C.M.C.; McLay, C.L. Use of camouflage materials as a food store by the spider crab *Notomithrax ursus* (Brachyura: Majidae). *N. Z. J. Mar. Fresh. Res.* **1994**, *28*, 97–104. [CrossRef]