

First records of *Sphyraena chrysotaenia* (Klunzinger, 1884) and *Diadema setosum* (Leske, 1778) in the Marine Protected Area of Zakynthos Island (Ionian Sea, Greece)

Charalampos Dimitriadis¹, Erika F. Neave^{2,3}, Peter Shum², Stefano Mariani²,
Manuela D'Amen^{4,5,6*} and Ernesto Azzurro^{5,6}

¹National Marine Park of Zakynthos, Zakynthos, Greece

²Biological & Environmental Sciences, Liverpool John Moores University, Liverpool, United Kingdom

³Department of Life Sciences, Natural History Museum, London, United Kingdom

⁴ISPRA, Italian Institute for Environmental Protection and Research, Roma, Italy

⁵IRBIM, Institute of Biological Resources and Marine Biotechnologies – CNR, National Research Council, Ancona, Italy

⁶SZN – Stazione Zoologica Anton Dohrn Naples, Napoli, Italy

Abstract: In 2021, three specimens of the Lessepsian yellowstripe barracuda *Sphyraena chrysotaenia* and eight specimens of the Indo-Pacific needle-spined sea urchin *Diadema setosum* were recorded along the coasts of Zakynthos Island, some within the Marine Protected Area.

Keywords: Invasive species; local ecological knowledge; Mediterranean Sea; Indo-Pacific needle-spined sea urchin; yellowstripe barracuda

Sažetak: PRVI NALAZ TUPOUSNE BARAKUDE *SPHYRAENA CHRYSOTAENIA* (KLUNZINGER, 1884.) I INDO-PACIFIČKE VRSTE JEŽINCA *DIADEMA SETOSUM* (LESKE, 1778.) U MORSKOM ZAŠTIĆENOM PODRUČJU OTOKA ZAKINTOS, JONSKO MORE, GRČKA). U 2021. godini, tri primjerka lesepsijske tupousne barakude *Sphyraena chrysotaenia* i osam primjeraka indo-pacifičke vrste ježinca *Diadema setosum* su pronađeni u području oko otoka Zakintos, neki unutar morskog zaštićenog područja.

Ključne riječi: invazivna vrsta; lokalno ekološko znanje; Sredozemno more; indo-pacifički ježinac; tupousna barakuda

INTRODUCTION

The Yellowstripe barracuda *Sphyraena chrysotaenia* is a Lessepsian invader recorded for the first time in Palestine under the misidentification of *Belone acus* (Spicer, 1931). The species is currently very common in large parts of the eastern Mediterranean Sea and overlaps its distribution with another Lessepsian sphyraenid, the yellowtail barracuda *Sphyraena flavicauda* Rüppell, 1838 (Golani *et al.*, 2021; Azzurro *et al.*, 2022). Palaoro and Dulčić (2001) reported *S. chrysotaenia* from the southeastern Adriatic Sea more than twenty years ago, while records from the Messiniakos Gulf (Peloponnese, Greece) and Kefalonia Island (Ionian Sea, Greece) occurred in 2011 and 2019, respectively (Pirkenseer, 2012; Katsanevakis *et al.*, 2020). Since then, and to the best of our knowledge, the species has never been observed again in the Adriatic and Ionian Seas and currently the distribution of *S. chrysotaenia* in the area between the southern Peloponnese and the southern Adriatic Sea is largely unknown (Golani *et al.*, 2021).

The Indo-Pacific needle-spined sea urchin *Diadema setosum* was first observed in 2006 along the southern coast of Turkey (Yokeş and Galil, 2006). Since then, it

has largely spread through the eastern Mediterranean coasts and has been reported in Cyprus and Greece (Rhodes, Crete Islands, and Peloponnese coast) (Bronstein *et al.*, 2017; Nour *et al.*, 2022 and references therein), with the westernmost records from the southern Ionian Sea (Proti Island - Greece) (Ragkousis *et al.*, 2020).

We hereby report the occurrence of *S. chrysotaenia* in the Ionian Sea, as well as the westernmost invasion front of *D. setosum* in the Mediterranean Sea (Zakynthos Island - Ionian Sea). These invasive species were discovered through the implementation of a joint monitoring strategy in the framework of the Interreg Med Project, MPA Engage, which was constituted of 15 Partners from seven countries, including the National Marine Park of Zakynthos (NMPZ) and five other Mediterranean marine protected areas (MPAs) (see <https://mpa-engage.interreg-med.eu/> for details).

MATERIALS AND METHODS

On September 29th, 2021, during the implementation of the Local Ecological Knowledge protocol 'LEK 1' (Garrabou *et al.*, 2019), we detected the capture of three individuals of *Sphyraena chrysotaenia* at the Zakynthos

*Corresponding author: manuela.damen@isprambiente.it

Received: 20 May 2022, accepted: 2 February 2023

ISSN: 0001-5113, eISSN: 1846-0453

CC BY-SA 4.0



Fig. 1. Locations of records of *Sphyraena chrysotaenia* and *Diadema setosum* at Zakynthos Island (Ionian Sea, Greece). The limits of the National Marine Park of Zakynthos are also shown.

Island main port landing site (Figs. 1 and 2). The interviewed fisher brought these individuals to our attention upon realization that they differed from the native barracudas. According to the fisher, these individuals were captured by trammel nets (28 mm mesh size knot to knot) deployed at 30 m depth just outside the easternmost borders of the NMPZ (Fig. 1; Table 1). The col-

lected specimens were brought to the NMPZ laboratory where they were photographed, weighted, measured, and morphologically analyzed. Additional information on the occurrence of *S. chrysotaenia* was retrieved by interviewing local fishers. One of the specimens was preserved in 80% ethanol.

In summer 2021 (July – October), eight specimens of *D. setosum* were observed at various locations across the south-western coast of Zakynthos Island (Figs. 1 and 3). Of these, six individuals were photographed and one specimen from Zakynthos MPA was collected by divers within the framework of the Citizen Science activities of MPA Engage project, for further taxonomic analysis. Two additional individuals were found and photographed outside NMPZ during a scientific survey dedicated to environmental DNA sampling and fish visual census (September 15-16, 2021) (Fig. 1; Table 1).

RESULTS

The collected fish, identified as *S. chrysotaenia* (Fig. 2), had a total length of 25.9 cm and weighed 86.50 g. Morphological analysis lead to the recognition of some taxonomic characters of the species, herein reported: Pectoral fin tips extending slightly over the origin of the first dorsal fin, reaching the second dorsal spine; pelvic fin origin located well before the origin of the first dorsal fin and below the pectoral fin, about half

Table 1. Details on the recorded specimens, regarding their location (coordinates, WGS84), the number of individuals found and the sampling method used.

Species and location	Coordinates	N. of Individuals	Detection method
<i>Sphyraena chrysotaenia</i>			
Site A (depth 30 m)	37.69672, 20.99852	3	Reported by fisher
<i>Diadema setosum</i>			
Site 1 (depth 4 m)	37.66209, 20.85988	2	Visual census
Site 2 (depth 6 m)	37.65489, 20.85728	3	Visual census
Site 3 (depth 4 m)	37.64563, 20.83172	1	Visual census
Site 4 (depth 10 m)	37.72106, 20.72644	2	Visual census



Fig. 2. *Sphyraena chrysotaenia* caught by small scale fisheries using trammel nets at the south-east borders of the National Marine Park of Zakynthos (Greece, Ionian Sea).

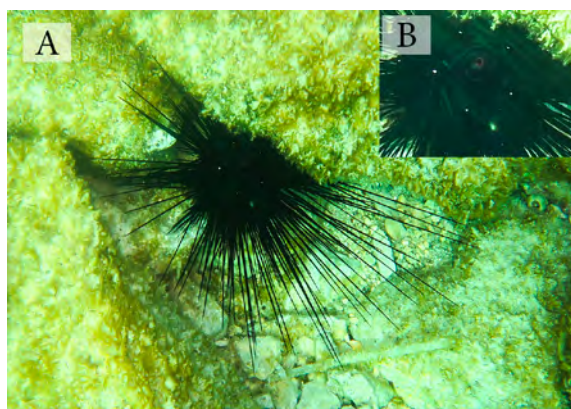


Fig. 3. *Diadema setosum* photographed at Zakynthos Island (Greek Ionian Sea) (A); close-up of the key morphological features for species identification (5 white dots, orange ring around the periproctal cone, blue iridophores) (B).

way its length; dorsal color gray and slightly yellowish, ventral color silvery white; caudal fin forked, yellow in color, with a visible black margin along the posterior edge. According to Kiparissis *et al.* (2020) and Golani *et al.* (2021), these traits are sufficient to distinguish *S. chrysotaenia* from other native and exotic sphyraenids occurring in the Mediterranean. Indeed, in the Lessepsian *S. flavicauda*, the pectoral fin tip does not reach the vertical of first dorsal fin origin and, in the native *S. sphyraena* and *S. viridensis*, the pelvic fin is located behind pectoral fin tip (Golani *et al.*, 2021).

All specimens of *D. setosum* were found at depths between 4-10 m in rocky substrate, which constitutes the preferred habitat for this species, which usually hides in crevices and under overhangs (Muthiga and McClanahan, 2020). Identification of the species was based on conspicuous morphological features (Fig. 3B) such as, the five white spots located on the interambulacra above the ambitus which are visible to the naked eye, the orange ring around the periproctal cone, the lines of blue iridophores down the mid-lines of the interambulacra and slender, elongated spines (Coppard and Campbell, 2006).

DISCUSSION

According to the interviewed fishers ($n = 20$), this was the first known catch of *S. chrysotaenia* in the

REFERENCES

- Azzurro, E., Smeraldo, S., Minelli, A., D'Amen, M. 2022. ORMEF: a Mediterranean database of exotic fish records. *Scientific Data*, 9(1), 1-7. <https://doi.org/10.1038/s41597-022-01487-z>
- Azzurro, E., Zannaki, K., Andaloro, F., Giardina, F., Tiralongo, F. 2018. First record of *Ophioblennius atlanticus* (Valenciennes, 1836) in Italian waters, with considerations on effective NIS monitoring in Mediterranean Marine Protected Areas. *Bioinvasions Records*, 7, 437- 440. <https://doi.org/10.3391/bir.2018.7.4.14>

coastal area of Zakynthos Island. Considering the paucity of information on the distribution of this species in the Adriatic and Ionian seas, the present observation could mirror a recent population expansion facilitated by climate change (D'Amen and Azzurro, 2020). Considering the morphological resemblance between *S. chrysotaenia* and the indigenous sphyraenids (*S. viridensis* and *S. sphyraena*), the occurrence of this invader could have been easily overlooked (Corsini-Foka, 2010; Kalogirou *et al.*, 2012), reinforcing the need for continuous and accurate monitoring in collaboration with local communities.

The observations of *D. setosum* raise motivated concern about a possible successful invasion in the Zakynthos MPA. This sea urchin is a dominant epibenthic grazer which in high densities can transform rocky reefs to barrens, outcompete indigenous echinoid species, and induce cascading effects on coastal ecosystems (Muthiga and McClanahan, 2020). Zakynthos MPA already suffers from overgrazing of rocky reefs by the thriving populations of other non-indigenous (*Siganus luridus* and *Siganus rivulatus*) and indigenous (*Sparisoma cretense*) herbivorous species, which are causing complex cascading effects in this protected ecosystem (Dimitriadis *et al.*, 2021). Thus, a possible outbreak of *D. setosum* would further amplify the on-going biodiversity loss and ecosystem structure alteration of Zakynthos Island, as previously demonstrated in the eastern Mediterranean (Rilov *et al.*, 2018).

CONCLUSIONS

Our study represents further evidence on the effectiveness of a joint observation system to the early detection of non-indigenous species in Mediterranean MPAs (Azzurro *et al.*, 2018; Ghanem *et al.*, 2021). Freely available monitoring tools (<https://mpa-engage.interreg-med.eu/>) empower Mediterranean MPAs in acting as sentinel sites for tracking their spread, building the basis for the management of biological invasions, in collaboration with research institutions and local communities.

ACKNOWLEDGEMENTS

We thank the fisher Giannis Augoustinos for providing the specimens of *S. chrysotaenia*.

- Bronstein O, Georgopoulou, E., Kroh., A. 2017. On the distribution of the invasive long-spined echinoid *Diadema setosum* and its expansion in the Mediterranean Sea. *Marine Ecology Progress Series*, 583, 163-178. <https://doi.org/10.3354/meps12348>
- Coppard, S.E., Campbell, A.C. 2006. Taxonomic significance of test morphology in the echinoid genera *Diadema* Gray, 1825 and *Echinothrix* Peters, 1853 (Echinodermata). *Zoosystema*, 28, 93-112.
- Corsini-Foka, M. 2010. Current status of alien fishes in Greek

- seas. In *Fish Invasions of the Mediterranean Sea: Change and Renewal* (eds. D. Golani, B. Appelbaum-Golani). Pensoft Publishers, Sofia-Moscow. pp. 219-253
- D'Amen, M., Azzurro, E. 2020. Lessepsian fish invasion in Mediterranean marine protected areas: A risk assessment under climate change scenarios. *ICES Journal of Marine Science*, 77, 388-397. <https://doi.org/10.1093/icesjms/fsz207>
- Dimitriadis, C., Fournari-Konstantinidou, I., Sourbès, L., Koutsoubas, D., Katsanevakis, S. 2021. Long term interactions of native and invasive species in a marine protected area suggest complex cascading effects challenging conservation outcomes. *Diversity*, 13, 71. <https://doi.org/10.3390/d13020071>
- Garrabou, J., Bensoussan, N., Azzurro, E. 2019. Monitoring climate-related responses in Mediterranean marine protected areas and beyond: five standard protocols. Institute of Marine Sciences, Spanish Research Council ICM-CSIC, Passeig Marítim de la Barceloneta. Barcelona, Spain, 36 pp. <http://hdl.handle.net/10261/176395>
- Ghanem, R., Ben Souissi, J., Azzurro, E. 2021. Documented occurrence of the exotic soldierfish *Argyrops filamentus* (Valenciennes, 1830) in the Specially Protected Area of Zembra (Tunisia): a result of a joint monitoring strategy. *Cahiers de Biologie Marine*, 62, 227-233. <https://doi.org/10.21411/CBM.A.BD3C4F5>
- Golani, D., Azzurro, E., Dulčić, J., Massuti, E., Orsi-Relini, L. 2021. *Atlas of Exotic Fishes in the Mediterranean Sea*. 2nd Edition, CIESM Publishers, 365pp.
- Kalogirou, S., Mittermayer, F., Pihl, L., Wennhage, H. 2012. Feeding ecology of indigenous and non-indigenous fish species within the family Sphyraenidae. *Journal of Fish Biology*, 80, 2528-2548. <https://doi.org/10.1111/j.1095-8649.2012.03306.x>
- Katsanevakis, S., Poursanidis, D., Hoffman, R., Rizgalla, J., Rothman, S.B.-S., Levitt-Barmats, Y., Hadjioannou, L., et al. 2020. Unpublished Mediterranean records of marine alien and cryptogenic species. *BioInvasions Records*, 9, 165-182. <https://doi.org/10.3391/bir.2020.9.2.01>
- Kiparissis, S., Tsaparis, D., Peristeraki, P., Giannakaki, A., Kosoglou, G., Metaxakis, M., Tserpes, G. 2020. The yellowstripe barracuda *Sphyraena chrysotaenia* (Klunzinger, 1884) in Crete (GSA 23, eastern Mediterranean): first genetically verified records and highlighted issues on the Lessepsian barracudas nomenclature ambiguities. *BioInvasions Records*, 9, 814-826. <https://doi.org/10.3391/bir.2020.9.4.15>
- Muthiga, N.A., McClanahan T.R. 2020. *Diadema*. In *Sea Urchins: Biology and Ecology*. (ed. J. Lawrence). Elsevier, Fourth Edition, Volume 4, pp 397-418. <https://doi.org/10.1016/B978-0-12-819570-3.00023-8>
- Nour, O.M., Al Mabruk, S.A.A., Adel, M., Corsini-Foka, M., Zava, B., Deidun, A., Gianguzza, P. 2022. First occurrence of the needle-spined urchin *Diadema setosum* (Leske, 1778) (Echinodermata, Diadematidae) in the southern Mediterranean Sea. *BioInvasions Records*, 11, 199-205. <https://doi.org/10.3391/bir.2022.11.1.20>
- Pallaoro, A., Dulčić, J. 2001. First record of *Sphyraena chrysotaenia* (Klunzinger, 1884) (Pisces, Sphyraenidae) from the Adriatic Sea. *Journal of Fish Biology*, 59, 179-182. <https://doi.org/10.1111/j.1095-8649.2001.tb02349.x>
- Pirkenseer, C. 2012. Records of four non-indigenous marine species, south of Koroni (Messiniakos Gulf, Peloponnese, Greece). *BioInvasions Records*, 2, 87-93. <http://dx.doi.org/10.3391/bir.2012.1.2.01>
- Ragkousis, M., Abdelali, N., Azzurro, E., Badreddine, A., Bariche, M., Bitar, G., Crocetta, F. et al. 2020. New alien Mediterranean biodiversity records (October 2020). *Mediterranean Marine Science*, 21, 631-652. <https://dx.doi.org/10.12681/mms.23674>
- Rilov, G., Peleg, O., Yeruham, E., Garval, T., Vichik, A., Raveh, O. 2018. Alien turf: Overfishing, overgrazing and invader domination in south-eastern Levant reef ecosystems. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 28, 351-369. <https://doi.org/10.1002/aqc.2862>
- Spicer, I.J. 1931. Fisheries. In *Report of the Department of Agriculture and Forests for the years 1927-30*. Printing Office, Russian Building, Jerusalem, pp 159-160.
- Yokes, B., Galil, B.S. 2006. The first record of the needle-spined urchin *Diadema setosum* (Leske, 1778) (Echinodermata: Echinoidea: Diadematidae) from the Mediterranean Sea. *Aquatic Invasion*, 1, 188-190. <https://doi.org/10.3391/ai.2006.1.3.15>