

First record of the Red Sea seagrass *Halophila stipulacea* in Corsica

Sébastien CNUUDE¹, Charles-François BOUDOURESQUE^{2*},
Michel MARENGO¹, Gérard PERGENT³, Thierry THIBAUT²

¹STARESO, Punta Revellata, BP 33, 20260 Calvi, Corsica, France.

²Aix Marseille University and University of Toulon, MIO (Mediterranean Institute of Oceanography), CNRS, IRD, Campus of Luminy, 13009 Marseille, France.

³Équipe Écosystèmes Littoraux, UMR CNRS SPE 6134, University of Corsica Pasquale Paoli, 20250 Corte, France.

*Corresponding author: charles.boudouresque@mio.osupytheas.fr

The seagrass *Halophila stipulacea* (Forsskål) Ascherson, native to the Red Sea, was among the first Red Sea species to enter the Mediterranean Sea *via* the Suez Canal (Por, 1978). For a long time, the species remained confined to the eastern Mediterranean basin, where it mainly inhabits muddy bottoms from sea level down to 30-45 m, within or in the immediate vicinity of harbours (Pérès and Picard, 1964; Lipkin, 1975a, 1975b). However, with climate warming, *H. stipulacea* began to invade the western basin: Vulcano Island (Messina, Italy) (Acunto *et al.*, 1995), Palinuro harbour (Salerno, mainland Italy) (Gambi *et al.*, 2009, 2018), northern Sardinia (Pica *et al.*, 2021) and more recently Cannes (mainland France) (Thibaut *et al.*, 2022).

The pathway by which the species entered the Mediterranean was the Suez Canal (Por; 1978; Boudouresque, 1999). Within the Mediterranean, two ways of dispersal occur: (i) the wave of advance model (diffusion spread), when the species spreads to adjacent areas, and (ii) the hopscotch jump model (saltation dispersal), for long-distance dispersal (Boudouresque and Sempéré, 2017). The main vector of saltation dispersal is the anchoring of pleasure craft and cruise ships, given the nature of the invaded sites (marinas, anchoring zones) (Calvo *et al.*, 2010; Thibaut *et al.*, 2022). From the Mediterranean, *via* anchoring and survival in anchor wells, *H. stipulacea* has been introduced to the Caribbean Sea (Ruiz and Ballantine, 2004; Willette and Ambrose, 2009; Maréchal *et al.*, 2013; Boudouresque *et al.*, 2016).

We observed *H. stipulacea* near Calvi (western Corsica), east of the *citadelle*, on February 22nd, 2022 (Latitude 8.770339, longitude 42.565443 – WGS 84 geodetic system) (Fig. 1); it was sparsely distributed at 21 m depth, on a fine sand bottom (Figs. 2, 3) (Table I). This locality lies near, but outside, the Natura 2000 zone FR09400574

‘Porto / Scandola / Revelatta / Calvi’. A possible second locality, in front of the outfall of the Calvi water treatment plant (Latitude 8.757262, longitude 42.573443), is under investigation. The latter locality lies within the Natura 2000 zone. The Bay of Calvi site constitutes a hot spot of pleasure craft anchoring, which is consistent with the hypothesis of dispersal *via* shipping (pleasure craft) and anchoring (Thibaut *et al.*, 2022).

Halophila stipulacea is considered as an invasive species in the Mediterranean (Boudouresque and Verlaque, 2002a, 2002b). The paramount role of anchoring in the dispersal of invasive species has also been stressed in the emblematic case of *Caulerpa taxifolia* (M.Vahl) C.Agardh, a green alga native to southern Australia (Jousson *et al.*, 1998, 2000; Langar *et al.*, 2002; Turan *et al.*, 2011). There is therefore an urgent need to control the anchoring of boats, in order to control the dispersal of such invasive species. A containment strategy, such as the strategy implemented by the Port-Cros National Park (eastern Provence), should also be considered (Jaubert *et al.*, 2015; Barcelo *et al.*, 2016).

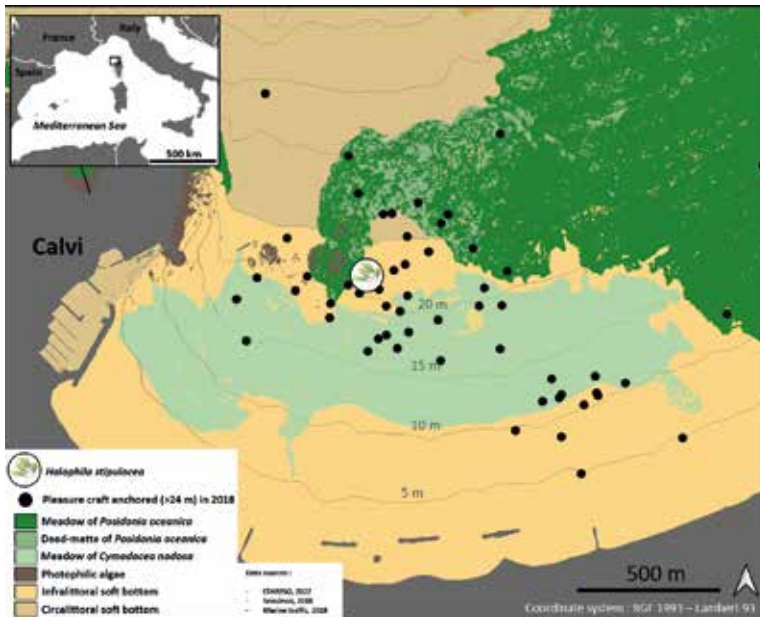


Figure 1. Map of the Bay of Calvi (Corsica), with benthic habitats, pleasure craft anchoring in 2018 (AIS – Automatic Identification System - database) and the location of *Halophila stipulacea* (a sketch of the seagrass shown in a circle).



Figure 2. Patches of the seagrass *Halophila stipulacea*, east of the *citadelle* at Calvi (western Corsica), 21 m depth, February 2022. Photo © Quentin Fontaine.



Figure 3. A patch of the seagrass *Halophila stipulacea*, east of the *citadelle* at Calvi (western Corsica), 21 m depth, February 2022. Photo © Quentin Fontaine.

The extent of *H. stipulacea* in the Calvi region should be monitored, considering its possible impact on two heritage value and protected species, the native seagrasses *Posidonia oceanica* (Linnaeus) Delile and *Cymodocea nodosa* (Ucria) Ascherson (Sghaier *et al.*, 2014; Conte *et al.*, 2023), and possible other interactions with local fauna.

Table I. Depth range and habitat of *Halophila stipulacea* in the northwestern Mediterranean Sea. Localities are arranged from North to South.

Locality	Depth range	Habitat	Reference
Cannes (French Riviera)	11-17 m	Dead <i>matte</i> of <i>Posidonia oceanica</i>	Thibaut <i>et al.</i> (2022)
Calvi (western Corsica)	21 m	Fine sand bottom	This study
Gulf of Aranci (Northern Sardinia)	6-8 m	Dead <i>matte</i> of <i>P. oceanica</i>	Pica <i>et al.</i> (2021)
Razza di Juncu (Northern Sardinia)	2-3 m	Coarse detritic sediment	Pica <i>et al.</i> (2021)
Palinuro (Salerno, Italy)	0.5-5 m	Sand and <i>P. oceanica</i>	Gambi <i>et al.</i> (2009)
Palinuro (Salerno, Italy)	1.5-4 m	Dead <i>matte</i> of <i>P. oceanica</i>	Gambi <i>et al.</i> (2018)
Vulcano	3-27 m	Sand with or without <i>Cymodocea nodosa</i> or <i>Caulerpa prolifera</i> (Forsskål) J.V. Lamouroux	Acunto <i>et al.</i> (1995)

Acknowledgements. The authors are grateful to Marc Verlaque and Jean-Georges Harmelin for valuable suggestions, and to Michael Paul for proofreading the text.

References

- ACUNTO S., MALTAGLIATI F., RINDI F., ROSSI F., CINELLI F., 1995. Osservazioni su una prateria di *Halophila stipulacea* (Forssk.) Aschers. (Hydrocharitaceae) nel Mar Tirreno meridionale. *Atti Soc. Tosc. Sci. Nat., Mem., Ser. B*, 102: 19-22.
- BARCELO A., COTTALORDA J.M., PEIRACHE M., ABIVEN T., GOMEZ M.C., VIVIANI R.A., BERGERE H., BAUDIN E., JULLIAN E., MOREAU S., MAXIME L., MASINSKI I., ESPOSITO G., FOURNIAL P., OBADIA C., PONCIN D., FORMENTIN J.Y., PIRONNEAU É., NIRONI M., CASALTA B., MORIN J.P., BARRAL M., BOUDOURESQUE C.F., 2016. Définition d'une politique et d'une stratégie globale de gestion concertées du chlorobionte invasif *Caulerpa taxifolia* à l'échelle des côtes et de l'aire marine adjacente du Parc national de Port-Cros (Provence, France). *Sci. Rep. Port-Cros Natl. Park*, 30: 45-64.
- BOUDOURESQUE C.F., 1999. The Red Sea - Mediterranean link: unwanted effects of canals. In: *Invasive species and biodiversity management*, Sandlund O.T., Schei P.J., Viken A. (eds.), Kluwer Academic publ.: 213-228.
- BOUDOURESQUE C.F., SEMPÉRE R., 2017. Biological invasions, habitat fragmentation, contamination and ecosystem-based approach in ports and adjacent coastal areas: problems and outlook. In: *What knowledge to reconcile the evolution of port facilities with sustainable development in the Mediterranean?* Actes du Forum Parmenides VIII, 21-23 March 2017, Genova. GID (Groupement Interdisciplinaire pour le Développement) publ., Paris: 28-32.
- BOUDOURESQUE C.F., VERLAQUE M., 2002a. Biological pollution in the Mediterranean Sea: invasive versus introduced macrophytes. *Mar. Pollut. Bull.*, 44: 32-38.
- BOUDOURESQUE C.F., VERLAQUE M., 2002b. Assessing scale and impact of ship-transported alien macrophytes in the Mediterranean Sea. In: *Alien marine organisms introduced by ships in the Mediterranean and Black seas*. BRIAND F. (ed.), *CIESM Workshop Monographs*, 20: 53-61.

- BOUDOURESQUE C.F., PERRET-BOUDOURESQUE M., VERLAQUE M., 2016. Donor and recipient regions for exotic species of marine macrophytes: a case of unidirectional flow, the Mediterranean Sea. *Rapp. P.V. Réun. Commiss. Internation. Explor. Médit.*, 41: 426.
- CALVO S., TOMASELLO A., DI MAIDA G., PIRROTTA M., BUIA M.C., CINELLI F., CORMACI M., FURNARI G., GIACCONE G., LUZZU F., MAZZOLA A., ORESTANO C., PROCACCINI G., SARÀ G., SCANNAVINO A., VIZZINI S., 2010. Seagrasses along the Sicilian coasts. *Chemical Ecology*, 26 (suppl.): 249-266.
- CONTE C., APOSTOLAKI E.T., VIZZINI S., MIGLIORE L., 2023. A tight interaction between the native seagrass *Cymodocea nodosa* and the exotic *Halophila stipulacea* in the Aegean Sea highlights seagrass holobiont variations. *Plants*, 12 (350): 1-26.
- GAMBI M.C., BARBIERI F., BIANCHI C.N., 2009. New record of the alien seagrass *Halophila stipulacea* (Hydrocharitaceae) in the western Mediterranean: a further clue to changing Mediterranean Sea biogeography. *Mar. Biodiv. Rec.*, 2 (e84): 1-7.
- GAMBI M.C., GAGLIOTI M., BARBIERI F., 2018. Sometimes they come back: the re-colonization of the alien seagrass *Halophila stipulacea* (Forsskål) Ascherson, 1867 (Hydrocharitaceae) in the Palinuro Harbor (Tyrrhenian Sea, Italy). *Bioinvasion Records*, 7 (3): 215-221.
- JAUBERT R., COTTALORDA J.M., BARCELO A., PEIRACHE M., BERGERE H., JULLIAN E., FORMENTIN J.Y., PASQUALINI B., BADAIRE C., PIRONNEAU É., MOUSSAY C., CLOU J.Y., 2015. Résultats de la campagne 2014 de recherche et d'éradication du chlorobionte invasif *Caulerpa taxifolia* (Vahl) C. Agardh dans les eaux de l'île de Port-Cros, cœur du Parc national de Port-Cros (Var, France). *Sci. Rep. Port-Cros Natl. Park*, 29: 255-258.
- JOUSSON O., PAWLOWSKI J., ZANINETTI L., MEINESZ A., BOUDOURESQUE C.F., 1998. Molecular evidence for the aquarium origin of the green alga *Caulerpa taxifolia* introduced to the Mediterranean Sea. *Mar. Ecol. Prog. Ser.*, 172: 275-280.
- JOUSSON O., PAWLOWSKI J., ZANINETTI L., ZECHMAN E.W., DINI F., DI GUISEPPE G., WOODFIELD R., MILLAR A., MEINESZ A., 2000. Invasive alga reaches California. *Nature*, 408: 157-158.
- LANGAR H., DJELLOULI A.S., SELLEM F., EL ABED A., 2002. Extension of two *Caulerpa* species along the Tunisian coast. *J. Coastal Conserv.*, 8: 163-167.
- LIPKIN Y., 1975a. *Halophila stipulacea*, a review of a successful immigration. *Aquatic Botany*, 1203-1215.
- LIPKIN Y., 1975b. *Halophila stipulacea* in Cyprus and Rhodes, 1967-1970. *Aquatic Botany*, 1309-1318.
- MARÉCHAL J.P., MEESTERS E.H., VEDIE F., HELLIO C., 2013. Occurrence of the alien seagrass *Halophila stipulacea* in Martinique (French West Indies). *Mar. Biodiv. Rec.*, 6 (e127): 1-5.
- PÉRÈS J.M., PICARD J., 1964. Nouveau manuel de bionomie benthique de la mer Méditerranée. *Rec. Trav. Stat. Mar. Endoume*, 31 (47): 5-137.
- PICA D., GALANTI L., POLA L., 2021. First records of the seagrass *Halophila stipulacea* in Sardinia (Tyrrhenian Sea, Italy). In: *New Alien Mediterranean Biodiversity Records*, Orfanidis S., Alvito A., Azzurro E., Badreddine A., Ben Souissi J., Chamorro C., et al. (eds.). *Mediterr. Mar. Sci.* 22(1): 180-198.
- POR F.D., 1978. *Lessepsian migrations. The influx of Red Sea biota into the Mediterranean by way of the Suez Canal*. Springer publ., Berlin: i-viii + 1-228.
- RUIZ H., BALLANTINE D.L., 2004. Occurrence of the seagrass *Halophila stipulacea* in the tropical West Atlantic. *Bull. Mar. Sci.*, 75 (1): 131-135.
- SGHAIER Y.R., ZAKHAMA-SRAIEB R., CHARFI-CHEIKHROUHA F., 2014. Effects of the invasive seagrass *Halophila stipulacea* on the native seagrass *Cymodocea nodosa*. In: *Proceedings of the 5th Mediterranean Symposium on Marine Vegetation*, Portorož, RAC/SPA publ., Tunis: 167-171.
- THIBAUT T., BLANFUNÉ A., BOUDOURESQUE C.F., HOLON F., AGEL N., DESCAMPS P., DETER J., PAVY T., DELARUELLE G., VERLAQUE M., 2022. Distribution of the seagrass *Halophila stipulacea*: a big jump to the northwestern Mediterranean Sea. *Aquatic Botany*, 176 (103465): 1-4.
- TURAN G., TEKOGUL H., CIRIK S., MEINESZ A., 2011. First record of the invasive green seaweed *Caulerpa taxifolia* (Bryopsidales) on the coast of Turkey. *Cryptogamie, Algologie*, 32 (4): 379-382.
- WILLETTE D.A., AMBROSE R.F., 2009. The distribution and expansion of the invasive seagrass *Halophila stipulacea* in Dominica, West Indies, with a preliminary report from St. Lucia. *Aquatic Botany*, 91: 137-142.