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Short communication

Distribution of the seagrass *Halophila stipulacea*: A big jump to the northwestern Mediterranean Sea

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ABSTRACT

The Red Sea and Indian Ocean seagrass *Halophila stipulacea* entered the Mediterranean in the late 19th century via the Suez Canal. Here, we report on the discovery of a population of *H. stipulacea* covering 16.5 ha off the harbour of Cannes, French Riviera, France. This represents the northernmost locality of the species and a jump of 350 km to the north from its closest western Mediterranean locality (Razza di Juncu in Sardinia). At Cannes, it was found dwelling between 11 and 17 m depth on a dead *matte* of *Posidonia oceanica*. The species has most probably been introduced through mega-yacht or cruise ship anchoring since the Bay of Cannes is among the most highly-frequented places for luxury yachting and tourism. The lack of effective regulation to prevent the introduction of non-indigenous species in France and Europe is highlighted.

1. Introduction

The Mediterranean Sea is a hot-spot of biological invasions (Galil, 2000). The Suez Canal, and the entry of Red Sea species into the Mediterranean (Lessepsian immigrants), together with shellfish aquaculture, are the main pathways of species introduction; shipping (fouling, clinging, ballast water) and aquarium release also constitute important vectors (Zenetos et al., 2012). Among the ca. 1000 Non-Indigenous Species (NIS) recorded in the Mediterranean Sea, 535 are naturalized, and 159 of them are macrophytes (C.F. Boudouresque, unpublished data), including two exotic seagrasses: *Halophila stipulacea* (Forsskål) Ascherson, introduced into the Mediterranean Sea via the Suez Canal more than a century ago (Por, 1978) and *Halophila decipiens* Ostenfeld, introduced, probably through shipping, in Greece and first discovered in 2018 (Gerakaris et al., 2020).

Since its first Mediterranean sighting (Rhodes Island, in 1894), *H. stipulacea* has colonized the eastern Mediterranean basin, the south of the Adriatic Sea and the south of the Tyrrhenian Sea: Albania, Cyprus, Egypt, Greece, Israel, mainland Italy (northernmost limit: Porto Palino, Salerno), Lebanon, Libya, Malta, Sardinia, Syria, Tunisia and Turkey (Winters et al., 2020; CABI, 2021; Pica et al., 2021).

Halophila stipulacea has been also introduced into the Atlantic Ocean where it was first observed in 2001 (Ruiz and Ballantine, 2004). Since

then, it has been rapidly invading the western tropical area: Curaçao, Dominica, Grenada, Grenadines, Guadeloupe, Martinique, Saint Eustatius, Saint Lucia, Saint Martin, Saint Vincent, US Virgin Islands and Venezuela; (Winters et al., 2020; CABI, 2021). The genotype that invades the Atlantic Ocean is believed to originate from the Mediterranean Sea and to have probably crossed the Atlantic in the anchor well of a pleasure yacht or cruise ship (Ruiz and Ballantine, 2004), the Mediterranean thus functioning as a hub for exotic species transfer (Boudouresque et al., 2016).

Here, we report on the discovery of *H. stipulacea* along the French Riviera (France), which represents a jump in its known distribution of several hundred kilometres from its previously known northernmost localities in the western Mediterranean (northern Sardinia), and we describe its habitat and morphological features.

2. Material and methods

The observations have been done by scuba-diving during a survey along the French Mediterranean coast, performed by the *Andromède Océanologie* Society, in the framework of the implementation of the EU directives WFD (Water Framework Directive) and MSD (Marine Strategy Directive) by the French State Agency *Agence de l'Eau Rhône Méditerranée & Corse*. Identification was made through documentation,

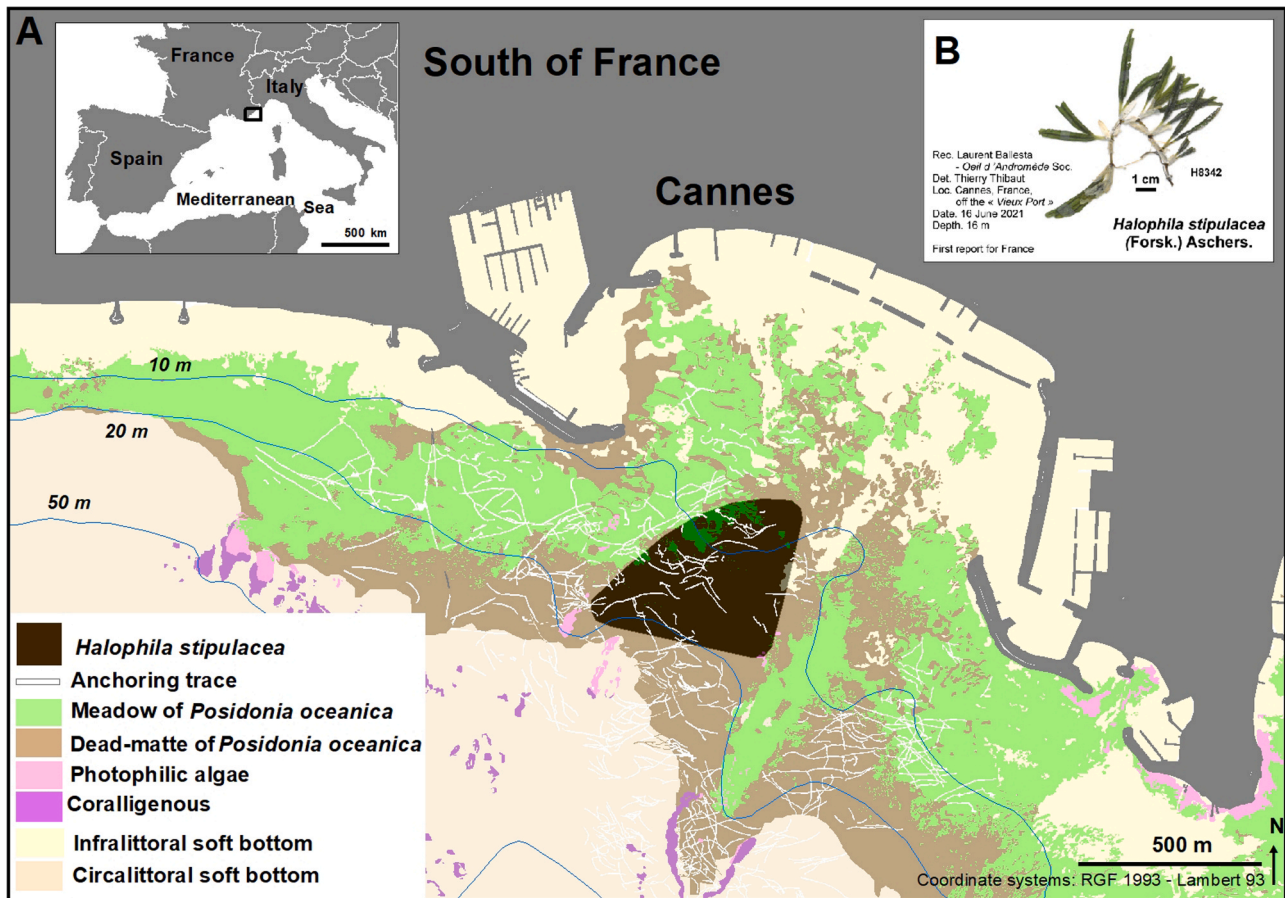


Fig. 1. A. Location of *Halophila stipulacea* at Cannes (French Riviera, France). Habitats have been extracted from the Medtrix platform (2021). B. *Halophila stipulacea*, specimen H8342 collected at Cannes in June, 2021.

literature, and vouchers – of the *Plateforme Macrophytes* of the MIO (Mediterranean Institute of Oceanography). Temperature and salinity data were extracted from the SOMLIT database (SOMLIT, 2021).

The shoot density of *H. stipulacea* was measured in situ within 20 cm × 20 cm frames (10 replicates), and the invaded area was accurately mapped using GPS positioning. The diver is positioned with a USBL positioning system, the MicronNav from Tritech. This system is fixed on the towing board to which the diver is attached; it transmits its numerous marine observations via a communication system (RCH's Aquacom) to the surface team, while being geo-located. The affected surface was calculated and a map was produced with ArcGIS, including habitats, bathymetry, as well as traces of anchoring injuries extracted from the Medtrix platform, a French governmental platform data centre hosting the data on marine habitats of the French Mediterranean coasts (Medtrix, 2021).

Collected specimens were deposited in the HCOM Herbarium under the references H8342 and H8343 (Macrophyte collection - MIO - Aix-Marseille University, Marseille).

3. Results and discussion

In June 2021, a population of *H. stipulacea* was discovered at Cannes (French Riviera, France) in front of the harbour entrance (43°32.479' N; 7°01.298' E) (Fig. 1A). The population was growing mixed with the invasive green alga *Caulerpa cylindracea* Sonder on a *Posidonia oceanica* (L.) Delile dead *matte* (natural network of rhizomes, roots and sediments subsisting a long time after the death of the seagrass) between 11 and 17 m depth. In the Bay of Cannes, the *P. oceanica* meadows have been severely damaged by the anchoring of large ships (mega-yachts and

cruise ships). In the area where the species was observed, the dead *matte* dominates and a dense network of conspicuous traces of anchoring is visible. The invaded area reached 16.5 ha with a density ranging from 143 to 437 shoots m⁻² (mean: 202; SE: 31; n = 10).

The morphological features of specimens match with the *H. stipulacea* diagnosis i.e. a pair of large, persistent, transparent scales, elliptical in shape at the base of the short petiole; linear, oblong and membranous blades (up to 57 mm long), with 10–40 branched cross veins and serrulate margins (Fig. 1B). Sexual reproduction was not observed.

The Cannes *H. stipulacea* record is the northernmost in the western Mediterranean, more than 340 km from Razza di Juncu the northeastern Sardinia (Pica et al., 2021). This record is also the first of an exotic seagrass for the French Mediterranean coasts.

Densities measured at Cannes are much lower than those measured in a shallow habitat, 2 m depth, at Palinuro (10,500 shoots m⁻²) (Gambi et al., 2009), between 5 and 25 m depth, at Vulcano Island (10,500–15,000 shoots m⁻²) (Procaccini et al., 1999), and at 4 m depth at Giardini Naxos in eastern Sicily (> 19,000 shoots m⁻²) (Cancemi et al., 1994).

Considering the large area invaded at Cannes, the introduction seems to date back to a few years ago, which means that the species has endured at least one winter period. The Bay of Cannes is among the world's most highly-frequented places for luxury mega-yachts and cruise ships, especially from May to the end of August, and in particular during prestigious cultural events such as the Cannes Film Festival, when a large number of large ships moor there. Anchors are an effective mode of dissemination for NIS (Boudouresque and Verlaque, 2002; West et al., 2007) and are strongly suspected of being responsible for the dissemination of *H. stipulacea* (Lipkin, 1975; Ruiz and Ballantine, 2004;

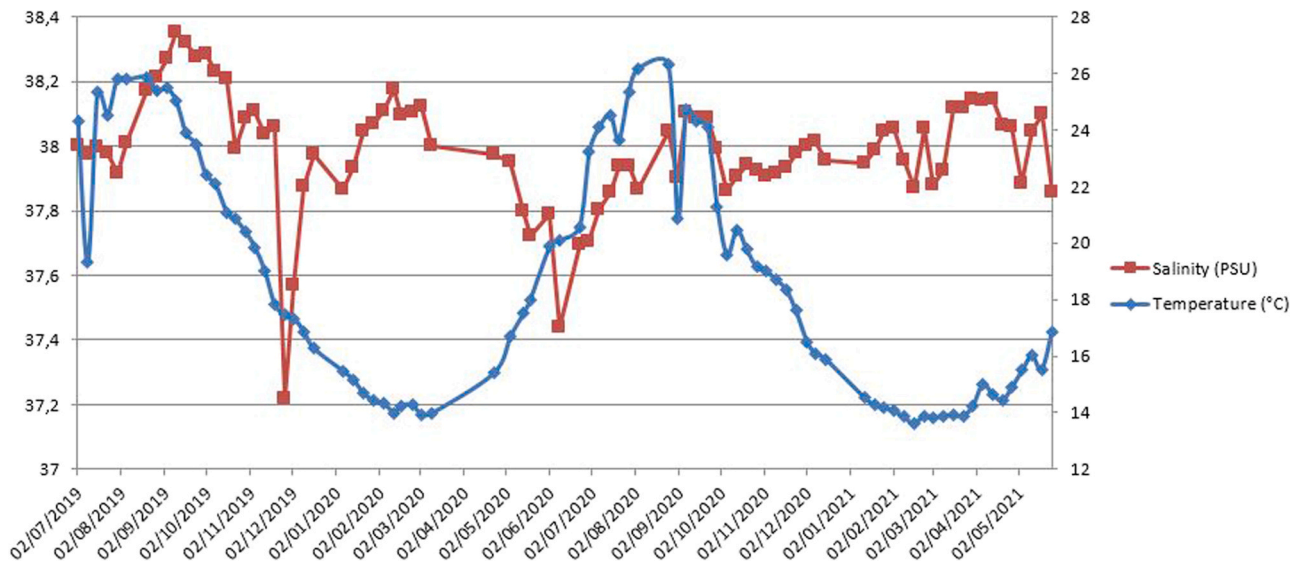


Fig. 2. Sea surface temperatures and salinities recorded between 2019 and 2021 in Villefranche-sur-Mer Bay (French Riviera) (SOMLIT, 2021).

Gambi et al., 2009).

Sexual reproduction was not observed at Cannes. In the Mediterranean, there is a bias towards male flowers (Gambi et al., 2009) and fruits have been reported only twice (Lipkin, 1975; Gerakaris and Tsiamis, 2015). The rarity of successful sexual reproduction, with production of fruits, has also been reported in the Caribbean Sea (Chiquillo et al., 2019). Unlike the natural range of *H. stipulacea* where both sexual reproduction and vegetative propagation occur, in its invasive range (Mediterranean Sea and Caribbean Sea), the latter mode appears to be dominant (Malm, 2006; Chiquillo et al., 2019; Nguyen et al., 2018).

Annual sea surface temperatures range from 13 °C to 28 °C and salinity from 37 to 38 in the very close bay of Villefranche-sur-Mer (SOMLIT, 2021; Fig. 2). Wesselmann et al. (2020), through thermo-tolerance experiments highlighted the wide temperature range (8–40 °C for 7 days) for survival of *H. stipulacea*, both in Red Sea and Mediterranean populations, and a possible thermal niche shift of *H. stipulacea* to the colder thermal regime of the Mediterranean Sea. The present new record supports the hypothesis that *H. stipulacea* is able to survive much colder temperatures (~ 13 °C in winter along the French Riviera) than those encountered in its native range. It will be interesting to follow the spread, decline or possibly extinction of the Cannes population over the coming years, especially after winters colder than those of 2020 and 2021. At Palinuro, 130 km south of Naples, *H. stipulacea* meadows declined from 2007, the year of its discovery, to 2010 and became extinct in 2011, before reappearing in 2017, possibly following a new introduction event. Grazing by the herbivorous fish *Sarpa salpa* (Linnaeus, 1758) was suggested as a possible cause of these local fluctuations (Gambi and Barbieri, 2013; Gambi et al., 2018).

The record from France highlights the absolute need for regulation and prevention of the spread of introduced species in the Mediterranean and European waters. The European Invasive Alien Species (IAS) regulation (1143/2014) provides a list of regulated IAS at European level (UE, 2016, 2019). To date, of the 66 IAS on this list, only two are marine species. After analysing their capacity for invasion, Pisanu et al. (2020) proposed to add 14 new taxa to this list but *H. stipulacea* was not included.

CRedit authorship contribution statement

T. Thibaut: Conceptualization, Writing. **F. Holon:** Field work. **N. Agel:** Field work. **P. Descamps:** Field work. **J. Deter:** Field work. **T. Pavy:** Field work. **G. Delaruelle:** Writing. **C.F. Boudouresque:** Writing. **A. Blanfuné:** Writing, GIS Analysis.

All authors have read and agreed to the published version of the manuscript. This manuscript has not been published previously.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Conflict of interest

We declare that we do not have any conflict of interest.

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