

# Northernmost report of *Posidonia oceanica* striped meadow, along the French Riviera coast (NW Mediterranean Sea)

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**Abstract.** The seagrass *Posidonia oceanica* can build specific formations when growing under certain environmental conditions. One of these particular structures, the striped meadow, is relatively rare in the Mediterranean Sea, with only a few sightings reported from Tunisia, Libya, Turkey, Sicily, Sardinia and Corsica. The development and easy deployment of drones for the study and mapping of shallow coastal habitats offers new opportunities for investigation. This technique facilitates the detection of particular *Posidonia* formations close to the sea surface such as barrier reefs, atolls and striped meadows. A striped meadow was reported for the first time on the northern coasts of the Mediterranean Sea, at Le Croûton, about ~10 km SW of Nice (French Riviera). This report additionally offers a review of the striped meadows recorded in the literature.

**Keywords:** French Riviera, *Posidonia oceanica*, striped meadow.

**Résumé.** Signalement de l'herbier tigré à *Posidonia oceanica* le plus septentrional de Méditerranée, sur la Riviera française (Méditerranée nord-occidentale). Dans des conditions particulières, la magnoliophyte marine *Posidonia oceanica* peut former des structures particulières comme les herbiers tigrés. Les herbiers tigrés sont relativement rares en mer Méditerranée et les quelques signalements se trouvent en Tunisie, Libye, Turquie, Sicile, Sardaigne et Corse. Le développement et la mise en œuvre de drones pour l'étude et la cartographie des habitats côtiers peu profonds offrent de nouvelles opportunités d'investigation. Cela facilite notamment la détection de formations particulières de posidonie proches de la surface de la mer telles que les récifs barrières, les atolls et les herbiers tigrés. Un herbier tigré a été observé au Croûton (commune d'Antibes Juan-les-Pins), à environ 10 km au Sud-Ouest de Nice, sur la Riviera française. Il s'agit du premier signalement sur la rive Nord de la mer Méditerranée. Cette note donne aussi l'occasion de faire le point sur l'inventaire des herbiers tigrés signalés dans la littérature.

**Mots-clés :** herbier tigré, *Posidonia oceanica*, Riviera française.

## Introduction

*Posidonia oceanica* is an endemic magnoliophyte of the Mediterranean Sea which forms extensive meadows between 0 and 40 m depth, depending on the transparency of the water (Pères and

Picard, 1964; Boudouresque and Meinesz, 1982; Ruiz *et al.*, 2009; Boudouresque *et al.*, 2012). It can present specific formations generally driven by environmental conditions (depth, salinity, water movement, nature of the substrate, slope, sedimentation), such as barrier reefs, atolls and striped meadows (Boudouresque *et al.*, 2012, 2014; Bonhomme *et al.*, 2015).

The first report of striped meadows (although this name was not yet coined) come from observations made on the north of the Kerkennah Islands in Tunisia by Blanpied *et al.* (1979) and Buroillet (1983).

The striped meadows were first specifically described by Boudouresque *et al.* (1985, 1990), as *herbier tigré* (in French). It consists of 1-2 m-wide *P. oceanica* strips, which are several dozen metres long and separated by dead *matte* occupied by the seagrass *Cymodocea nodosa* and/or the green alga *Caulerpa prolifera*. Each meadow strip shifts, parallel to itself, against the dominant current, at an average speed of 10 cm year<sup>-1</sup>. A cross-section of a strip shows on one side a front of plagiotropic (horizontal) rhizomes that progresses onto the dead *matte*, a gentle slope behind the front, and a small erosive scarp where the strip disintegrates (Boudouresque *et al.*, 2012).

Striped meadows have only rarely been recorded in the Mediterranean Sea, mainly in the southern basin: Kerkennah Islands in Tunisia (Blanpied *et al.*, 1979; Buroillet, 1983; Ramos Esplá *et al.*, 2000; Bouafif *et al.*, 2019), Zarzis in Tunisia (Pergent *et al.*, 2010), in the Farwa lagoon and along the eastern coast of Tripoli in Libya (Pergent *et al.*, 2002), in Stagnone lagoon at Marsala, Sicily (Calvo and Fradà Orestano, 1984), in the Gulf of Oristano, Sardinia (Coppa *et al.*, 2019), in Corsica in the Gulf of Portivechju at Bennedettu and Cala Rossa (Cancemi and Bartoli, 2007; Barralon *et al.*, 2018; Rouanet *et al.*, 2022) and in Turkey in the Bay of Gülbahçe (Massey, 2013).

Striped meadows have been observed at shallow depths (less than 10 m), both in lagoons and open sea, generally at sites with few human activities and stable environmental conditions (temperature, salinity) (Calvo *et al.*, 2003, 2009; Tomasello *et al.*, 2009).

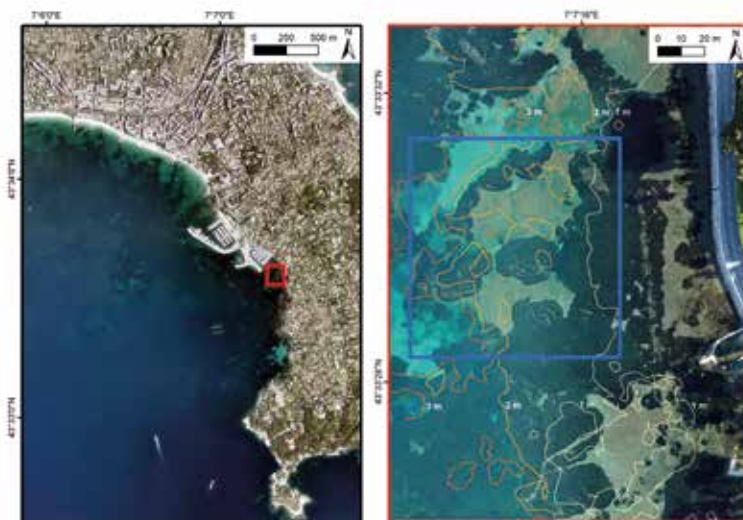
## **Material and methods**

The development and easy deployment of drones for the study and mapping of shallow coastal habitats offers new opportunities for investigation. In the framework of an inventory and acquisition of aerial images for the production of maps of *Posidonia oceanica* barrier reefs in the French Mediterranean (Rouanet *et al.*, 2022), georeferenced images have been produced by a drone (DJI Phantom 4 Pro) with

overflight conducted at 100 m height above sea-level to obtain a high-resolution orthomosaic (2.7 cm pixel<sup>-1</sup>).

## Results

A striped *P. oceanica* meadow was observed 250 m from the entrance to the Le Croûton marina (Antibes Juan-les-Pins, ~10 km SW of Nice, French Riviera). This is the first report of a sighting on the northern shores of the Mediterranean Sea. This striped meadow occurs between 1 and 3 m depth over an area of 0.8 ha (blue square on Fig. 1). It has an overall circular shape with bands of live *P. oceanica* 1.0-1.7 m wide separated by bands of dead *matte* 0.5-1.0 m wide.



**Figure 1.** **Left.** Localisation of the study area (red square). The very intensive urbanization of the area, on land and at sea (marinas), is clearly apparent. **Right.** Aerial images of the striped meadow (inside the blue square) at Le Croûton, obtained by drone (overflight at 100 m). The depth contour lines (white, yellow and orange; 1, 2 and 3 m respectively) come from Litto 3D from SHOM.

This striped meadow is located to the north of a fringing *P. oceanica* reef (Francour *et al.*, 2003; Rouanet *et al.*, 2022), in an area where boat traffic and anchoring are prohibited. The striped meadow is nevertheless located in a highly urbanized area, near the marinas of Le Croûton (350 berths, certified "clean harbour") and Gallice (525 berths) with many activities (shipyard, careening area, refuelling station, etc.), leading to high human pressure, in particular chemical, exerted on the environment. Two aquaculture farms with a combined surface area of 2 900 m<sup>2</sup> are located 600 m from the striped meadow. They produce sea bass *Dicentrarchus labrax* and sea bream

*Sparus aurata* in accordance with a French quality charter with a cage density between 15 and 20 kg m<sup>-3</sup>. The coastline has been extensively artificialized, with the construction of a dyke supporting a road and artificial beaches.

## Discussion and conclusion

Two types of striped meadows can be defined. (i) The **classical type**, as described by Boudouresque *et al.* (1990, 2012) on the basis of photographs by Blanpied *et al.* (1979) in Tunisia, then *in situ* observations of these meadows. It is characterized by narrow (less than 2 m) and elongated (up to several hundred metres) strips, generally curvilinear, separated by wide areas (up to several dozen metres) of dead matte. (ii) **The tight type**, which corresponds to the striped meadows observed e.g. in Corsica, Turkey and French Riviera. The strips of *P. oceanica* are shorter and closer together than in the classical type; the spacing can be as little as 1 m; they are arcuate, coalescent and form ovoid bodies of several hundred square metres of surface area (see Pergent *et al.*, 2010). In both types, the convexity of the strips is linked to the prevailing currents, in that they are perpendicular to the currents.

The striped *P. oceanica* meadow and the fringing reef at Le Croûton are now well mapped (Rouanet *et al.*, 2022). Current protection must continue and the establishment of a stronger protection zone by the French authorities is recommended. This striped meadow is the northernmost one in the western Mediterranean basin.

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