Biol. Mar. Mediterr. (2024), 28 (1): 129-132 www.biologiamarinamediterranea.it

52° Congresso SIBM: Benthos

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EFFECTIVENESS OF A *POSIDONIA OCEANICA* (L.) DELILE TRANSPLANTATION IN THE GULF OF TIGULLIO (LIGURIAN SEA) 23 YEARS LATER

EFFICACIA DI UN INTERVENTO DI TRAPIANTO DI POSIDONIA OCEANICA *(L.) DELILE NEL GOLFO DEL TIGULLIO (MAR LIGURE) 23 ANNI DOPO*

Abstract - Posidonia oceanica *meadows represent an emblematic marine ecosystem in both scientific and conservation contexts. Despite regulatory efforts, the meadows in the Mediterranean coastlines have declined due to escalating human impact. Restoration initiatives aim to counteract anthropogenic damage and facilitate natural recolonization. To date, in the absence of a standardized methodology, transplanting techniques, although in continuous development, are still not very effective when compared to terrestrial reforestation techniques. This study evaluated the success of one of the first experimental transplantation attempts carried out on* P. oceanica *in the Ligurian Sea in 1996, in Rapallo. Monitoring in 2019 revealed sustained growth and expansion of the reforested area, with shoot density tripling since 1996. The transplantation's success is surprising given the significant human impact on the site, which is located within a marina. This is a unique instance as there is a lack of documented success over an extended period in existing literature.*

Key-words: Posidonia oceanica*, transplantation, seagrass, restoration, Ligurian Sea*

Introduction - *Posidonia oceanica* Delile meadows are one of the most valuable ecosystems in the Mediterranean Sea both environmentally and economically (Rigo *et al.*, 2021). Despite being a protected habitat, many seagrass meadows are found to be regressing, particularly near urban centers and man-made coastlines (Boudouresque *et al.*, 2006). *Posidonia oceanica* is a slow-growing plant and its natural recolonization, where local anthropogenic pressures cease, would take an extremely long time (Marbà & Duarte, 1998). These premises have led, in recent years, to the need to protect seagrass meadows through active conservation interventions that involve transplanting portions of the meadow in order to restore the degraded ecosystem.

In 1996 a pioneering intervention of meadow restoration was planned to reconstruct a small portion of the meadow within the marina of Rapallo (Genoa; Bavestrello & Cattaneo-Vietti, 1997), in the Tigullio Gulf, North-Western Ligurian Sea (Fig. 1). Regression of *P. oceanica* meadows in Liguria has become particularly severe since the 1970s, because of the huge coastal development that characterized this region. During this period, the *P. oceanica* meadow developing within the marina of Rapallo has been impacted by the extension of the dam of the touristic harbour. In addition, two significant events took place in the same period: i) the construction of the Carlo Riva Port; and ii) the huge urbanization along the coastline near the Rio Tuja. Both events caused, for several years, significant water turbidity in the whole Tigullio Gulf.

The narrow entrance of the Rapallo harbour and the consequent diminished water exchange with the open sea further damaged the seagrass meadows. A healthy meadow is only left in the eastern side of the Tigullio Gulf.
A first transplanting was carried out in November 1996 in the shallow waters in front of the Avenaggi Street. A total of 200 cuttings were collected from the nearby meadow of San Michele di Pagana at a depth of 12 m. Five metallic grids, covering a surface of 2 m² each, were fixed at the bottom characterized by dead matte, at a depth of 5 m. Cuttings were fixed at the grids by means of plastic bands.
A second transplanting was carried out, in the same area, in March 1997. A total of 300 cuttings were collected in the nearby Prelo cove, at a depth of 5 m. Each cutting was then secured to a metallic stake and the stakes were planted at the bottom along six 10 m parallel transects, at 20 cm intervals. At the end of the intervention, 500 cuttings were transplanted over a surface of about 20 m², resulting in a density of 61.8 shoots per m². After one year from the transplantation, both techniques showed positive results in terms of shoot survival and rhizome length. Cuttings over the grids recorded a loss of about 15%, while those fixed by stakes had a loss of about 50% (Bavestrello & Cattaneo-Vietti, 1997). Following the first year after the intervention, no further monitoring activities were conducted until 2019, when we have had the chance to come back on the site to monitor and map again the meadow. This study therefore reports the results of the latest monitoring activities and aims to assess the effectiveness and success of one of the first experimental transplantation attempts carried out on a *P. oceanica* meadow.

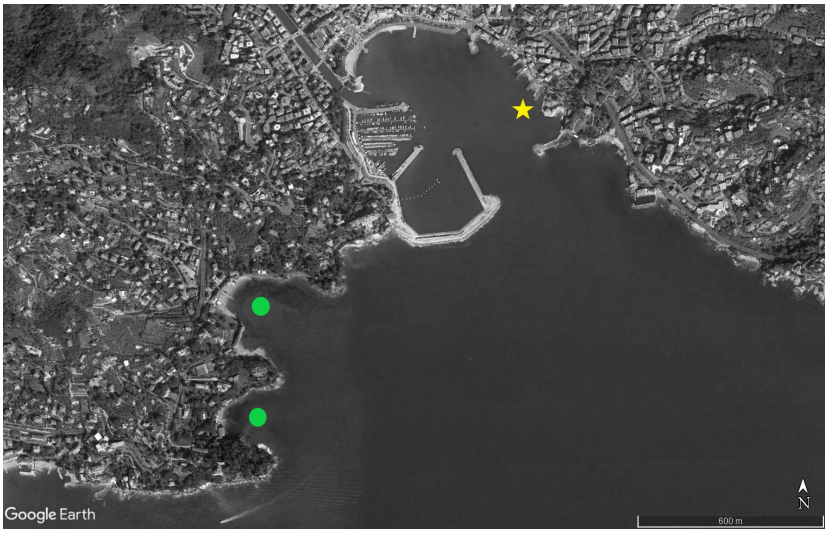

Fig. 1 - Selected area (yellow star) for transplanting *Posidonia oceanica* within the marina of Rapallo (Genoa) and the two donor sites (green dots), San Michele di Pagana and Prelo cove.
Area selezionata (stella gialla) per il trapianto di Posidonia oceanica *nel porto di Rapallo (Genova) e i due siti donatori (pallini verdi), San Michele di Pagana e baia di Prelo.*

Materials and methods - Monitoring activities in 2019 were carried out by scuba diving. The meadow was mapped in detail by using the closed polygon technique

(Alvisi, 1991) and plotting all measurements on an underwater slate. Length, width and diagonal of the transplanted *Posidonia oceanica* patch were measured in situ using a metric rope and their orientation detected with a compass. The shoot density was also measured in 6 replicates within a 20 cm × 20 cm square frame. The total area covered was drawn and measured on GIS platform.

Results - The transplanted meadow was still there, and its surface appeared increased. The metallic grids used in the first transplanting were still visible on the bottom (Fig. 2), whilst the stakes used in the second transplanting were not found. The total area covered by the meadow slightly increased in the last 23 years, from 20 m² to 24 m² (Fig. 3A). The most significant result concerns the shoot density: the estimated number of shoots on the total area covered by the meadow in 2019 is about 4767, with an average value of 195 ± 8 shoots per m², compared to the 61.8 shoots per m² in 1996-97 (Fig. 3B). Although the meadow area increased by "only" 17%, the success of transplanting is most evident looking at the shoot density, which increased approximately three times.

Fig. 2 – Grids used during the first transplanting intervention are still visible on the bottom 23 years later (©*Federico Betti).*
Le griglie utilizzate nel primo intervento di trapianto sono ancora visibili dopo 23 anni.

Conclusions - The location of the transplanted meadow within a touristic marina cannot be disregarded when discussing the success of this intervention. Being in a heavily anthropized area that is often exposed to high water turbidity and intense hydrodynamics, the success of this transplanting is even more remarkable. However, the location of the site in the eastern side of the Rapallo gulf shelters the transplanted area from the most severe storm (Oprandi *et al.*, 2020), thus ensuring the survival of the shoot for the last 23 years. This restoration intervention represents a unique case,

since there are no other documented examples in the literature of successful transplantations over such a long time scale.

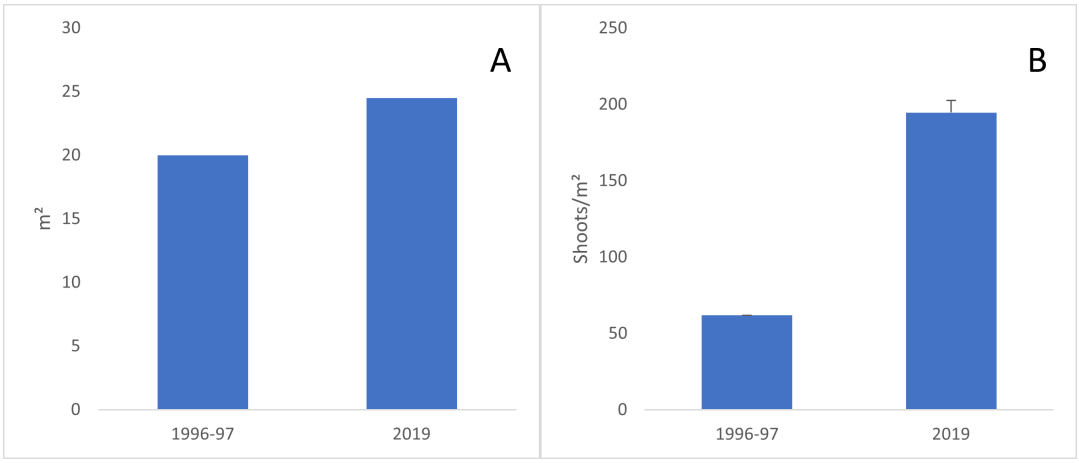

Fig. 3 - A) Total area (in m²) covered by the transplanted meadow in 1996-'97 and in 2019. B) Meadow shoot density (shoots m^{-2}) of the transplanted meadow in 1996-'97 and in 2019.
A) Area totale (in m²) ricoperta dalla prateria trapiantata nel 1996-'97 e nel 2019. B) Densità dei fasci fogliari (fasci m^{-2}) della prateria trapiantata nel 1996-'97 e nel 2019.

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