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The Effect of Transplantation Depth on the Restoration Success of *Gongolaria barbata* (Fucales) in the Mediterranean Sea

Marletta Giuliana[1,2] | Sacco Domenico[1] | Danovaro Roberto[1,2] | Bianchelli Silvia[1,2]

[1]Dipartimento di Scienze della Vita e dell'Ambiente, Università Politecnica delle Marche, Ancona, Italy | [2]National Biodiversity Future Centre, Palermo, Italy

Correspondence: Bianchelli Silvia (silvia.bianchelli@univpm.it)

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Keywords: extreme events | *Gongolaria barbata* | macroalgal forests restoration | Mediterranean Sea

ABSTRACT

In the Mediterranean Sea, *Cystoseira sensu latu* species are experiencing a severe decline, and in the last decades, many restoration attempts have been carried out to contrast such decline. Available experience suggests that the choice of the restoration site can be more important than the methodology used. As an example, episodic events, such as intense storms, can cause the loss of the transplants used for restoration attempts, hampering the long-term success of the interventions. Here, we tested the success of restoration of the macroalga *Gongolaria barbata* at different outplanting water depths along the Conero Riviera (Adriatic Sea, Mediterranean Sea). After growth of *G. barbata* individuals in mesocosms, they were transplanted at 1, 1.5, and 3 m depth. During the monitoring period ad sea (from late July to December 2023), two strong storms were recorded. The highest success in terms of survival and growth rates increased with increasing transplanting depth. This study confirmed that, even within a narrow bathymetric range, transplantation at deeper depths of the upper infralittoral zone can reduce the impact of wave energy enhancing the success of restoration interventions.

1 | Introduction

Biodiversity severely declined in the last decades, due also to habitat loss and degradation, which represent a major threat (Duarte et al. 2020), causing the impairment also of ecosystem functioning worldwide (Hoekstra et al. 2005; Crain et al. 2009). At sea, coastal habitats are severely impacted by human pressures, which are causing the decline of associated biodiversity, ecosystem functioning and services (Orth et al. 2000; Cesar 2000; Valiela et al. 2001; Pandolfi et al. 2003; Duke et al. 2007; Barbier 2012; Micheli et al. 2013; Costanza et al. 2014). The pattern of biodiversity loss needs to be reversed, and ecological restoration is increasingly acknowledged as the most effective strategy (Elliott et al. 2007; Possingham et al. 2015; Kienker et al. 2018; Abelson et al. 2020), together with conservation, both fostered by the high level of resilience showed by marine ecosystems once the pressures are mitigated or removed (Duarte et al. 2020).

Marletta Giuliana and Sacco Domenico contributed equally to the paper.

Ecological restoration was defined by the Society of Ecological Restoration (SER 2004; Gann et al. 2019) as "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed", aiming at moving "a degraded ecosystem to a trajectory of recovery that allows adaptation to local and global changes, as well as persistence and evolution of its component species". The United Nations General Assembly recently declared the "UN Decade on Ecological Restoration" (2021–2030), as solution to ameliorate ecosystem degradation (Possingham et al. 2015). The European Union recently approved the Nature Restoration Regulation (NRR), setting the targets for the next decades (by 2025) to restore all the habitat types of the European seas in a significant portion of degraded areas (EU 2024). Although marine ecosystem restoration is relatively recent when compared to the terrestrial, significant progress is going on for several coastal habitats, including seagrasses, saltmarshes, oyster reefs, mangroves, and Fucales forests (Bayraktarov et al. 2016). This scientific and technical advancement suggests that the upscaling of interventions on a large spatial scale is feasible, as well as necessary and urgent.

In the Mediterranean Sea, habitat-forming species, such as *Cystoseira sensu lato* (order Fucales) are facing a severe regression (Serio et al. 2006; Perkol-Finkel and Airoldi 2010; Blanfuné et al. 2016; Mariani et al. 2019) and their habitats are considered among those to be urgently restored in the European seas (habitat Group 2 "Macroalgal forests" in the Mediterranean Sea, NRR Annex II; EU 2024). Restoration, indeed, has been proposed as promising approach to halt their decline (Gianni et al. 2013), and several European projects (e.g. MERCES, AFRIMED, FORESCUE) already developed and tested new techniques to reintroduce *Cystoseira s.l.* after local extinction, regenerating self-sustaining populations (Verdura et al. 2018; Gran et al. 2022; Bianchelli, Fraschetti, et al. 2023; Bianchelli, Martini, et al. 2023). A roadmap and a decision-support framework for a successful restoration of Mediterranean macroalgal forests was recently proposed to assist researchers and stakeholders in decision-making, considering the most effective methods, success evaluation (at species and ecosystem level) and long-term management (Cebrian et al. 2021; Smith et al. 2023; Galobart et al. 2023).

Analysing the results of restoration effort on macroalgal forests, it has been recently proposed that *where* a restoration activity is undertaken is of greater relevance for a successful restoration intervention than *how* the restoration is carried out (Fraschetti et al. 2021). The ecological factors (such as ecosystem and habitat type, geographical location, depth, hydrodynamism, sedimentation rates, local stressors, historical presence of the species in a site, ecological interactions with existent assemblage in an area) are crucial to plan future restoration actions (Cebrian et al. 2021). Therefore, site selection and the identification of species requirements are important for defining appropriate restoration interventions (Gianni et al. 2013; Fraschetti et al. 2021; Fabbrizzi et al. 2023; Smith et al. 2023).

In the last decades, the Conero Riviera (Northern Adriatic Sea, Mediterranean Sea) experienced a severe decline (up to 70%) of the macroalgal forests formed by canopy forming species *Gongolaria barbata* (Munda 1993; Perkol-Finkel and Airoldi 2010). At local level, this regression has been related to high hydrodynamic forces (seasonal storms, currents, waves) and human-induced chemical and physical modification of the habitat, which hampered the natural recovery of algal forests (Perkol-Finkel and Airoldi 2010). Recently, a successful restoration intervention of *G. barbata* was obtained using both ex situ and in situ recruitment approaches, but the results also showed that storms can impair restoration interventions in the most exposed sites (Bianchelli, Fraschetti, et al. 2023).

In the present study, we used the ex situ recruitment approach, and tested the effect of transplanting depth on the restoration success of the macroalgae *G. barbata*, to counteract the hydrodynamics' negative effect on the survivorship and growth of transplanted juveniles.

2 | Materials and Methods

2.1 | Donor and Receiving Sites

This study was conducted along the Conero Riviera (Marche region, Italy, North-Western Adriatic coast; Figure 1A), stretching for about 8 km and representing the seaward limit of a terrestrial protected regional park hosting three Sites of Community Importance (*sensu* EU Habitat Directive; SIC IT5320005 "*Costa tra Ancona e Portonovo*", IT5320006 "*Portonovo e falesia calcarea a mare*" and IT5320007 "*Monte Conero*") and one of the few natural rocky outcrops along the otherwise extensively urbanised sandy coastline of the Italian Adriatic Sea. These rocky outcrops mainly consist of marls and limestones and extend to ca. 8 m in depth (Perkol-Finkel and Airoldi 2010).

Along the Conero Riviera a severe decline of *G. barbata* was documented (Perkol-Finkel and Airoldi 2010), with only few sites remaining (as Piscinetta Passetto and Scalaccia rock pools, Sassi Neri, and Numana, Bianchelli, Fraschetti, et al. 2023). We identified the site of Scalaccia as donor site (43.61° N 13.55° E; Figure 1B), due to the presence of healthy and well-structured stands of *G. barbata* down to 1.5–2 m of depth.

Recently, Bianchelli, Fraschetti, et al. (2023) implemented a restoration intervention along the Conero Riviera, previously testing several sites to find the most suitable for *G. barbata* growth. In that occasion, La Vela Portonovo site (43.56° N 13.61° E) was considered, since scientific literature reports historical presence of *G. barbata* there (Airoldi et al., 2008). For this reason, this site was selected as possible receiving site for restoration interventions (Bianchelli, Fraschetti, et al. 2023), and in that occasion, authors observed that the recruits transplanted to La Vela showed high growth rates (from 5 to 13.3 cm in heigh, from June to September 2020) among all the possible receiving sites, but unfortunately, it was the only site in which individuals were detached by a strong storm after 4 months (data and information are reported in Figure 2 and Supplementary Table S1 in Bianchelli, Fraschetti, et al. 2023).

In accordance with Bianchelli et al. (2023), we selected La Vela, Portonovo, as receiving site, even if characterised by a high hydrodynamism, testing the effect of water depth to counteract the hydrodinamism effect.

FIGURE 1 | (A) Geographical location of the Conero Riviera. (B) Location of Scalaccia, La Vela and UNIVPM, respectively donor site (DS), receiving site (RS) and hosting aquaria facility (AF). Map created using the Free and Open Source QGIS.

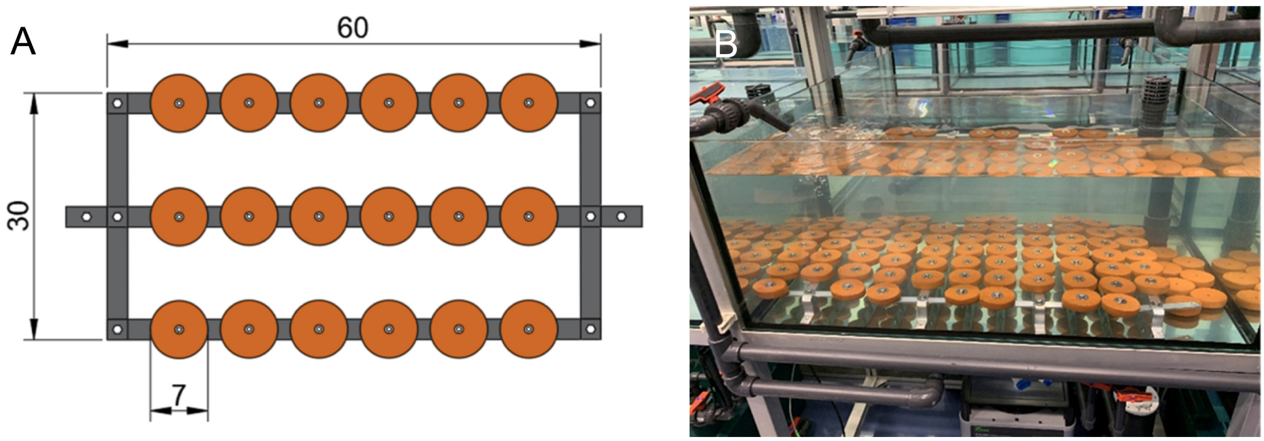

FIGURE 2 | (A) Scheme of the structure used with clay tiles attached (dimensions are in cm). (B) Example of structures in the tanks used for *G. gongolaria* ex situ recruitment (Aquaria Facility at DiSVA-UNIVPM).

On the 1 March 2023, we collected fertile receptacles of *G. barbata* from the donor site and transported them to the Aquaria Facilities of the Department of Life and Environmental Sciences, Polytechnic University of Marche (DiSVA-UNIVPM), at Ancona city (Figure 1B). Here, we placed the receptacles inside aluminium foils and stored them for 24 h in the refrigerator at 4°C in dark conditions, to stimulate gametes' release and zygotes' development.

2.2 | Maintenance in Mesocosms

For the ex situ recruitment and cultivation of *G. barbata*, three mesocosms were employed. After the storage in dark and cold conditions, receptacles were cleaned in filtered seawater to remove epiphytes and were included into small PVC nets, suspended in the mesocosms to enhance zygotes' formation and deposition. Eighteen clay tiles (with a diameter of 7 cm, a thickness of 1.4 cm), perforated at the centre and attached to a 65-cm-long steel structure for the following anchoring at the restoration site, Figure 2A) were distributed in each mesocosm for a total of 54 tiles (see as example, Figure 2B). Moreover, five glass slides for each tank were added to check the zygote development and the first segmentation phases. The receptacles were maintained in the bags for 5 days; then, they were removed from the mesocosms.

To guarantee the highest standards in the maintenance of algae in the mesocosms, we used the LSS (Life Support System). The system consisted of 40-L tanks, a reserve in which there are three socks of 100 µm for mechanical filtration, immersed razor clams for biological filtration, Teco TK 500 cooler to maintain the temperature, and movement pumps to guarantee the water circulation. Fluorescent lamps produced 260-nm (λ) UV-C rays, sterilising the water, damaging nucleic acids, and preventing microbes' proliferation. In the tanks, light intensity was generated by two LED lamps (Silver Moon Marine 10 thousand Kelvin and Silver Moon Universal 6.5 thousand

Kelvin) 40 cm above the water surface. Irradiance was measured with a Photometer of the apogee Model MQ-500. The temperature was set at 20° C throughout the controlled environment. The used photoperiod underwent a change, transitioning from 13:11 L:D to 15:9 L:D h cycle, after the first month of stabilisation, and light intensities were set to 80–100 μmol photons $m^{-2} s^{-1}$. The main parameters (temperature, salinity, pH and light intensity) were monitored once a week. Furthermore, for routine maintenance of the system, water loading and unloading, lights, movement pumps, cooler, any water leaks at the pipe joints were checked. To complete this management process, the socks were washed, tubs syphoned to remove organic debris and a water change of about 10% per week was done.

Embryos and individuals were checked twice a week in correspondence of water changes observing the glass slides. After the fourth week, Von Stosch culture medium was added to enhance individuals' growth in the mesocosms. The maintenance of *G. barbata* in mesocosms lasted about 5 months (from March to July). During the first month, the slides were checked to evaluate zygote and embryo development and growth. In particular, the length (μm) and density (as number of embryos per slide) were evaluated at light microscope. Subsequently, when individuals reached about 0.5 mm in length (after 1 month), all slides were removed and only the clay tiles were monitored. The height was measured on 15 individuals and the density on 4 areas in 5 random tiles per mesocosm (4 × 5 = 20 areas per mesocosm; Marletta et al. 2024). The density was reported as the number of individuals cm^{-2}. Data were collected using a stereomicroscope (magnification 6.4), an Olympus TG-6 camera and were then analysed with the software ImageJ.

2.3 | Transplanting at the Restoration Site

On 25 July 2023, immediately after the last measurements in mesocosms, the tiles anchored to the structures were transported to La Vela site. The structures were transported to the receiving site through 200-L tanks full of tanks water. To minimise temperature fluctuations and prevent thermal shocks during the transport, we added 1 L of seawater approximately every 10 min. The tiles, screwed to three 65-cm-long steel structures, were fixed to the sea bottom, using pins with a double nut, 8-mm-diameter fisher anchors and a steel screw. The holes were made with an underwater drill. Each structure contained 18 clay tiles and was positioned at a 10–15 m distance. The three structures were anchored at three water depths, selected according to the seabed morphology and the documented range of depth of *G. barbata* in this area (Perkol-Finkel and Airoldi 2010; Bianchelli, Fraschetti, et al. 2023; Rindi et al. 2023): 1 m, 1.5 m and 3.0 m. This phase was very delicate, due to the mechanical damage that may occur, and the high individuals' susceptibility during the transport and fixation. Monitoring of the tiles in the field was carried out for 5 months: August (T1), September (T2), October (T3), November (T4) and December (T5). Over this period, two storms occurred in October and November with waves 3-m high (ISPRA 2023). The tiles were subsequently checked after both storm events, which did not destroy or damage the structures.

2.4 | Data Collection, Data Treatment and Statistical Analyses

In mesocosms and at sea, growth was measured through changes in length over time ($n = 15$, randomly selected per each mesocosm/structure at each time, reported in mm), density was calculated as number of individuals on a standardised surface (n. ind cm^{-2}, in mesocosm and at sea, respectively, in 4 area in 5 tiles randomly selected per each mesocosm/structure at each time) and their survival (%) as $(numb.\,recruits\,at\,Tn + 1 \div numb.\,recruits\,at\,Tn) \times 100$, where $n = 1, 2, 3, 4$.

The length of individuals (mm) was measured through a ruler and their density on five tiles for each different structure were assessed by taking photos and processing them through ImageJ.

Due to the non-independence among the mesocosms (due to aquaria structural characteristics), data on the individuals' length and density from the cultivation phase in mesocosms were treated only with descriptive statistics.

Concerning the data after transplanting at sea, two-way ANOVA was applied considering water depth and time as source of variance: depth (fixed factor, 3 levels: 1 m, 1.5 m and 3.0 m) and month (random factor, 5 levels: August (T1), September (T2), October (T3), November (T4) and December (T5)) for growth in length, density on the tiles and survival. Verification of the assumptions of normality (Shapiro–Wilk) were checked prior to conduct the analyses. Post-hoc comparisons on significant terms ($p < 0.05$) were performed by Tukey test. The statistical analyses were performed through the software Jamovi 2.3 (Jamovi project 2022).

3 | Results

All the data are reported in the Supplementary online material.

3.1 | Maintenance and Cultivation in Mesocosms

During the cultivation in mesocosms, *G. barbata* individuals grew up from 0.20 ± 0.02 to 5.80 ± 0.70 mm, from the beginning (T1) to the end (T5) of the maintenance period (Figure 3A). Individuals' density decreased from 95.9 ± 4.34 to 22.4 ± 1.85 n. ind cm^{-2} from T1 to T5 (Figure 3B).

3.2 | Growth After Transplanting at sea

Two-way ANOVA analysis showed that the factors depth, month and month × depth had a significant effect on individuals' length (ANOVA $p < 0.01$; Table 1). At all water depths the length of individuals significantly increased over time (pair wise $p < 0.01$; Figure 4A), but the highest growth rates were observed at 3-m depth. Starting from month T2 and over the entire period (i.e. T3, T4 and T5), the length of individuals was significantly higher at 3 m (range 6.17 ± 0.82–29.60 ± 4.31 mm, T1 and T5, respectively) than at 1 m

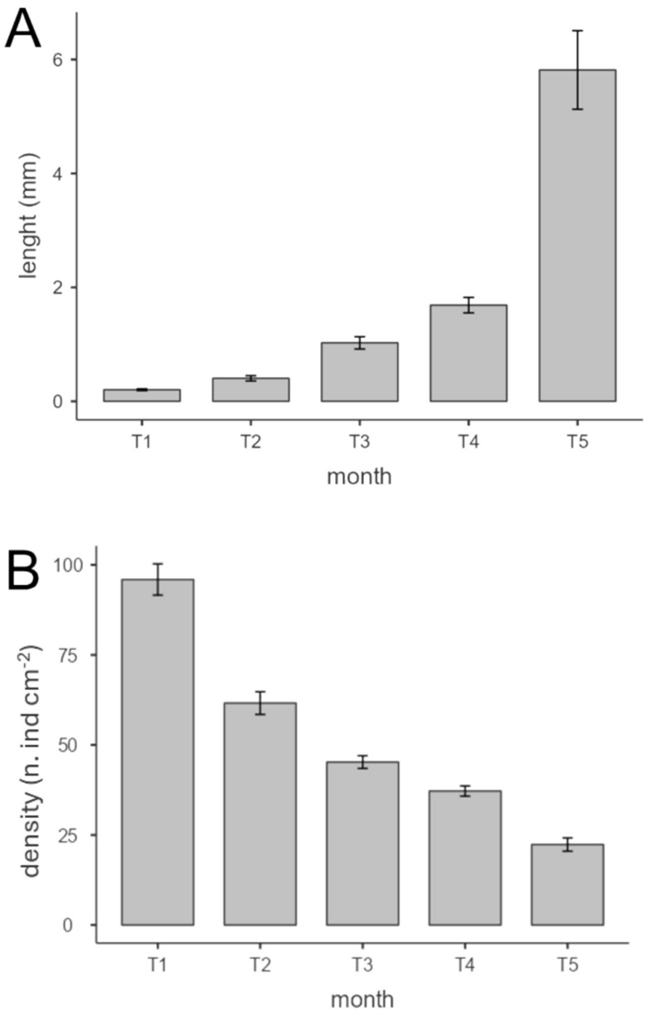

FIGURE 3 | Individuals' length (A) and density (B) from the beginning (T1) to the end (T5) of the cultivation in mesocosms. Data are expressed as mean ± standard error (T1 = March, T2 = April, T3 = May, T4 = June, T5 = July 2023).

TABLE 1 | Results of ANOVA on individuals' length, density and survival after transplanting at sea.

	Factors	*df*	*F*	*p*
Individuals' length	Month	4	14.33	0.001
	Depth	2	7.78	0.013
	Month × depth	8	3.69	0.001
Individuals' density	Month	4	17.23	0.001
	Depth	2	16.97	0.001
	Month × depth	8	0.4	ns
Survival (%)	Month	4	3.43	ns
	Depth	2	44.42	< 0.001
	Month × depth	8	1.82	ns

(4.44 ± 0.61–18.90 ± 1.56 mm, T1 and T5, respectively) and 1.5-m depth (5.40 ± 0.52–19.30 ± 1.99 mm, T1 and T5, respectively) (pair wise $p < 0.01$).

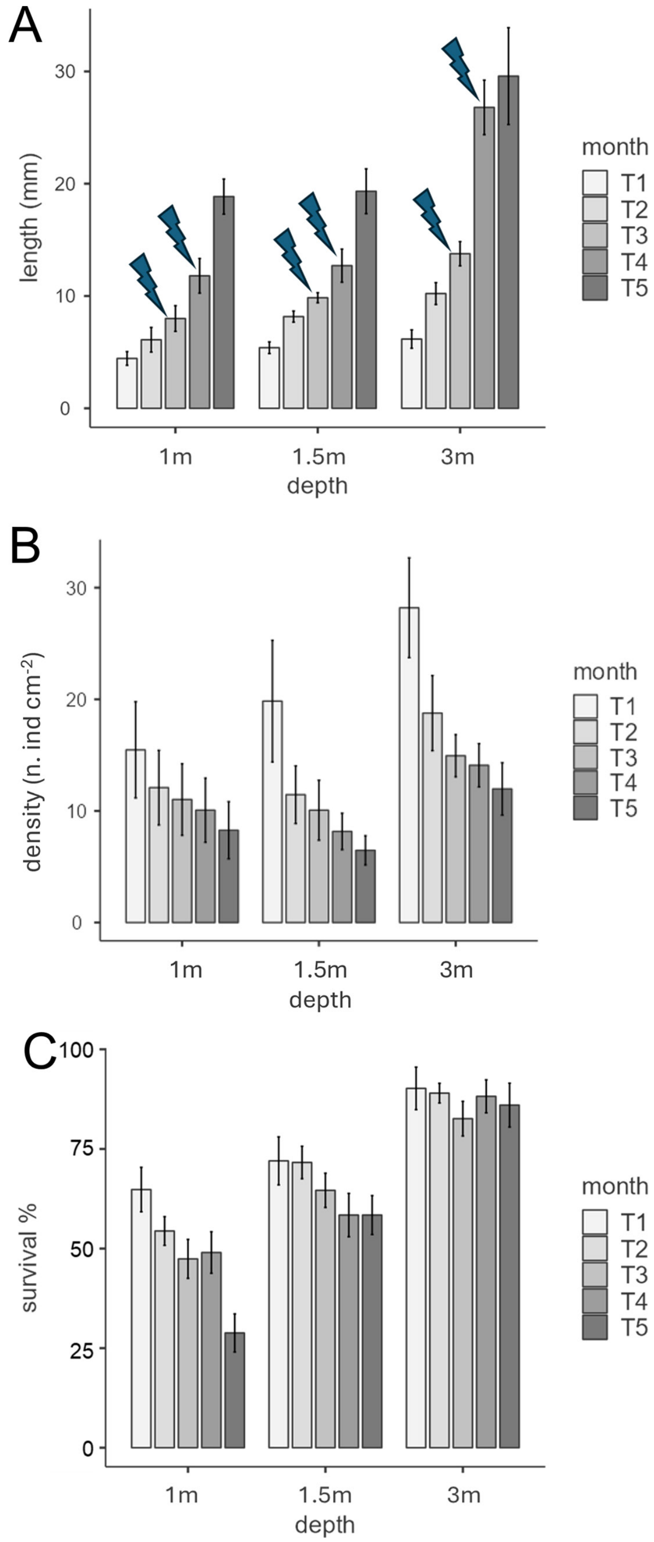

FIGURE 4 | Individuals' length (A), density (B) and survival (C) from the beginning (T1) to the end (T5) of the experiment, after the transplanting at sea. Data are expressed as mean ± standard error. The lightning indicates the storms occurred during the study. (T1 = August, T2 = September, T3 = October, T4 = November, T5 = December 2023).

Two-way ANOVA analysis showed that the factors depth and month had a significant effect on individuals' density (ANOVA $p < 0.01$; Table 1). At all depths, the density significantly decreased over time (pair wise $p<0.01$; Figure 4B). Starting from month T2 and over the entire period (i.e. T3, T4 and T5), the density of individuals was significantly higher at 3 m (28.20 ± 4.47–12 ± 2.35 n. ind cm^{-2}, T1 and T5, respectively) than at 1 m (15.5 ± 4.31–8.27 ± 2.56 n. ind cm^{-2}, T1 and T5, respectively) and 1.5 m depth (19.8 ± 5.45–6.47 ± 1.30 n. ind cm^{-2}, T1 and T5, respectively) (pairwise $p<0.01$; Figure 4B).

Two-way ANOVA analysis showed that the factor depth had a significant effect on individuals' survival (ANOVA $p<0.01$; Table 1). At 1 and 1.5 m depth, the survival decreased over time, whereas at 3 m, the values did not significantly change (Figure 4B). Survival at 3 m (90 ± 5–86 ± 6%, T1 and T5, respectively) was higher than the other depths (1 m $= 65 \pm 6$–29 ± 5%; 1.5 m $= 72 \pm 6$–58 ± 5%, T1 and T5, respectively) in all periods.

4 | Discussion

The effect of water depth is often neglected in research focusing on restoration of *Cystoseira sensu lato* species, even though it has a pivotal role in the distribution, recruitment and population dynamic of many species belonging to the *Cystoseira complex* (Mangialajo et al. 2012). In the Mediterranean Sea *Cystoseira complex* comprises ca. 40 species, adapted to a wide spectrum of bathymetry, from very shallow and lagoon habitats (e.g. *Ericaria amentacea* and *G. barbata*; Mangialajo et al. 2012; Gran et al. 2022) to deeper ones, down to > 50 m water depth (e.g. *Ericaria zosteroides*, considered "deep algae"; Ballesteros et al. 2009; Capdevila et al. 2015).

The results of the present study indicate that the effect of water depth can be significant also in restoration intervention of *Cystoseira s.l.* species, and particularly also for those species having a spatial distribution along a narrow bathymetric range, as *G. barbata*. Along the Conero riviera (NW Adriatic coast), indeed, this species is typically observed between 0.5 and 5 m water depth, due to the natural characteristics of the Monte Conero cliff, which provides narrow and shallow rocky bottoms surrounded by sandy habitats, thus providing highly heterogenous substrates. Due to this heterogeneity, the experiment was conducted only in one site, La Vela, known to be the most impacted by winter storms, since it represents the most exposed along the Riviera (Bianchelli, Fraschetti, et al. 2023). Even if not replicated over a wider spatial scale, the approach used in this study has been repeatedly used for restoration purposes, due typically to logistic, environmental constrains or the lack of availability of huge number of new individuals recruited with ex situ techniques (Bianchelli, Fraschetti, et al. 2023; Bianchelli, Martini, et al. 2023; Orlando-Bonaca et al. 2022; Galobart et al. 2023). However, overall, our results could give additional information in the light of planning future restoration interventions (Cebrian et al. 2021; Smith et al. 2023).

In the last years, many restoration interventions recommended site prioritisation to enhance the recovery of *Cystoseira s.l.* populations, indicating also that the siting is one of the most important aspects to consider whenever a restoration intervention is projected (Cebrian et al. 2021; Fraschetti et al. 2021; Bianchelli, Fraschetti, et al. 2023; Bianchelli, Martini, et al. 2023; Fabbrizzi et al. 2023; Smith et al. 2023). Considering the high genetic and phenotypic variability of *Cystoseira s.l.* species and the populations' variability within each species (Sadogurska et al. 2021), also within the same site it is important to identify the most suitable conditions to favour the long-term success of restoration interventions (Cebrian et al. 2021; Smith et al. 2023). In this regard, our data suggest that also within the same site, *G. barbata* transplanted juveniles can develop differently, in terms of abundance and growth rates, over a very narrow depth gradient (i.e. from 1 to 3 m water depth), possibly determining different success level of restoration interventions. In the case of the present study, this is can be because of water depth in counteracting the impact of high-level of hydrodynamism and autumnal storms, which have been identified as a reason for restoration failure, due to their capability to destroy the artificial structures used for the juveniles transplanting (Bianchelli, Fraschetti, et al. 2023).

Burel et al. (2019), by studying the small-scale effect of hydrodynamism on macroalgal communities, demonstrated a negative relationship between wave height and cover of several Fucales, and that strong hydrodynamics causes a severe regression of canopies. Previous studies conducted along the Conero Riviera confirmed that severe storms can cause the fragmentation or complete detachment of *G. barbata* stands (Bianchelli, Fraschetti, et al. 2023; Marletta et al. 2024). Here, for the first time, we tested the effect of transplanting depth as a potential factor that could protect the new juveniles transplanted from the high hydrodynamic impact or, at least, guarantee the highest survival and growth rates.

In this study, during the maintenance in mesocosms, the embryos and individuals of *G. barbata* cultured for 5 months showed a growth in length; nevertheless, the individuals' density decreased over the same period. The negative relationship between the individuals' length and their density is expected (Savonitto et al. 2021) and can be attributed to the process of "self-thinning", which occurs also once the juveniles are outplanted in the natural environment (Marletta et al. 2024). Indeed, when individuals grow in height, competition for space takes place, causing an increase in mortality and thus resulting in a decrease in the number of individuals (Ang and De Wreede 1992; Steen and Scrosati 2003). Even if it is not considered a cost-effective solution (Orlando-Bonaca et al. 2022), in this study, we prolonged the maintenance of individuals in mesocosms further to increase their growth and their survival in the field. Consequently, the higher costs associated with the longer maintenance (Verdura et al. 2018) in mesocosms allow the individuals to better forefront environmental stress (as high sedimentation rates or grazing pressure) as well as wave energy impact, which could impair the growth of too small (mm in heigh) individuals (Bianchelli, Fraschetti, et al. 2023; Bianchelli, Martini, et al. 2023). Even, it has been recently demonstrated that *Cystoseira s.l.* forests with 100% cover reduced the wave action, protecting the Mediterranean coasts from erosion, thus providing a fundamental ecosystem service and representing a nature-based solution as an alternative to unsustainable and costly artificial constructions (Papadimitriou et al. 2024).

In the present study, during the monitoring of the tiles in the field, as expected, two strong storms occurred: one on the 30 October and one on the 25 November, both with waves of 3 m in height (ISPRA 2023). Since the impact of wave action did not displace the artificial structures, these latter were efficiently deployed and anchored to the substrate. Nevertheless, it was observed that the individuals located at 3 m depth showed the best performance in terms of survival, growth rates and density (Figure 5). Moreover, differently from the other depths, the individuals located at 3 m depth showed remarkable stability of the transplanted individuals (expressed as survival over time). As previously documented (Sadogurska et al. 2021; Orlando-Bonaca et al. 2022; Bianchelli, Fraschetti, et al. 2023), *G. barbata* stands can show high variability even at small spatial scale and this, as shown by Marletta et al. (2024) and in the present study, can affect the development, survival and growing of the new individuals. In this study, the variability among growth and survival is driven only by the narrow differences in water depth, it can be assumed indeed that across a bathymetric range of 2 m (from 1 to 3 m water depth) all other environmental and ecological conditions (as sedimentation rates, herbivory pressure, Figure 6) were similar.

Our data confirm that even small changes in the water depth of the transplants can result in significant differences in growth and survival (Figure 6). Therefore, in the context of the

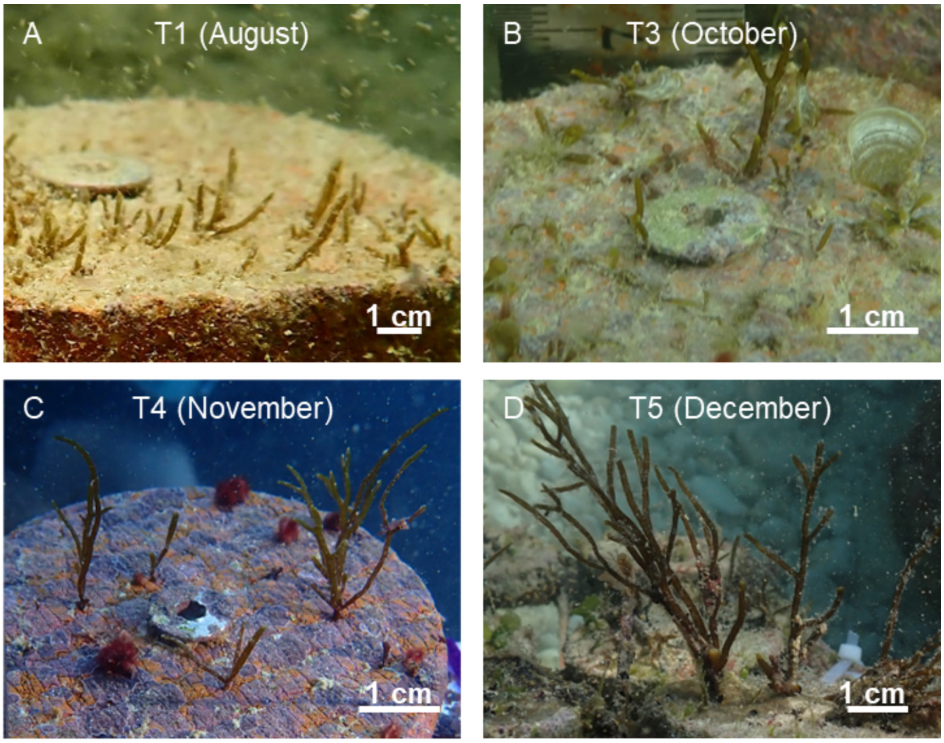

FIGURE 5 | *G. barbata* growing over time at 3 m water depth.

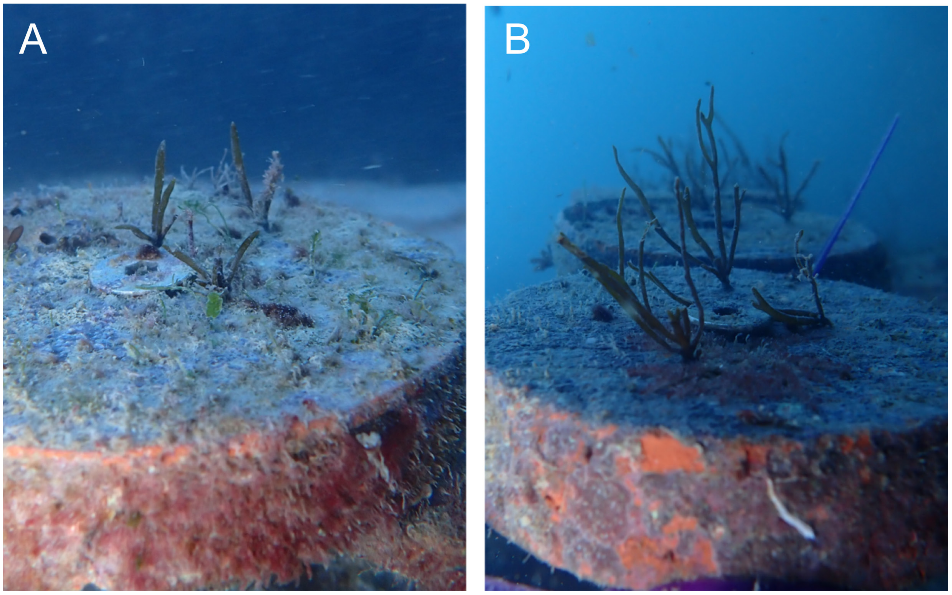

FIGURE 6 | *G. barbata* at 1 m (A) and 3 m (B) water depth at the T4 (November 2023) of the experiment.

restoration upscaling, it would be important to identify the most favourable conditions able to optimise the interventions' success, which would ensure the highest individuals' performance of the species selected, and thus a long-term success. In the case of *G. barbata*, depth is an environmental factor influencing the success of restoration interventions by protecting the transplants from the storms' effects and cannot be neglected in future restoration projects (Cebrian et al. 2021).

As episodic events and rough sea conditions are predicted to increase because of climate change, the results of this study suggest that a slightly higher depth of transplantation can increase the resistance of the transplants to the impact of wave actions. This concept perfectly fits with the European Nature Restoration Law and EU's Biodiversity Strategy 2030 goals, aiming to restore biodiversity and enhance ecosystem resilience to climate change (Verdura et al. 2023).

Author Contributions

GM, RD, SB conceived and designed the research; GM, DS performed the experiments; GM, DS collected and analysed the data; GM, SB wrote the draft manuscript; GM, DS, RD, SB wrote and edited the manuscript.

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Ethics Statement

The authors have nothing to report.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data are reported as Supplementary file of the article.

Permission to Reproduce Material From Other Sources

Not applicable.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.