COASTAL LAGOON RECOVERY BY SEAGRASS RESTORATION. A NEW STRATEGIC APPROACH TO MEET HD & WFD OBJECTIVES

Facca C.[1], Bonometto A.[2], Boscolo R.[2], Buosi A.[1], Parravicini M.[3], Pedrali, C.[3], Siega A.[4], Volpe V.[4], Sfriso A.[1]

[1] Department of Environmental Sciences, Informatics and Statistics, Ca' Foscari University of Venice, via Torino 155, 30172 Venice, Italy, facca@unive.it
[2] Italian National Institute for Environmental Protection and Research (ISPRA)
[3] Laguna Venexiana ONLUS
[4] Interregional Superintendence for Public Works in Veneto, Trentino Alto Adige, Friuli Venezia Giulia

Abstract: Seagrass meadows play a crucial role for the preservation of coastal environments, as they support biotic communities, improve water quality and reduce erosion effects. SeResto (LIFE12 NAT/IT/000331) has been recently funded to achieve the following objectives in Venice Lagoon (Adriatic Sea, Italy):
- Restoring and consolidating Habitats 1150* by transplantation of aquatic seagrasses;
- Contributing to achieve a good ecological status and demonstrating the effectiveness of the proposed actions to meet the objectives of the WFD (2000/60/EC);
- Quantifying and highlighting the value of ecosystem services provided by the lagoon environment and the angiosperm meadows.
The basic idea is to restore the *Nanozostera noltii* and/or *Zostera marina* meadows on a large scale by triggering and supporting the natural re-colonization processes, in areas where the environmental conditions returned to be suitable for the rooting of these species.
The methodological protocol does not require heavy restoration interventions but widespread transplantations of small sods of seagrasses and manual dispersion of rhizomes and seeds. Concrete restoration actions will be mainly made by local fishers (associated with a partner) daily living the lagoon for recreational activities that will be specifically trained in the framework of the project and supported by the staff of scientific partners.
An intensive monitoring activity, started in April 2014, will be carried out during the entire project time. Biological Quality Elements (BQEs) required by Dir. 2000/60/CE as indicators (seagrasses, macroalgae, macrobenthos and fish fauna) and supporting abiotic elements in water and sediments will be monitored to investigate the effectiveness of this measure in improving the ecological status of the area. Environmental parameters will support also the cause analysis of possible not-rooting of transplanted seagrasses, addressing the necessary management activities.

Keywords: 1150 * Coastal lagoons, eutrophication, biomanipulation/population control, increasing public support and participation

Introduction

Seagrass meadows play a crucial role for the habitat preservation, since they support numerous biologic communities and increase the stability of the tidal flats by reducing sediment resuspension and increasing the friction capacity of the sea-beds that decreases the wave height and energy. Moreover, the meadows contribute to permanently stock CO_2: as an example, in 2003, it was estimated that these plants, covering an area of approximately 56 m^2 (Sfriso & Facca, 2007), can permanently store ca. 40,000 CO_2 tons.
Since 1980, worldwide the seagrass cover loss was estimated to be 29%, accounting for an annual regression of 110 km^2 per year (Waycott et al., 2009). In Europe, several coastal habitats experienced dramatic seagrass reduction: as an example in the Wadden Sea (Dutch) from 1919 to 1994 *Zostera marina* Linnaeus coverage has decreased from 150 km^2 to 2 km^2 (Krause-Jensen et al., 2004) and in the Mondego estuary (Portugal) from 1986 to 1997 *Nanozostera noltii* (Hornemann) Tomlinson & Posluszny has decreased from 15 ha to 0.02 ha (Cardoso et al., 2004; Martins et al., 2005).
In Venice lagoon (Italy), between the '70s and the '80s beds of *Ulva rigida* C.Agardh and other ulvaceans replaced seagrass meadows because they better exploited the high nutrient availability and outcompeted seagrasses causing abnormal blooms in most of the lagoon with dramatic consequences for fish and macrofauna (Sfriso & Facca, 2007). At the beginning of 2000s the environmental conditions changed significantly thanks to regulations that have strongly limited disturbance elements reducing the nutrient inflow from the watershed ("Ronchi Costa" Decrees, 28 April 1998) and regulating clam harvesting (Province of Venice, 1999). Hence, anoxia diminished and seagrasses started to colonize the areas where the macroalgal biomass had disappeared.
At present, in the project area (SCI IT3250031) in the Northern Venice Lagoon, the factors causing natural population decrease were reduced and the specific environmental features seem to be suitable for the recolonization of *N. noltii* and/or Z. *marina*. However, the morphological characteristics and the low hydrodynamism of choked areas hamper the natural seed spread, slowing down the seagrass recolonization.
To improve the seagrass spread the project SeResto (Habitat 1150* - Coastal lagoon – recovery by SEgrass RESTOration. A new strategic approach to meet HD & WFD objectives, LIFE12 NAT/IT/000331) was funded by the European Commission LIFE+ Programme with the following objectives:
1. Restoring and consolidating water habitats no. 1150* by transplanting of submerged seagrasses;
2. Contributing to achieve a good ecological status of transitional water bodies and demonstrating the effectiveness of the proposed actions to meet the objectives set in the Framework Water Directive (Dir. 2000/60/EC art. 4);
3. Quantifying and highlighting the value of ecosystem services provided by the lagoon environment, and particularly by the angiosperm meadows in habitats no. 1150*.

Materials and methods

The lagoon of Venice is a highly antrophizied wetland, ~550 km^2 wide, connected to the Adriatic Sea through three inlets. The project area is in northern lagoon (included in the list of Sites of Community Importance SCI IT3250031), where the priority habitat 1150* Coastal lagoon covers 3660 ha.

The complexity of large scale seagrass restoration is related to high costs and impact on donor sites. The core project's idea is to trigger and support the natural re-colonization processes by widespread transplantations of small sods of seagrasses and manual dispersion of rhizomes, leaving to the natural reproduction capacity the task of achieving a complete re-colonization of the study areas. Therefore the proposed restoration strategy does not require heavy restoration interventions and low quantity of seagrasses (less than 50 m^2) will be taken from donor sites. A careful study was conducted to investigate the environmental features in order to establish which species are the more suitable for the proposed activities.

During the first year of activity 17 implantation sites were identified and the following year 18 further sites will be selected to cover the entire project area (Figure 1a). In each site 9 sods (diameter 30 cm) were implanted following the diagram in Figure 1b. The size of the triangle and the layout of sods were planned on the basis of the growth rate of plants to favor their merging.

Plants were explanted from well-developed beds located inside the fishing pods with a corer 30 cm large and rapidly transported to the implantation sites, where they were implanted (Figure 2a). Moreover, seasonally distribution of seeds and rhizomes is planned until the beginning of 2018 to reinforce the plant colonization (Figure 2b).

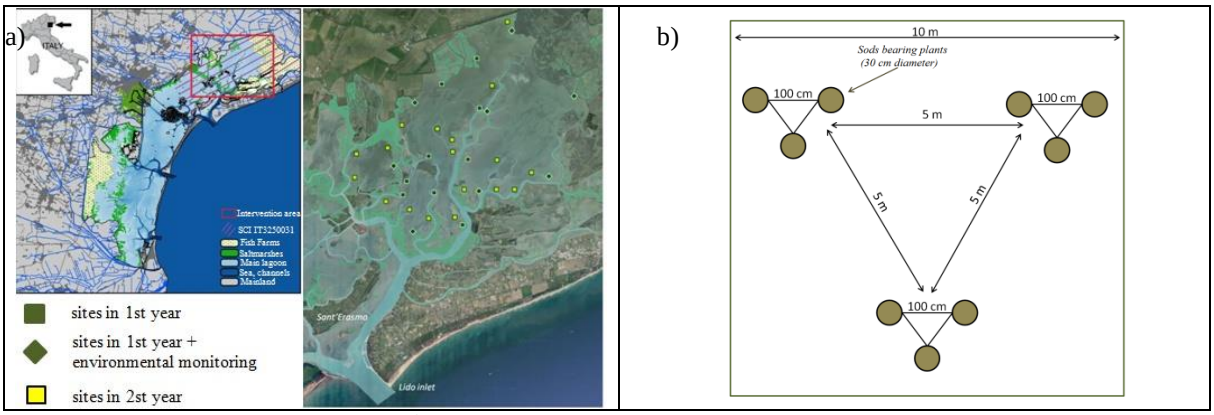

Figure 1. a) map of intervention area, b)seagrass implantation diagram in each site.

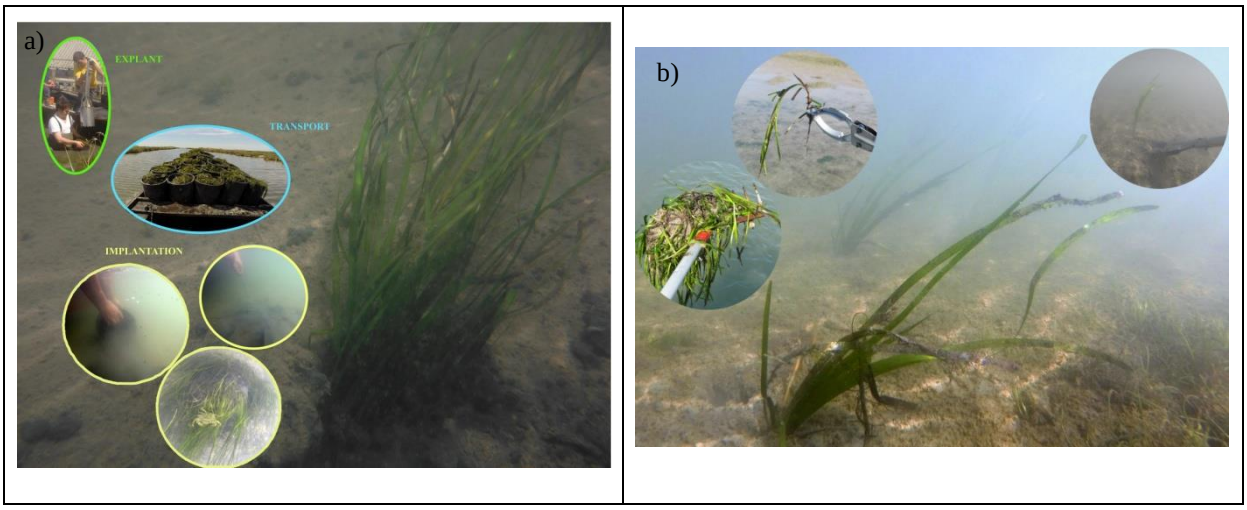

Figure 2. a) Seagrass transplantation and b) manual rizhoes dispersion procedures (Photos by Staff SeResto)

The technical proposal is characterized by a low cost due to the use of small tools and the involvement of local fishermen (associated with a project partner), that were specifically trained in the framework of the project to carried out the transplantation activities.

An intensive monitoring activity, starded in April 2014, will be carried out during the entire project time. Biological Quality Elements (BQEs) required by Dir. 2000/60/CE as indicators (seagrasses, macroalgae, macrobenthos and fish fauna), and supporting abiotic elements in water and sediments, will be monitored to investigate the effectiveness of this measure in improving the ecological status the area. Environmental parameters will support also the cause analysis of possible not-rooting of transplanted seagrasses, addressing the necessary management activities. In 8 out of 35 sites (Figure 3), selected as representative of different environmental conditions within the project area, the monitoring activities will include high frequency sampling and a more complete set of parameters.

Results and discussion

The project started on 1st of January 2014, so few preliminary results are available.
Transplantations were carried out from the end of May to the mid of June 2014 in 17 sites (Figure 1a). In all sites, at least three sods bearing *N. noltii* were planted, because the environmental conditions are the most suitable for its uprooting and growth.
In 12 sites, *Z. marina* was also included and in few stations, with peculiar features, some attempts with *Cymodocea nodosa* (Ucria) Ascherson and *Ruppia chirrosa* (Petagna) Grande were carried out. In September 2014 (2-3 months after transplantations), the first monitoring survey showed that from 2 to 6 of the 9 initial sods remained in 13 sites. In 8 sites the uprooting and coverage resulted particularly successful, and in the areas where 3 sods were recorded they were clearly merging in one larger spot.
In the remaining 4 sites no plants were detected (Figure 3). These preliminary results have to be confirmed by next monitoring, because the roots of translanted seagrasses could be still present and shoot during the next spring/summer. Meteorological, environmental and biological data were analyzed to understand which parameters affected seagrass uprooting and growth in these sites, initially chosen because characterized by few anthropogenic pressures and, on the basis of long-term observations, scarce macroalgal coverage and low nutrient concentrations (factors that can favor plant colonization). Despite these considerations the summer 2014 period resulted highly rainy with approximately 45 days of precipitations from July 1st to September 15th. In August the precipitations were +49% than the previous years and the temperatures were always some degrees below the means of summertime (http://www.arpaveneto.it/temi-ambientali/acqua/file-e-allegati/bollettini/risorsa-idrica/2014/Bollettino%20n.%20177%20del%2031%20agosto%202014.pdf). These weather conditions determined an increase of river runoff and, hence, of nutrient concentrations, that was particularly evident in the 4 stations where plants disappeared (Figure 3). This hypothesis seem to be supported by the first results of water sampling. At stations 1 and 5 low Salinity and high Dissolved Inorganic Nitrogen (DIN) concentrations were recorded. At station 5 also high Reactive Phosphorus concentrations were found. The described water conditions favor the proliferation of ulvaceans which biomass never degradated due to the low water temperatures. The presence of floating *Ulva* thalli till September reduced light penetrations to the bottoms preventing seagrass photosynthetic activities.

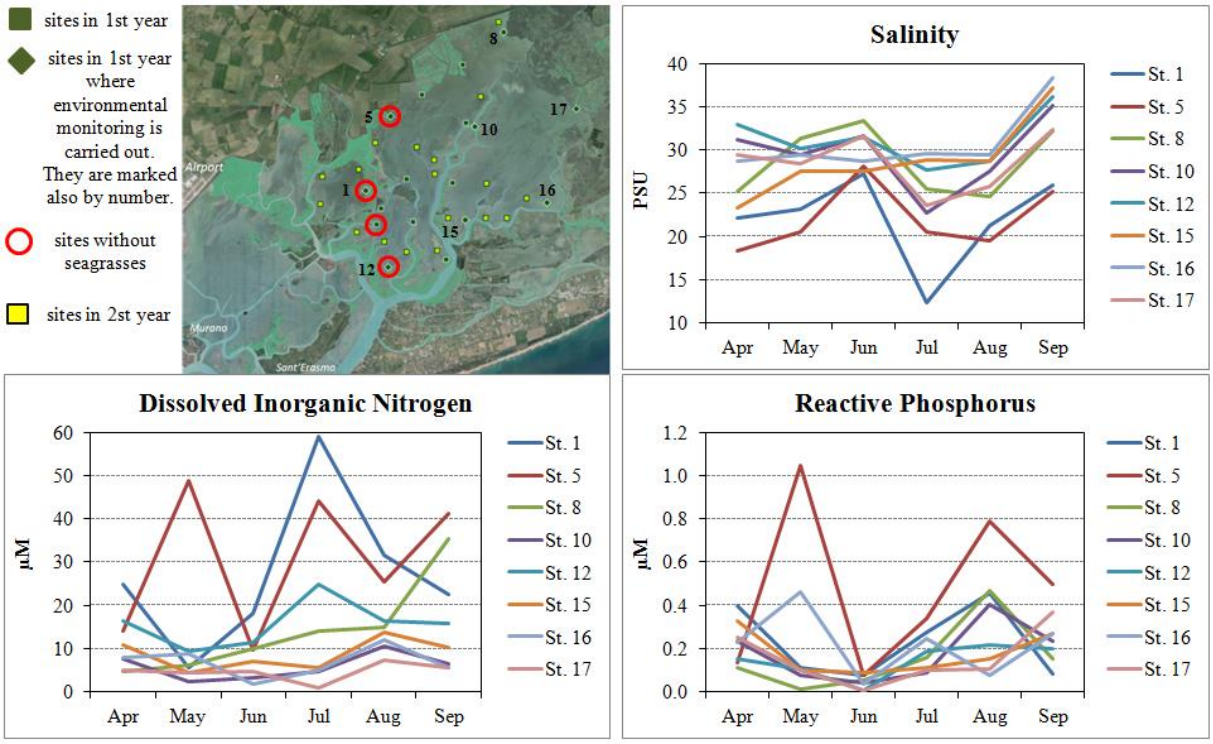

Figure 3. Map of the intervention area (top left) and trends of the main chemical-physical parameters from April to September 2014.

Conclusions

The project is just started and only the first six months of observations are available. In most of sites the rooting of translanted seagrasses is going as or better than expected. In few site results are below expectations, probably because of adverse weather conditions during the summer as discussed above. First results will be useful to identify the 18 transplantation sites to be chosen for the second year.

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