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FIRST RESULTS OF AQUATIC ANGIOSPERM TRANSPLANTS IN SOME PO DELTA LAGOONS AND IN FATTIBELLO POND

PRIMI RISULTATI DEI TRAPIANTI DI ANGIOSPERME AQUATICHE IN ALCUNE LAGUNE DEL DELTA DEL PO E NELLO STAGNO DI FATTIBELLO

Abstract - Following the success of aquatic angiosperm transplants in the Venice Lagoon achieved through the Life SeResto project (LIFE12 NAT/IT/000331) which, 10 years after the initial interventions, led to the colonization of approx. 20 km² of lagoon bottom with *Zostera marina* Linnaeus, *Nanozostera noltei* Hornemann Tomlinson & Posluszny, and *Ruppia cirrhosa* (Petagna) Grande, a similar environmental restoration effort was proposed for some lagoons in the Po Delta (Barbamarco, Caleri, Goro) and for the Fattibello pond in the Comacchio Valleys under the Transfer project (LIFE19 NAT/IT/000264).

Keywords: Aquatic angiosperms, transplants, Po Delta lagoons, Fattibello pond.

Introduction - The lagoons of the Po Delta and Comacchio Valleys, located in the northwestern Adriatic Sea, are shallow and large basins heavily influenced by freshwater inputs and anthropogenic activities leading in high trophic levels and degraded ecological conditions (Sfriso *et al.*, 2016). In the past, these lagoons had a significant presence of aquatic angiosperms, particularly *Ruppia cirrhosa* (Petagna) Grande in the Po Delta (Sfriso *et al.*, 2016), as well as macroalgae of high ecological value and *Nanozostera noltei* (Hornemann) Tomlinson & Posluszny in the Comacchio Valleys (Giaccone, 1974). However, in recent decades, these species have disappeared due to eutrophication and the fishing of the Manila clam *Ruditapes philippinarum* (A. Adams & Reeve, 1850). Based on the analysis of the trophic conditions, some areas of these lagoons are now considered suitable for potential colonization by *R. cirrhosa*, as well as *N. noltei*, *Zostera marina* Linnaeus, and *Cymodocea nodosa* (Ucria) Ascherson. For transplant efforts we have selected the lagoons of Goro, Barbamarco and Caleri in the Po Delta and the pond of Fattibello in the Comacchio Valleys. Transplants, carried out in spring and autumn, are performed by local fishermen with support from researchers in Venice and Ferrara. It is estimated that a total of at least 144 sods, each 15 cm in diameter, will be transplanted annually over a period of five years in each lagoon. Under suitable ecological conditions, these species can grow over one meter per year, eventually merging into extensive meadows, as observed in the Venice Lagoon (Sfriso *et al.*, 2019).

Study area - The Po Delta (44°57'N, 12°23'E) spans a large portion of the Veneto Region (northwestern Adriatic Sea, Italy) with a water area of approx. 200 km², of which about 100 km² are influenced by tidal expansion. The main river course (Po di Venezia) is divided into five active branches: Po di Maestra, Po di Pila, Po di Tolle, Po di Gnocca or Donzella, and Po di Goro. These branches form transitional basins with distinct geomorphological and environmental characteristics, including the areas analyzed in this study: Goro, Caleri and Barbamarco (Fig. 1). An additional station was selected at Fattibello in the Comacchio Valleys located further south. The key variations

concern salinity, which is affected by river inflows, seawater exchange, and depth (ranging from 0.5-1 m to 1.5-2.5 m), depending on the basin. The lagoons are largely devoid of hard substrata, except for a few levees and natural oyster beds scattered along the bottoms.

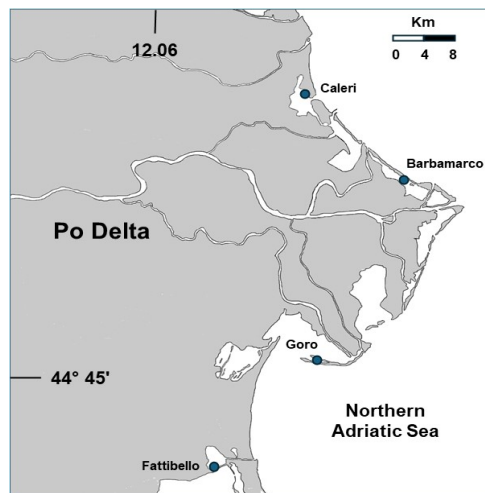


Fig.1 – Study area and intervention stations of Caleri, Barbamarco, Goro, and Fattibello.
Area di studio e stazioni di trapianto di Caleri, Barbamarco, Goro e Fattibello.

Results and Discussion - From autumn 2021 until the end of the year 2023 the number of transplanted sods was 1759, accounting for 26,206 equivalent rhizomes (Tab. 1).

Tab. 1 – Aquatic angiosperm transplants carried out since the late 2021.
Trapianti di angiosperme acquatiche realizzati dalla fine del 2021.

Total transplants			
Lagoon	Year	Sods	Equivalent rhizomes
Goro	2021	207	3519
	2022	289	4604
	2023	192	3118
		688	11241
Fattibello	2021	80	1360
	2022	140	2380
		220	3740
Barbamarco	2022	160	2135
	2023	210	2730
		370	4865
Caleri	2021	7	100
	2022	184	2420
	2023	290	3840
		481	6360
Total		1759	26206

After approx. two years from the first transplants of sods and single rhizomes of the different species, a luxuriant colonization of *N. noltei* and some patches of *Z. marina* were recorded in Caleri while, currently, no angiosperm rooting were found in Goro, Barbamarco, and Fattibello.

The analysis of the main environmental parameters and macroalgal variables during one year of monthly sampling showed that high concentrations of phytoplankton (mean total Chl-*a* values $>2.5 \mu\text{g L}^{-1}$, see Sfriso *et al.*, 2023) and high macroalgal biomass ($2\text{--}5 \text{ kg fwt m}^{-2}$) persisting for 1-3 months are the parameters that hindered the rooting and growth of aquatic angiosperms (Fig. 2).

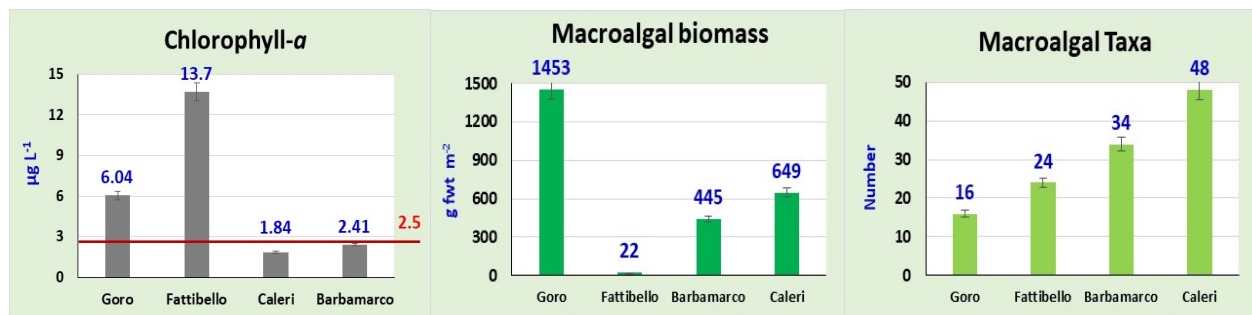


Fig. 2 - Total Chl-*a* concentrations, macroalgal biomass and number of taxa in the four lagoons.
Concentrazione totale di Chl-*a*, biomassa e numero di taxa delle macroalghe nelle quattro lagune.

The station selected in Caleri, with 48 macroalgal taxa, a value much higher than in the other stations, also showed the highest macroalgal biodiversity. Among them, three taxa were sensitive taxa, i.e. *Alsidium corallinum* C. Agardh, *Centroceras gasparrinii* subsp. *minus* Wolf *et al.*, and *Dasya punicea* (Zanardini) Meneghini.

The application of the Macrophyte Quality Index (MaQI) to determine the Ecological Status of the four stations showed poor conditions in Goro and Barbamarco, bad conditions in Fattibello and moderate conditions in Caleri. In this latter lagoon, the preliminary results recorded in 2024 showed a further improvement due both to the meadow increase and the recording of other sensitive taxa.

The Principal Component Analysis (PCA) of the main water column and surface sediment parameters recorded at the four stations highlighted their correlation/association with some macroalgal variables and the presence of aquatic angiosperms (Fig. 3).

Aquatic angiosperms, as well as the number of macroalgal taxa, the cover of Rhodophyceae, the algal biomass, and the total algal cover were associated with water transparency, Dissolved Oxygen (DO), pH of the water column (pH_w), and organic Carbon (Porg) in the surface sediments. In contrast, the cover of Chlorophyceae was associated with Nitrogen compounds (NH_4^+ , NO_2^- , NO_3^-), Reactive Phosphorus (RP), Total Suspended Solids (TSS), Settled Particulate Matter (SPM), Chl-*a*, Phaeo-*a*, and salinity.

Conclusions - Water transparency and Chl-*a* concentrations are the two main opposing parameters/variables that regulated the growth of the benthic vegetation and the potential rooting and growth of aquatic angiosperms in the Po Delta lagoons and in Comacchio Valleys. Moreover, rapid macroalgal growth can inhibit the presence of aquatic angiosperms, even though macroalgae last 1-3 months before almost disappearing. For this reason, transplants have so far been successful only in the Caleri lagoon where waters are clearer. Instead, blooms of phytoplankton and macroalgae have prevented angiosperms from taking root in the other lagoons. However, ongoing transplants in new areas offer hope for success in other lagoons as well.

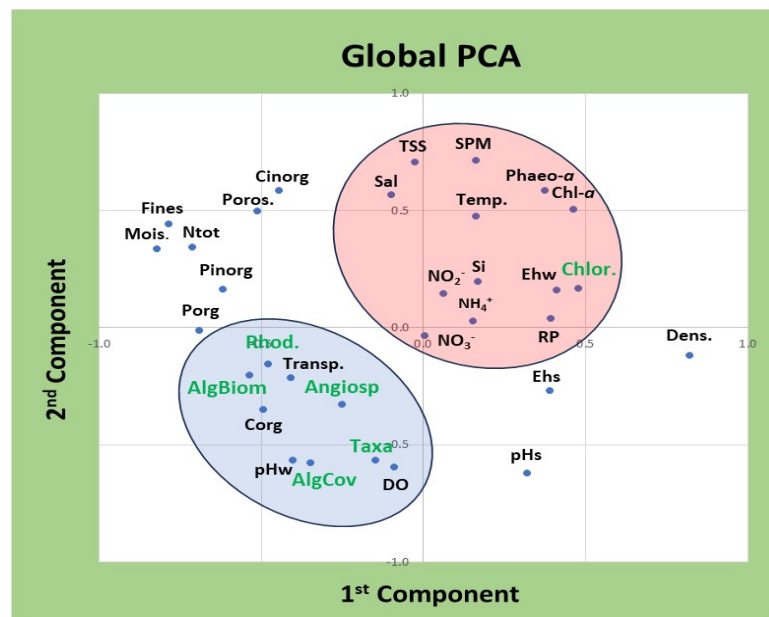


Fig. 3 – PCA analysis. **Macrophyte variables:** Angiosp. = Angiosperm cover; AlgBiom = Algal biomass; AlgCov = Algal cover; Chlor. = Chlorophyceae abundance; Rhod. = Rhodophyceae abundance; Taxa = Number of macroalgae. **Environmental parameters:** Chl-a = Chlorophyll-a; Cinorg = Sediment inorganic carbon; Corg = Sediment organic carbon; Dens. = Sediment density; DO = Dissolved oxygen; Ehs = Sediment Eh; Ehw = Water Eh; Fines = Sediment fraction <63 μm ; Moist. = Sediment moisture; NH_4^+ = Ammonium; NO_2^- = Nitrites; NO_3^- = Nitrates; Ntot = Sediment total nitrogen; Phaeo-a = Phaeophytin-a; Pinorg = Sediment inorganic phosphorus; Porg = Sediment organic phosphorus; Poros. = Sediment porosity; pHs = Sediment pH; pHw = Water pH; RP = Reactive phosphorus; Sal. = Salinity; Si = Silicates; SPM = Settled particulate matter; TSS = Total suspended solids; Temp. = Water temperature; Transp. = Water transparency.

Analisi PCA. Variabili delle macrofite: Angiosp. = copertura angiosperme; AlgBiom = biomassa algale; AlgCov = copertura algale; Chlor. = abbondanza Chlorophyceae; Rhod. = abbondanza Rhodophyceae; Taxa = numero di macroalghe. **Parametri Ambientali:** Chl-a = Chlorophyll-a; Cinorg = carbonio inorganico nei sedimenti; Corg = carbonio organico nei sedimenti; Dens. = densità dei sedimenti; DO = ossigeno disciolto; Ehs = Eh dei sedimenti; Ehw = Eh dell'acqua; Fines = frazione dei sedimenti <63 μm ; Moist. = umidità dei sedimenti; NH_4^+ = ammonio; NO_2^- = nitriti; NO_3^- = nitrati; Ntot = azoto totale nei sedimenti; Phaeo-a = feofitina-a; Pinorg = fosforo inorganico nei sedimenti; Porg = fosforo organico nei sedimenti; Poros. = porosità dei sedimenti; pHs = pH dei sedimenti; pHw = pH dell'acqua; RP = fosforo reattivo; Sal. = salinità; Si = silicati; SPM = particolato sedimentato; TSS = solidi sospesi totali; Temp. = temperatura dell'acqua; Transp. = trasparenza dell'acqua.

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