Living with Nature as a Water Community Network

Nature-based Solution for improving the socio-ecological status of the Venice Lagoon and beyond [1]

Ing. Giovanni Cecconi
Former director of the Information Service of the Venezia Nuova Consortium, Founder and Linkman of the Venice Resilience Lab, a project of the Wigwam Local Community.

Abstract

The Venice Lagoon presents a unique case study for the application of Nature-Based Solutions (NBS) to environmental management, aimed at the sustainable development of its community and the adaptation to climate and social changes. Over centuries, the lagoon has been shaped by human intervention, aimed at improving living conditions through trading, fishing, and harvesting. In recent decades, a large-scale restoration initiative has been undertaken to counteract erosion and biodiversity loss caused by sea-level rise. This report by Giovanni Cecconi, former director of the Information Service of the Venezia Nuova Consortium and founder and linkman of the Venice Community Lab, outlines the critical degradation challenges faced by the lagoon, including altered hydro-morphological structures and significant loss of intertidal zones.
The document provides a detailed analysis of the causes and effects of lagoon degradation, such as eustatism, subsidence, nutrient enrichment, and anthropogenic impacts like port development and mechanical fishing gear. Cecconi emphasizes the necessity of a strategic approach to restoration, focusing on the interception and channeling of tidal and wind currents, creation of mudflat and salt marsh habitats, and the implementation of adaptive management practices. He advocates for a participatory process that harmonizes conservation efforts with socio-economic development, adapting the lagoon landscape to meet the needs of society and nature, including visitors to be acclimatized as temporary residents. This adaptive laboratory approach underscores the potential of the Venice Lagoon to serve as a model for the world water communities living in harmony with nature, demonstrating how targeted, nature-based interventions can foster interconnected ecological restorations while supporting community resilience and sustainable development for the pleasure of encountering the identity and cultures of other water communities, especially the ones that are more interested in each other's such as Italy and Japan.

1. The degradation of the lagoon system

The lagoon today has a profoundly altered hydro-morphological structure, with the dominance of high depths in a vast area, detached from the lagoon eaves, which goes from Murano to Santa Maria del Mare and then, beyond the strip of waters, from Pellestrina to Chioggia. In these two areas, which represent more than 50% of the entire tidal surface, the depth of the seabed is always lower than the level of the minimum syzygial low tides of -0.6 m a.s.l., so that the bottom surface is always

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[1] English version of previous paper: Cecconi G. 2017: "Learning and Building with Nature". Quaderni della Laguna del Consorzio Venezia Nuova, Anno 0/num. 0, dicembre 2017.

submerged, while in the past, before the 50s, it could always emerge or have a small blade of water (the *clear*) at low tide (Figure 1). As is proved by the comparison of the bathymetric survey of 1970 with that of 1930 and then by the aerial photos of 1955[2], in percentage terms the lagoon has lost about two thirds of the intertidal surface, mainly the mudflats on the side of the canals and to a lesser extent the salt marshes.

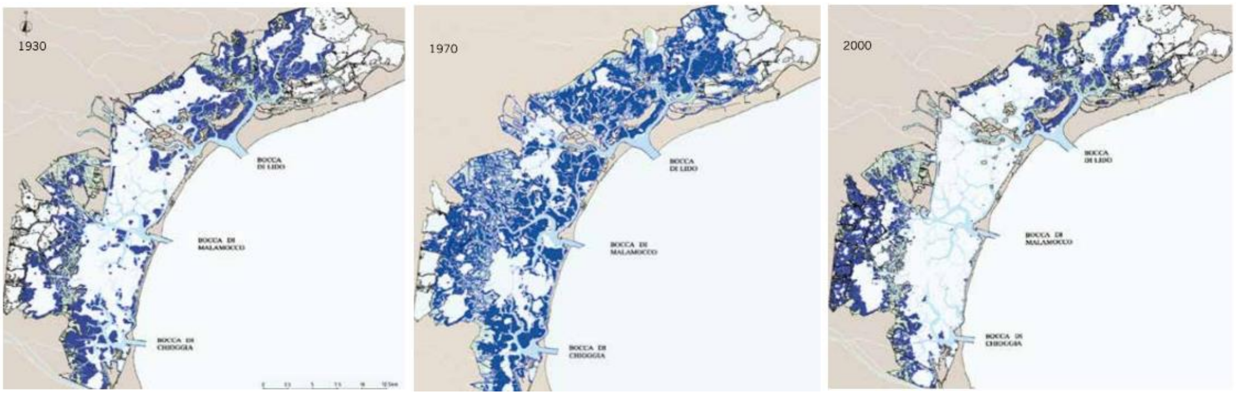


Fig. 1. The progressive disappearance of the shallow intertidal seabed above -60 cm a.s.l., exposed to the prevailing bora wind (1930: 168 km^2 1970: 105 km^{2}2000: 60 km^2) shows how the wave motion activated by sea level rise and pollution and no longer contained by the shallow seabed, was the primary cause of the change in the state of the lagoon system from 1950 to 1970. This shows the importance of the reconstruction of the mudflats for the restoration of bio stabilizing habitats with areas protected from excess of wave energy (interception) or placed to separate artificial canals (canalization).

The primary cause of this greater depth was the higher average sea level with respect to the seabed due to eustatism (13 cm in a century), subsidence (12 cm at the stronghold of the tide gauge of Venice Punta Salute, but much more in the lagoon in the areas near the industrial area most affected by water extraction until 1970) and then due to the erosion of the seabed induced by four different factors: wind waves; the dredging of artificial canals (especially the Canale dei

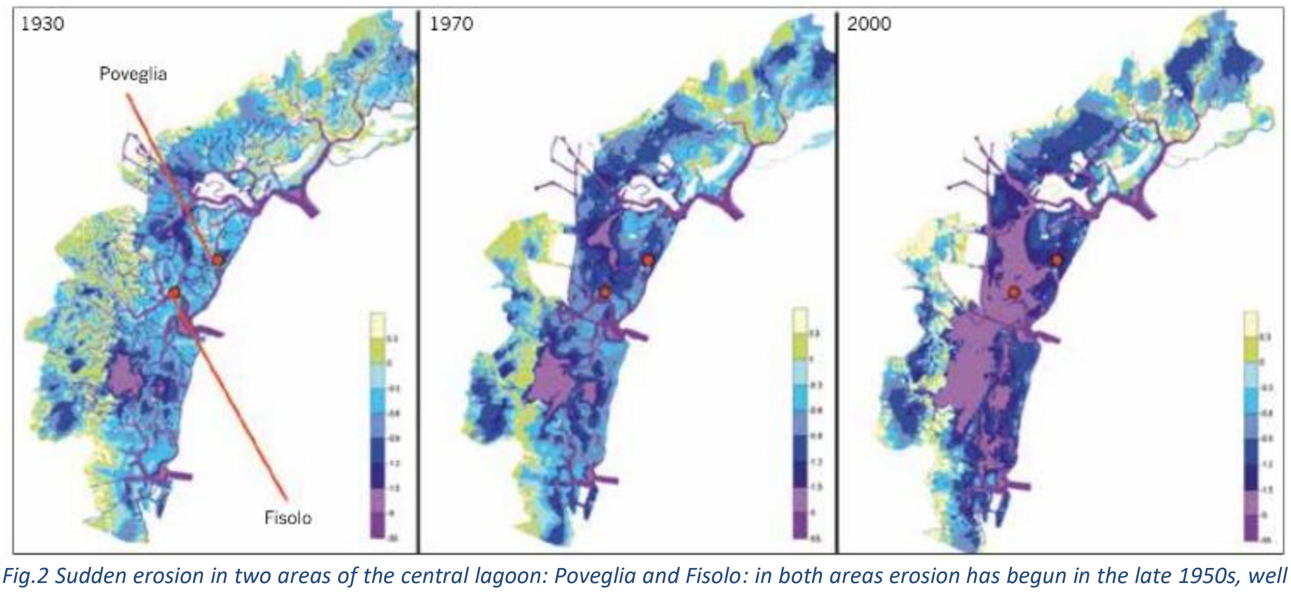


Fig.2 Sudden erosion in two areas of the central lagoon: Poveglia and Fisolo: in both areas erosion has begun in the late 1950s, well before the excavation of Petroli Channel (built from 1961 and 1969). Thus, the first change in the status of the intertidal seabed, with elevation just below the average of the low tides, -0.50 cm, was due to the20 cm sea level rise, with an increase of the water volume and wave energy. Greater depth and turbidity contribute to accelerating and extending the erosion: +Depth → +Erosion of shallow

[2] In the absence of other evidence in the following years on the stability of the seabed, 1955 is here taken as the origin of the rapid increase in depth caused by wind erosion.

waters → +Filling of channels → +Loss of sediment and nutrients into the sea → +Turbidity → +Loss of bio-structuring communities → +Erosion of salt marsh edges and lagoon margins → + Waves → +Turbidity → +Depth.

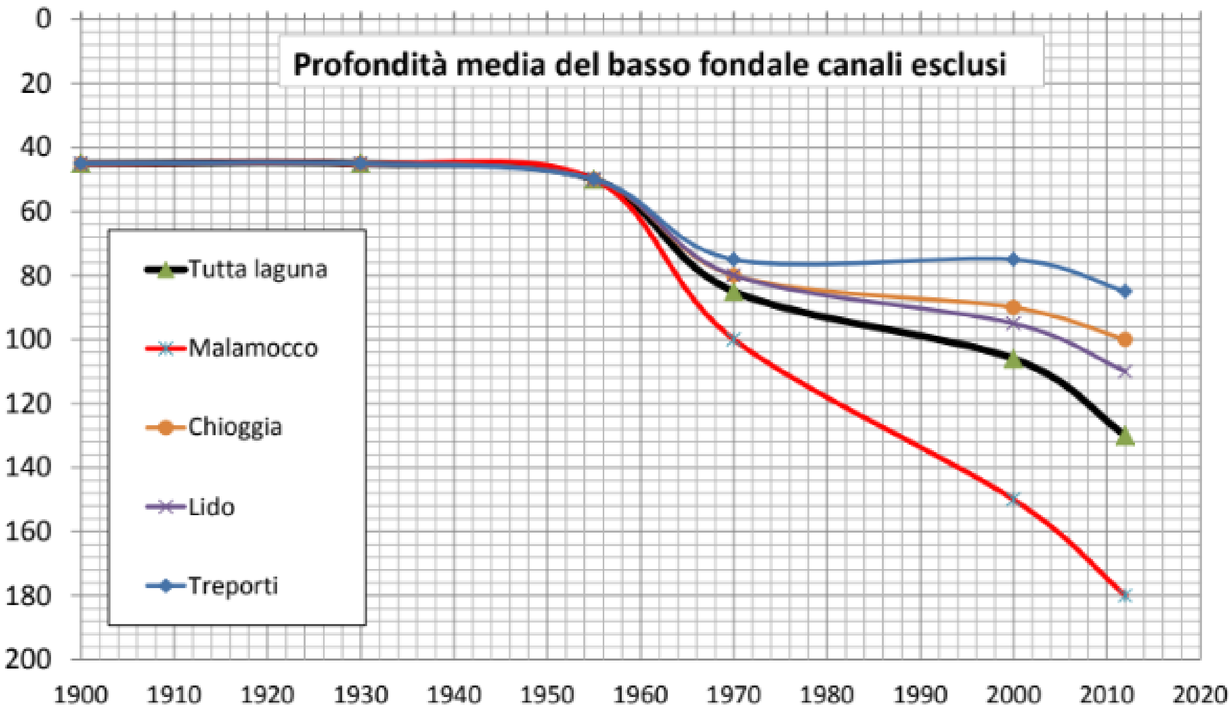


Figure 3. Erosion of the four lagoon sub-basins: temporal correlation with the dredging of the Petroli Channel for the Malamocco basin and relative sea level rise.

Petroli, the Allacciante Canal in Chioggia and the San Giacomo and Tessera canal in the northern lagoon); port and lagoon navigation; fishing with mechanical gear. This portion of the lagoon continues to erode and deepen, affecting an increasingly large area arranged according to the direction of the prevailing wind in the south-west direction, as demonstrated by the bathymetric survey of 2000 and subsequent checks by the Water Authority.

Erosion produces a net annual flow of sediment from the seabed to the water column of about 2.1 million cubic meters, concentrated in the 15-20 typical annual days of bora with winds greater than 10 m/s. From the water column, about 50% of the sediments are transported and dispersed into the sea (resulting in a strongly negative lagoon sedimentary budget as significant contributions from the drainage basin have been missing since historical times); the remaining 50% reaches and is deposited in more or less equal parts in the canals and in the lagoon eaves, confined by mudflats and sandbanks or by artificial structures such as the bridge of Venice and Chioggia or the reclaimed basins, as well as on the surface of the salt marshes themselves, which capture about half a centimeter of sediment per year, they are still able to maintain their share unchanged with respect to the mean sea level, benefiting from the excess of sediment in suspension.

In the lagoon, therefore, there are: a significant net erosive sedimentary flow on bora or sirocco days, which generally occur from October to April; a depositional flow in the eave's areas without seagrass and in sedimentation, with persistent resuspension and turbidity due to water traffic or, fishing with mechanical gear and wind waves. In these confined areas without seagrasses, the proliferation, deposition, degradation of algal biomass together with turbidity maintain degraded conditions for the spontaneous formation of bio-structuring habitats (dominance of fine and incoherent sediment, persistent turbidity, ploughing of the seabed with fishing gear, alternation of macroalgae and sediment deposits, non-assimilable nutrients, anoxic crises). The process of degradation that has taken place is summarized below.

The main historical causes, which activated the process of morphological degradation, which then manifested itself from 1955 to 1970 with the strong loss of altitude, then accompanied until 1990 by the degradation due to eutrophication with extensive blooms of macroalgae (Sfriso A. et al., 1987) are: subsidence and eustatism (Teatini et al., 2012); nutrient enrichment (Zirino et al., 2016); port development with artificial canals and lagoon confinement with reclaimed areas, the airport, the bridges of Chioggia and Venice and finally the enrichment of lagoon water and sediments in pollutants (Solidoro C. et al., 2010; Tagliapietra D. et al. 2011; Ferrarin C. et al., 2013). These processes have manifested themselves in a delta hydro-morphological system that for centuries had been impoverished of the contribution of sediments from the rivers, with the diversion of the Piave and Brenta rivers, and more recently also from the sea with the construction of the breakwaters at the inlets of the port (D'Alpaos L., 2010), a system that had managed to maintain its dominant intertidal structure over almost the entire lagoon since 1791 (shallow water situation in 1930).

The effects induced by these historical causes have been the lack of sedimentary contribution of a sandy nature; the loss of the bio-structuring communities of the shallow water due to the increase in depth; the increase in wave energy from wind and water traffic; fishing with mechanical gear; turbidity; anoxic crises; tidal currents transversal to the channels. With the reduction of bio-structuring communities, the lagoon has not been able to resist erosion, mainly due to the progressive rise in sea level and erosion of the seabed that more than doubled from 1955 to 1970, a period in which wave energy and disordered currents with respect to the structure of the channels grew exponentially (Fig.2). An important question remains open for the design of environmental remediation interventions: if the lagoon had maintained the hydro-morphological structure with the habitats it had in the 50s before the great erosion, would it have been able to adapt to the excess of nutrients without dystrophic crises and deaths of organisms?

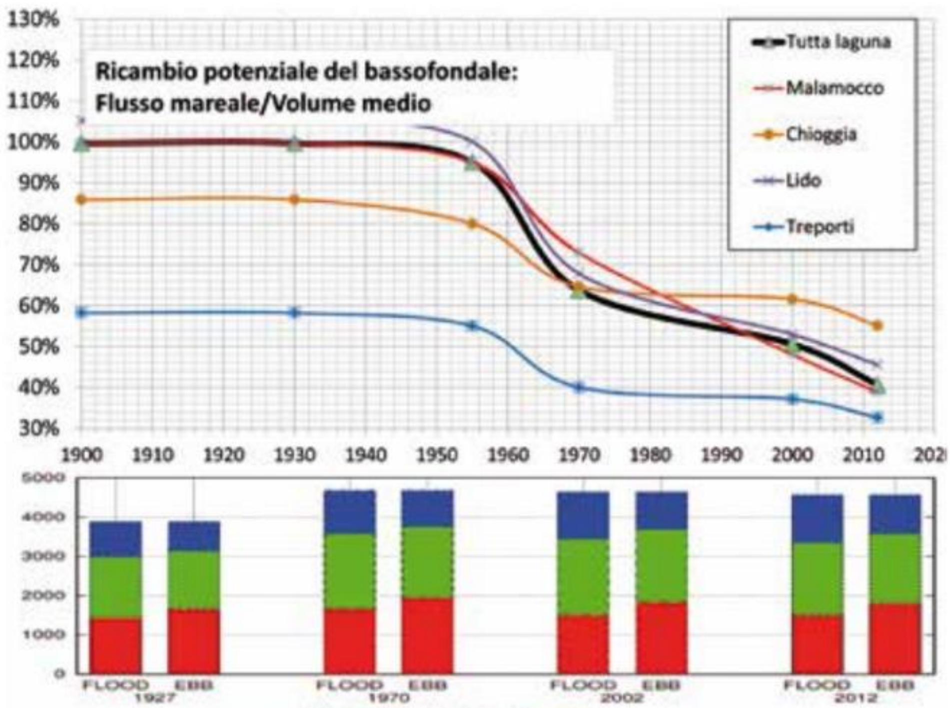
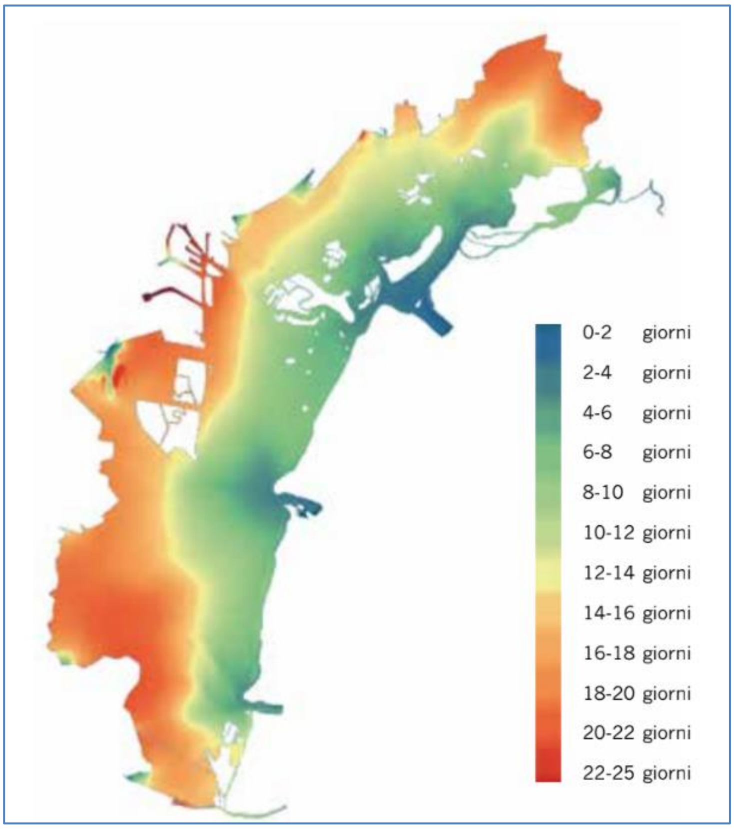


Fig. 4. Potential shallow water replacement index calculated as the ratio between the volume of the tidal flow (flow data from Ferrarin et al., 2013) and the resident volume (morphological data on the depth from Molinaroli et al., 2007).

The process of rapid transition from the state of lagoon, which at low tide exposed most of the seabed, to a deep bay with less transparency of the waters remains, affecting increasingly large areas of the central-southern lagoon and the possibilities of natural improvement are prevented by



the hydro-morphological degradation and sedimentary plane as well as by the intensification of anthropic pressures[3].

Without extensive restructuring and reduction of wave motion and its effects, first of all the turbidity of the water and the mobility of the sediment, necessarily, even with the use of resistant artificial materials and structures, any possibility of more or less complex reorganization of the lagoon system through the processes of compaction of sediments by seagrasses and limestone organisms is compromised, despite the fact that nutrient intake has been reduced and even though the impacts of ports, water traffic and fishing with mechanical gear have already been reduced.

Fig. 5 Residence times (Ghezzo M., 2010) of the water in the lagoon: less than one day near the vents, two weeks at the Fondamente Nove, more than three weeks in the inner confined areas. Despite the beneficial effect of the wind, the greater depth of the seabed and the lagoon bridge with the passages clogged with oysters, limit the tidal circulations. Note the great variability of the resident time, and therefore of the texture of the seabed, transparency of the water, salinity, temperature and, consequently, the great difference of the seabed communities, in particular those that determine the status of good ecological quality according to the Water Directive (angiosperms or valuable macroalgae and macrozoobentos).

2. Current degradation factors

The current factors of degradation, general or localized, are many: the lack of adequate replacement in the Marghera area, straddling the bridge across the lagoon with passages occluded by oyster banks, in Valle Millecampi and Val di Brenta; situations that facilitate the deposition of fine resuspended sediments: by wave motion locally or in unconfined areas of the lagoon; maritime traffic along the Canale dei Petroli, bordered only in part by salt marshes and artificial islands; water traffic for goods and passengers at high speeds and on underground lagoon canals; shellfish fishing with mechanical gear in prohibited areas; finally, sea level rise on a global scale and the increase in summer water temperatures and the possibility of dystrophic crises due to ongoing climate change.

The effects induced in the current situation, in which the effects of climate change are already beginning to manifest themselves with an increase in the maximum summer water temperature and a variation in the monthly rainfall and wind regime, are characterized by the persistence of the possibility of algal proliferation, especially in the eaves areas with little turnover, although the lagoon in general is in a condition of general oligotrophy (for example, as a result of a possible enrichment of phosphorus from the pore waters of the seabed in continuous resuspension; Zirino A. et al., 2016); in the presence of persistent turbidity due to water traffic and maritime traffic due to the reduced depth of the channels due to silting, with no prospect of dredging to restore the depth, at least in the short term due to the constraints imposed by the regulations in place; in the erosion of shallow waters and the production of turbidity due to waves generated by water and maritime traffic, waves not contained within the channels, and by wind waves no longer limited by shallow waters and salt marshes (Zhou Z. et al., 2017); in the silting up of canals due to the lack of longitudinal tidal currents and the dominance of transverse currents, again due to the disappearance of the longitudinal mudflats and salt marshes, the *channel gums,* or the absence of any other lateral containment structure, with additional sediments that are suspended by the propellers or waves by water traffic and dispersed.

3. Degradation situation in lagoon water bodies according to the Water Directive

As has happened in other deltas such as the Mississippi delta (Scarton F. et al., 2000; Seminara G. et al., 2011) also in Venice the triggering factor of the degradation process of the shallow waters on which to focus attention has been the increase in the depth of the water with respect to the seabed due to subsidence, eustatism first and then anthropogenic impacts, such as navigation and clam fishing and the subsequent removal and dispersion of the sediment in the sea and in the lagoon due to wave motion (Manenti S., 2006); while in the lagoon, a persistent turbidity of the waters is maintained due to the resuspension of the sediment along all the channels affected by maritime traffic and lagoon traffic which contributes to limiting, together with the excess of turbulent energy, the settlement of structuring communities. Considering the extension of the network of unconfined canals affected by the growing water traffic and the lack of maintenance dredging, and mitigation works, navigation is clearly the main factor of degradation both in terms of eroded volumes and in terms of production and persistence of turbidity.

Clam harvesting with mechanical tools should certainly not be overlooked, particularly harmful in areas with fine sediment, located far from canals, where the seabed is still bio-stabilized and without ploughing, which modifies its roughness, and is able to resist wave motion, whether it is produced by the wind or by water traffic. Finally, the wind waves, which in 15-20 days a year resuspend and disperse large quantities of sediments, which navigation and fishing had prepared by making them less cohesive. In the Venice lagoon, in fact, we have gone from shallow waters bio-stabilized by seagrasses, benthic organisms and in particular microbial felts (the mud flats, *velme*), which were almost totally uncovered at low tides or *marshes* that had high transparency of water at high tide, to tidal flats that no longer emerge at low tide, except in the most inland areas, protected from the bora, confined and sheltered in the salt marshes. In the deeper areas, before the 1970s, the seabed was stabilized by seagrasses, as is the case in much of the lagoon south of the Canale dei Petroli.

Similarly, salt marshes are more easily eroded at the edges, but above all, as the monitoring conducted under the supervision of Professor John Day twenty-five years ago has shown, sediments and nutrients are easily removed from bio-structured surfaces (Day J.W. et al., 1998) to be dispersed in the sea or deposited in more confined areas, leading to the rapid degradation of vegetation on the surface of salt marshes by removal of sediments and nutrients. Microbial felts and seagrasses can also be affected by anthropogenic disturbances and/or excess turbidity and sediment removal, as in the case of the strong reduction of *Zostera noltii in the northern lagoon*, without the possibility of biological recovery and bio-stabilization, even from areas that were initially protected from wave motion with fascinates. The *resistant mudflats*, once very widespread - Giovanni "Nino" Giupponi said that in the '50s it was still possible to walk easily on the gums on the side of the canals from Giudecca and to the Lido, collecting clams and oysters; also in the '70s and '80s, since the seabed was limered by many organisms that form calcareous substrates; and so Italo Svevo[4], half a century earlier, in 1899 he described the seabed between Venice and Murano-Sacca Serenella, where it lived, like a shoal emerging at low tide, a triumph of lights that held Venice in a grip of mud - have now disappeared almost everywhere, with the exception of the strips sheltered from the sandbanks of the northern lagoon, or visible only for a few hours during particular winter shoals. Even John Ruskin in 1852 in *The Stones of Venice*, described the lagoon bottom as follows: "At low tide the scene is transformed ... A lowering of 20 inches is enough to uncover the land over much of the lagoon... the city looks like it's in the middle of a dark plane of dark-colored seaweed... the oar at every movement is embarrassed among the thick grasses ... driven by the uncertain dominion of the exhausted tide." Also from the point of view of tidal vivification, the situation has drastically changed due to the increase in depth of the shallow seabed: at the lagoon scale, the resident volume has more than doubled as the average depth has varied from about 50 cm to over one meter (Figure 3), while the volume of the tidal flow on the shallow-water (tidal prism referring only to the shallow-water surface) has increased by only 20% (Ferrarin C. et al., 2013). The lagoon now resembles a corpulent organism with impaired circulation, which in any case fails to guarantee sufficient oxygenation in the innermost areas (Figures 4 and 5; Ghezzo M. et al., 2010). The situation is aggravated by the turbidity of the waters (because of the bora and sirocco waves, which are now no longer limited by the shallow waters and because of navigation and aquaculture practices) even in the confined residual areas where sediment is deposited that is not dispersed into the sea. However, the lagoon has managed to maintain its original characteristics in the areas adjacent to the inlets, which are more enlivened, with sandy bottoms and seagrass meadows. The southern lagoon has also largely maintained its original characteristics for a number of reasons, first of all that it has been less subject to erosion due to the rise in sea level due to the extraction of water from the subsoil, which has been concentrated in Venice and in the industrial area, and to erosion due to the dredging of the canals. In addition, this part of the lagoon is mainly colonized by seagrasses and clam fishing has taken place or takes place in limited areas, so the sediments are well structured. The greater presence of a sandy matrix of geological origin (Molinaroli E. et al., 2007) and the lower exposure to pollutants, maritime and water traffic in general have certainly contributed to the lower erosion in the southern lagoon. Finally, this area can benefit from the contribution of sediments removed from the northern lagoon during bora storms.

As described above, the loss of confinement in areas exposed to the bora wind on bodies of water that have lost their initial morphological diversity (due to erosion due to the rise in sea level and the opening of the Canale dei Petroli) and the excess of erosive energy and turbidity, have produced in the confined areas a further silting up with the compromise of the original habitats by fine and polluted sediments[5], in particular with reference to water bodies:

1. the water body of **Val di Brenta**, confined due to the trans-lagoon bridge and also subject to the contributions of reclamation, continues to fill in silt as continuously reported by wandering fishermen who have had to reduce their activities, despite the fact that twenty-five years ago the passages of the bridge were widened, and the pre-existing canals dredged up to a depth of -3.5 m;

4 Svevo writes in *Serenella*: "... It was enough to climb to a height of one meter to discover the small lakes that formed in the swamp, clear, the capricious contours. Standing up perhaps on tiptoe, the glimpses of the distant canals widened."

5 For the part not dispersed in the sea, coming from the great erosion of the unconfined areas of the 70s, erosion that continues close to the Canale dei Petroli.

2. in the **Teneri water body**, confined by the reclaimed areas and with significant contributions from the Mirese, the silting up of the seabed and the vivification canals continues, which have only been partially dug due to the difficulty of reusing the sediment at different degrees of pollution

3. in the **Millecampi** water body, confined by natural salt marshes and peaty bottoms very exposed to bora waves, the silting up of the seabed closest to the gutter continues, despite the fact that some dredging of vivification channels has been carried out, but immediately buried due to the great turbidity and the difficulty of authorization to insert resistant and long-lasting canal edge protections made, for example, small-sized stones contained within polyethylene geo-grids;

4. in the **Dese water body**, bordered by salt marshes and natural mudflats with the greatest amounts of river pollutants and turbidity from water traffic from the gutter to the sea, especially in the summer, the ecological quality of the seabed is influenced by the fine and inconsistent nature of the seabed, which limits the growth of seagrasses and the formation of microbial felts, as is the case in the border strip of the Maggiore marsh;

5. in the **Marghera** water body, very confined due to the Railway Bridge, the Littorio Bridge and the doubling of the railway bridge tracks in the 70s, first due to the effect of the piers of the bridges and the provisional construction works, then due to the recently reported occlusion of the clogged passages due to the abnormal growth of oysters up to beyond the Marino Municipality, at +40 cm above sea level[6], due to the fact that under the deck the algae do not grow due to lack of light, so the oysters can grow freely. The high resuspension of sediments, passing over the jagged oyster beds, traps the sediments themselves, forcing the oyster grove to develop vertically. In addition, the increase in temperature and mean sea level over the last decade has also contributed to the development of oyster beds (Ridge et al., 2015). This body of water is particularly degraded by the persistent turbidity generated by water traffic, especially on the non-dredged canals: Canale dei Petroli, Canale San Secondo, Canale Campalto and especially Canale Tessera.

6.in the **Tessera** water body, naturally confined and dominated by a persistent turbidity due to the passage of boats on channels with limited draught, and by the concessions for clam seed fishing, canals that if not protected from bora quickly fill up, despite repeated dredging[7];

7.in the water body of the **Palude Maggiore**, naturally confined and subject to the deposit of fine sediment due to the long residence times and the greater depth of the seabed compared to the past due to the rise in sea level, as is the case in Millecampi, we still have areas of good quality in the most vivified areas located close to the salt marshes, today affected by the extensive improvement interventions of the Life-Seresto program (www.lifeseresto.eu);

8.in **the water body of Sacca Sessola** and **Chioggia**, which are not confined but subject to turbidity from water traffic and due to fishing with mechanical gear, there is a greater depth of the seabed than in the past, which does not allow effective bio-structuring.

[6] For the purposes of the Water Directive and the assessment of its state of quality, due to the presence of the bridge, this body of water should be considered confined, rather than unconfined, at least until all the passages have been reopened and circulation has been restored with connecting channels at least at -2m.

[7] Turbidity is generated by the propellers of the vessels themselves and by the breaking of the waves produced by the vessels on the surrounding shallow waters.

In terms of current monitoring of transitional water quality, in relation to ecological status, the quality status in general can only be poor due to the lack of bio-structuring benthic components or valuable macroalgae, as well summarized by the R-MaQI indicator (Sfriso A. and Boscolo R. 2011).[8]
Based on the results of the chemical and ecological status, the classification of the lagoon water bodies was approved - with Resolution of the Regional Council no. 140 of 20.02.2014. With this classification, all the lagoon gutter water bodies, except for the central-southern lagoon with good ecological quality and Lido, Chioggia, Sacca Sessola, with sufficient quality, have a poor quality and the reason is always the same: the prevalence of fine surface sediment and not compacted by bio-structuring[9] communities. In essence, the ecological quality of water bodies follows the distribution of residence time which represents tidal turnover and therefore also the persistence of turbidity in the water column. In fact, where the time is long, there are deposits of fine incoherent sediments that are then resuspended by local water traffic, fishing with mechanical gear and by the wind, thus generating a persistent turbidity as in the water bodies of Marghera, Tessera and Dese. In Millecampi and Teneri it is the peaty nature of the local sediment (erosion of pre-existing reeds) and the contribution of sediments, eroded on the side of the Canale dei Petroli and transported to these confined areas by the circulation induced by the bora wind, that makes the situation precarious. In Val di Brenta, confinement, sedimentation and resuspension, fishing and the bora wind are once again detrimental to the situation. In addition, in some of these areas there are also significant inputs of fresh water, sediments and pollutants which, together with resuspension turbidity, affect the engraftment of valuable macrophytes (as documented by the Life-Seresto project). So, it can be concluded that the poor ecological quality, evidenced by the absence of seagrass and sensitive macroalgae, is now maintained by the unstable bottom type and turbidity.
As well interpreted by the ecological index of macrophytes of the Water Directive, there have been no intermediates of improvement for environments now dominated by persistent turbidity (see, for example, the recent results of the seagrass transplant of the Life-Seresto program in the northern lagoon in terms of the possibility of development of valuable seagrasses and macrophytes, not always satisfactory even in a water body that still preserves its original characteristics).
It is therefore necessary to carry out a decisive treatment, which experience indicates to us to be the interception and containment of wave motion and the channeling of tidal and wind currents, creating strips of mudflats and salt marshes resistant to wave motion arranged in such a way as to orient and concentrate the currents along the main and secondary channels (Cecconi G., 2005).

[8] Perhaps also because in the application of the directive, the optimal ecological status of reference is that of a seagrass site, Santa Maria del Mare, well vivified and at the same time protected for its proximity to the coast and sandy base sediment to allow the growth of sea truffles, noble fins, and sea urchins. Such a favorable hydrodynamic situation is unthinkable or possible to be achieved throughout the lagoon.

[9] See the results of the Life-Seresto program and in particular the poor proliferation result obtained in the two areas 1 and 5 of the Dese water body.

4. How to improve the state of environmental quality with interception and ducting strips

The regulation of pleasure boating, freight, passengers and maritime traffic, an activity that is constantly expanding because of a growing international demand, although useful and necessary, is not sufficient to reverse the degradation process as the greatest erosion is produced by wind waves. Today we are well aware of the agents of degradation, erosion and turbidity, and we have developed the tools to contrast them, but it is required that they be used without delay to produce a radical change of state capable of regenerating the hydro-morphological and biological system, as the Life-Seresto (www.lifeseresto.eu) and Life-Vimine (www.lifevimine.eu) programs are demonstrating at the local participatory scale and as the interventions of the Superintendent had already extensively demonstrated to the Public Works (former Water Authority) with the construction of morphological structures with mud flat and salt marshes and the transplantation of seagrasses on suitable mud flats or treated with sand, undertaken in the last thirty years[10]. Finally, a question of merit arises that concerns all the lagoons now strongly conditioned by man such as the Venice lagoon, which have undergone transformations with irreversible or in any case technically unfeasible changes of state[11]: to which reference lagoon do we want, and can we direct the reclamation actions?

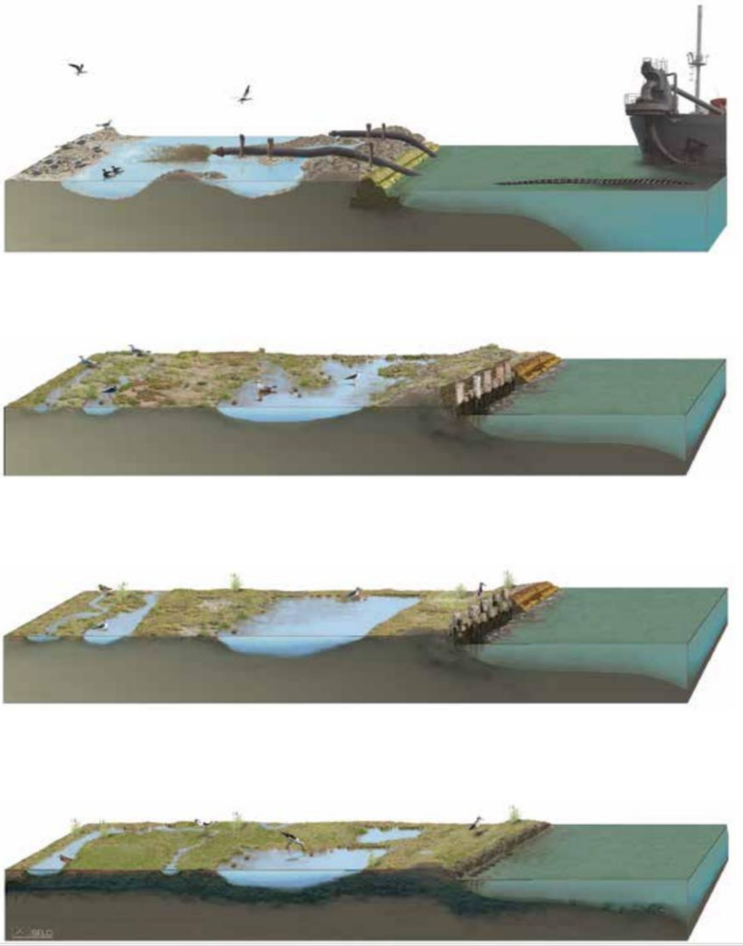


Fig.6.The colonization of the salt marsh deposit takes place by transitions between states with successions of species and their spatial organization, depending on the altitude resulting from the compaction of the artificial soil by thickening and from the new inputs: in the end, after about ten years, the natural growth compensates for the compaction and the rise of the sea level and the artificial salt marsh thus maintains its altitude in a self-regulating way.

Excluding the possibility of recovering the altitude everywhere with the sediment carryover, it is now established that waves and wind turbidity will continue to grow even limiting water traffic (a difficult task as it limits the possibilities of development of economic activities essential to maintain residence, allowing the development of sustainable tourism in the lagoon) All that remains is to protect and regenerate the shallow waters with rigid structures and sediment carryover to form

[10] Professor John Day has recently published an article that Prove Convenience to intervene immediately to rehabilitate the delta of the Mississippi for this very reason. See the ongoing co-exploration activities of the Venice Lab , or of the international academy at the Venice International University by Boston University (M. Balsamini, 2014), or of the University of Ca' Foscari with the summer course The Environment and Economics of Coastal Lagoons on management of salt marshes with Utrecht University.

[11] For example, in the Venice lagoon, the restoration of the depth of the seabed to pre-subsidence and eustatism values, capable of reconciling a good state of vivification quality without an excess of wave energy, would involve the introduction of about 200 million cubic meters of sediment as well as the redesign of mudflats and salt marshes by man and in a not immediate time.

mudflats and salt marshes that interrupt the width of the free seabed on which the prevailing winds blow, direct the tidal currents along the natural and artificial channels to limit silting, allow the interception of waves and turbidity while protecting the natural and artificial environment behind.

The shape and position of these works, which will have a progressive adaptive location, will have to be such as to provide local protection against excess energy and turbidity and at the same time create areas with different degrees of confinement: a hydro-morphological diversity to create the conditions for the guided or spontaneous settlement of a diversity of interconnected habitats or in succession for ecological evenings (Fig. 6).

Figures 7a and 7b. The process of artificial colonization of salt marsh deposits over the course of ten years, as an adaptive response to the loss of altitude of the artificial deposit through soil fertilization and vegetation growth.

The mud-flat, *velma*, and salt marsh design belts have been extensively tested over the past thirty years with excellent results, allowing the triggering of *velma* and salt marsh habitats for over 16 sq km of eroding shallow water through the reuse of 20 million cubic meters of dredging sediment (Fig. 7 and 8; Scarton F. et al. 2011). On the basis of these considerations, the improvement of the hydro morphological and, consequently, ecological quality status of water bodies, both for the purpose of identifying the most effective interventions and for the purpose of documenting progress to ensure a good quality status by 2020, must be understood in a probabilistic sense, restoring the most favorable conditions for the formation of habitats with valuable species, so as to condition evolutionary processes by increasing the probability of rapid transitions to a scale large enough to be detected, and such that it can remain on a significant and detectable portion of the body of water in question.

These probabilities of habitat distribution can now be evaluated on the basis of the foreseeable variations (with hydro-morphological mathematical models) of the chemical-physical indicators of the system as a result of the interventions in the design phase (such as for the seagrass meadows at the inlets: exposure to air, residence time, turbidity, proximity to the channel, temperature, percentage of sand, TDP Total dissolved phosphorus or for the probability of nursery habitats for the flounder: salinity, turbidity, dissolved oxygen temperature, sand percentage (Zucchetta M. et al. 2010; Newton A. et al., 2014) or with trophic chain models (Brigolin D. et al., 2014).

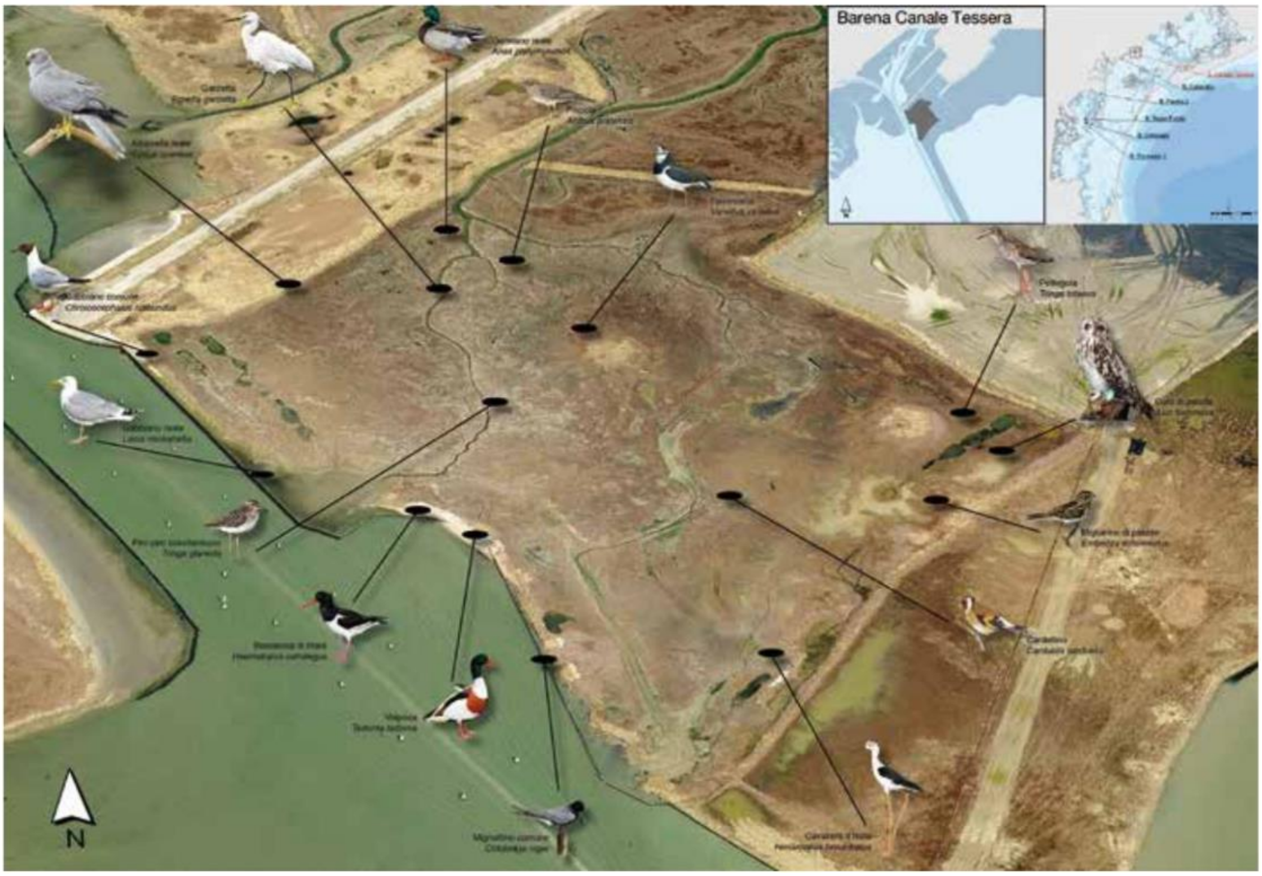


Fig. 8. It has been proven that artificial salt marsh deposits located in areas of natural salt marshes threatened by wave erosion are those most frequented by species of conservation interest. Expert ornithologists such as Francesco Scarton have confirmed the importance of the newly formed areas for nesting and wintering, to the point of envisaging a continuous conservation activity of the SPA Venice lagoon based on the continuous reconstruction of new mudflats and salt marshes of appropriate size

The Morphological Plan of the Water Authority - Consorzio Venezia Nuova, which is configured as an action of active management of the system, also for the purposes of the Habitats and Natura 2000 Directive and the related management plans of the Venice lagoon as a Special Protection Area, addresses this issue, proposing technically feasible and already tested interventions to slow down the general degradation and restore through vivification, the confinement and reduction of pollutant loads, at least locally, the morphological complexity, biodiversity, and ecological quality of water bodies. This is a practical way of ecological quality control that considers the current level of exposure to wave motion and the technically feasible interventions for an assisted bio-structuring of intermediate and more confined areas in poor quality conditions due to a combination of current degradation factors (water traffic, fishing with mechanical gears) that act on environments transformed due to climatic effects and anthropic factors now historicized.

The complex natural transformations of the biota, which often proceed by succession of habitats, have an evolutionary character that does not allow reversibility to previous states, although it is possible to start a new evolutionary process. In fact, it is possible to artificially restore the hydro-morphological and sediment conditions to facilitate the re-settlement of the communities, as was done in the area behind the reclaimed areas in the 90s with the filling of over 100,000 cubic meters of sand to form a homogeneous thickness of 40 cm at the initial inter-tidal level and the reopening of the underground canals from the reclaimed tanks (Bona F. et al., 2000). However, it is impossible to regain everywhere the generalized loss of depth of the seabed and its texture (a volume of sediment, 200 million cubic meters, would be necessary) so the interventions of reconstruction of

mud and salt marshes can only be aimed at the confinement and vivification of surfaces limited to longitudinal development, for example, arranged along the hydrographic network that was still present in the '30s (Scarton F. et al., 2000). The achievement of the good ecological quality status of the lagoon water bodies in a short time, with modification of the local quality indicators of benthic macrophytes and macro-invertebrates, through interventions to protect and regenerate seabed strips with adaptive solutions for intelligent transformation of the lagoon landscape, very different from the simple cliff separating the economic functions related to the port and water traffic, from the conservation of shallow water habitats, requires a participatory process capable of reconciling conservation with socio-economic development, adapting the lagoon landscape to the needs of society and nature, in harmony with the millennial co-evolution of the lagoon system.
If we are able to harmonize the spatial and temporal distribution of wave protection works, including reversible ones, with those of vivification and canalization (through the dredging of canals and the reuse of sediments in the restoration of protected strips for the development of mudflats and salt marshes) it will be possible to seize formidable opportunities for socio-ecological regeneration, starting with the necessary restoration of a new social cohesion between old and new Venetian citizens. It is essential to begin to regulate the tourist demand in the city and in the lagoon with the new infrastructures to continue sailing, first the new protected network of port and lagoon water transport, to help maintain the Venetian cultural identity of living on the water by balancing port development with a new sustainable island tourism[12].

5. *Living with Nature Toolbox*

The main tool developed over the years is the ability to move safely and in a protected way, both from the point of view of erosion and contamination, large quantities of sandy and silty sediment to form new soils[13] on which to activate the development of seven *natural engineers*, autonomous ecological systems that use the energy of the sun and the natural flow to grow and structure the lagoon landscape, providing the ecosystem services necessary for the social and cultural development of the territory (Figure 9; Day J.W. et al., 1998; Cecconi G., 2005; Cecconi G. et al. 2009; Tiezzi E. et al., 2010; Scarton F. et al., 2013).

Here are the *natural engineers* that we know how to activate, on which we can confidently count to improve the ecological quality of the Venice lagoon:

1. **microbial felts with diatoms and cyanobacteria** capable of covering and protecting the forming mudflats.

[12] A problem that is deeply felt both by the few Venetian citizens of the islands who remain, and by the many inhabitants of the municipalities of the lagoon inner part and by the Veneto Region which looks at eco-tourism and cultural tourism as a perspective of social regeneration: for example, Jesolo is investing to become an international center of well-being and culture connected with Venice by water; An intensification of water transport has long been requested, which has always been denied due to the fragility of the lagoon system, thus losing opportunities for development and innovation that we can now explore, looking for solutions that are not simply increasing the number and capacity of motor vessels, but something more complex and acceptable. A similar problem of the same magnitude is the regulation of cruise ship arrivals in Venice after the Clini-Passera decree.
[13] Which can be both protected from waves and enlivened by tidal flow.

2. **angiosperms and in particular the four species of seagrasses** (including *Ruppia* fundamental in confined areas) capable of stabilizing the deeper seabed surrounding channels and mudflats in formation or areas downwind/under bora waves;
3. **the associations of halophytic salt marsh plants**, able to capture the sediment and increase the height of the salt marsh, thus compensating in homeostatic conditions for the relative rise of the mean sea level with respect to the vegetated and submersible soil at ordinary high tides;
4. **the reeds**, which, like the salt marshes, produce stable soil and absorb nutrients and other pollutants released at the river mouths, along the lagoon eaves, structuring this part of the territory in such a way as to increase the residence time of nutrient inputs in areas more suited to phytoremediation than in transition areas, which are more revived;
5. **the ammophila** (*Ammophila arenaria*) of the coast that promote the formation of dunes by intercepting the sand carried by the wind, thus protecting the coast from storm surges and flooding due to overtopping;
6. **macrozoobentos** that in various ways reshape and stabilize the sediment, for example some nematodes, by digging tunnels and cementing the sediment, produce an increase in volume, altitude, and stability of the seabed.
7. **communities encrusted with oysters and mussels** that can produce by accretion of original nuclei barriers capable of driving tidal energy and reducing wave energy, improving the conditions of stability, transparency of the water and bio-structuring and of the seabed thus sheltered, benefiting from the expected increase in temperatures.

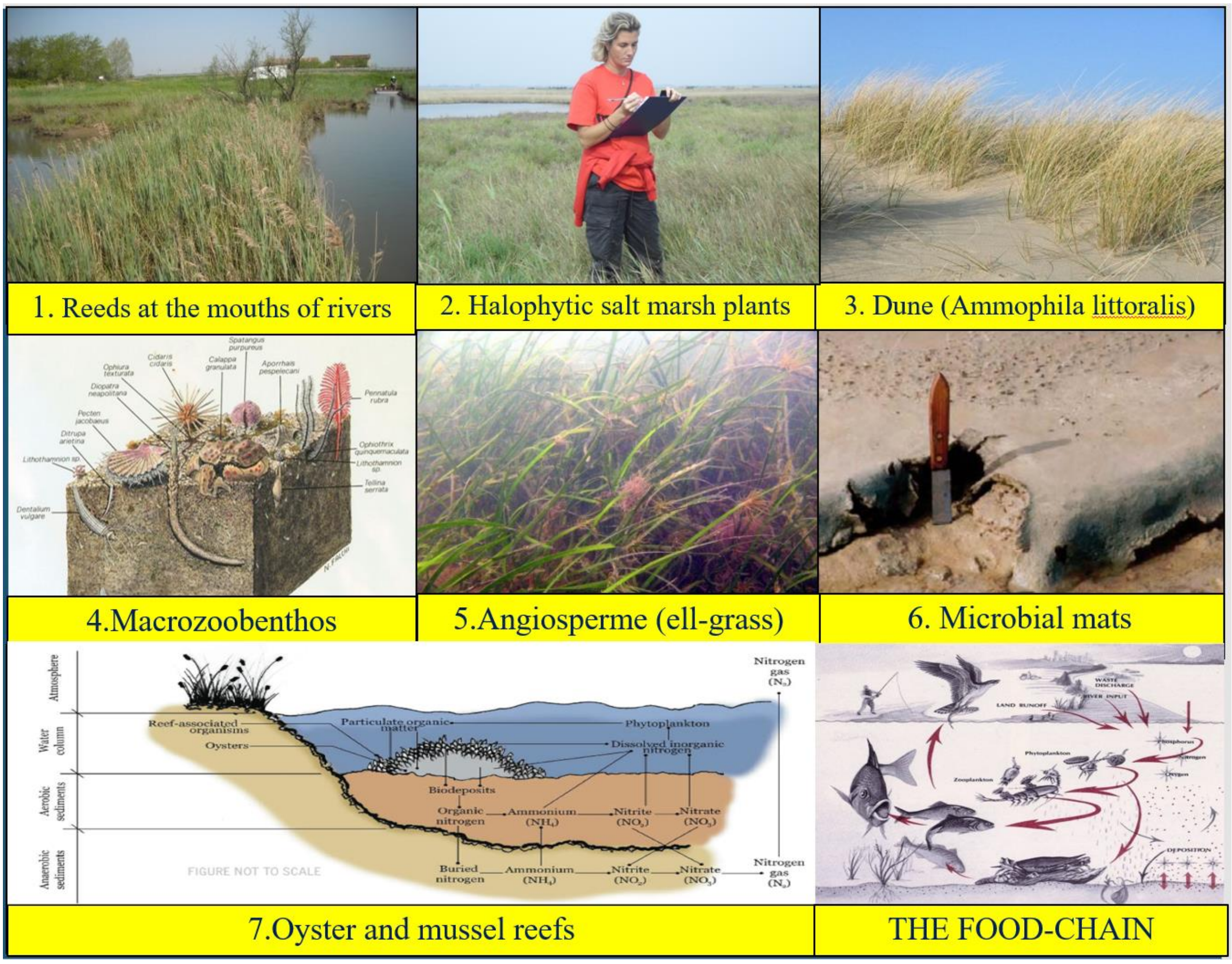


Fig. 9 the seven bio-structuring communities.

The toolbox will be used adaptively (D'Alpoas L. et al., 2007; Adly N. et al., 2011), in line with the millenary Venetian tradition of *learning by doing*, to generate the resilience necessary to cope with the current and future effects of climate change and global social changes: with the rise in sea level and the greater erosive force of waves and the growth of tourist and migratory pressure and the

Fig. 10. Gabion "burghe" to protect the edges of artificial and natural salt marshes

increase in the cost of fuels for maritime works (e.g. we already have to take into account that the cost of fuel to carry out the large dredging and sediment handling works has increased[14]).

The toolbox is completed with the mobile barriers of the Mose system, which, once completed, will intercept the tidal flow only when necessary to control the excess tidal volume during high waters, without limiting the natural tidal exchange, and protecting the salt marshes from excess wave motion during high waters, retaining the sediments resuspended inside the lagoon; The mobile barriers can at least partially be manoeuvred differentially to produce a greater marine turnover with forced circulation from one mouth to the other.

The use of the seven natural engineers makes it possible to activate the ecosystem services most necessary for the development and conservation of the lagoon:

1. from the provisional ones of food, natural materials, biochemical products;
2. those regulating air quality, climate, tidal flow and wave motion;
3. purification and mineralization of polluting inputs, bio-stabilization of the soil and the lagoon network;
4. biodiversity support and nurseries for multiple species of fish and birds;
5. cultural and landscape aspects, both from the point of view of aesthetic value per se;

[14] Professor John W. Day recently published an article demonstrating the convenience of intervening immediately to rehabilitate the Mississippi Delta for this very reason (Day J.W. et al., 2017).

6. and the value of recreational, cultural, artistic, and educational activities such as the development of eco-tourism, aesthetic pleasure, artistic inspiration, cultural identity, scientific research;
7. finally, socio-ecological education [15], which is fundamental for the co-exploration and adaptive management of the Venice asset, so that it survives for the good of future generations of the country system and humanity.

6. *Adaptive Hospitality for local co-management and global co-exlorations*

To empower the application of this special toolbox it is necessary a wider participation of the local community members and their interconnection with other global water communities sharing similar challenges in different places and conditions. To implement this strategy of empowerment of the local culture of livening , learning and building with nature it is necessary to organize and conduct a new form of experiential tourism based on the acclimatation of global community visitors and locals who will receive adaptive hospitality to pair them with the Venice model by : - exploring the beauty and impermanence of Venice; understanding and communication of lagoon processes and ecosystem services. This is in itself a new business model for tourism and also a bottom-up participated approach to restoration and adaptation, consisting in helping nature to help us to improve the habitat capacity to structure the landscape, thus contributing to: - the dissipation of motor boat and wind wave energy, - the guidance of tidal and wind currents along the existing network of channels, - the spontaneous formation of microbial mats that will evolve into stable mudflats and salt marshes, a more favourable condition for biodiversity and species of commercial interest. The participatory process will harmonize resident expectations and visitor demands as well as conservation efforts and socio-economic development. The lagoon landscape will be transformed harmonizing the needs of society and nature, including the visitors that will be acclimatized as temporary residents. This approach underscores the potential of the Venice L agoon to serve as a model for the world water communities for living in harmony with nature, demonstrating how targeted, nature-based interventions can foster interconnected ecological restorations while supporting community resilience and sustainable development for the pleasure of encountering the identity and cultures of other water communities, especially the ones that are more interested in each other's such as Italy and Japan.

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[15] See the co-exploration activities of the Venice Laboratory for Resilience, or by the international academy at the Venice International University by Boston University (Balsamini, 2014), or by the University of Ca' Foscari with the summer course *The Environment and Economics of Coastal Lagoons* on the management of salt marshes with the University of Utrecht.

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