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**Nautical Tourism, Carrying
Capacity and Environmental
Externality in the Lagoon of
Marano and Grado**

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Summary

Tourism and environmental preservation are often conflicting activities, mainly in areas such as coastal lagoons, where seaside mass-tourism comes into contact with a very sensitive ecological system. In this paper we deal with a classical problem of both environmental and tourism economics, the internalization of environmental costs of tourism, focusing on the nautical fruition of the Lagoon of Marano and Grado (North-Eastern Italy, Friuli Venezia Giulia Region). Using different instruments, both theoretical (Carrying Capacity framework, Polluter-Payer principle, Coase compensation) and empirical (Cluster analysis, Log-log regression, Forecasting model, cost and benefit calculation through actual market values), we get the result that a standard Coasian equilibrium (unit external cost equal to unit private benefit) doesn't hold, and a higher coverage of the local berths endowment (i. e. a higher vessels transit in the Lagoon) is more effective for nature conservation than a tempered fruition. Another interesting result is that the best available solution to internalize environmental externality is a mixed one, comprehensive of a command and control rule (a speed-limit prescription), and a compensation scheme.

Keywords: Tourism Carrying Capacity, Nature conservation, Externalities, Empirical studies

JEL Classification: Q01, Q26, Q57

This paper is the result of the studies made for the Sustainable Tourism Plan for the Natura 2000 Site IT3320037 (Marano and Grado Lagoon), commissioned by Regione Friuli Venezia Giulia, Department of Hunting, Fishing, and Nature Conservation. We thank Mauro Cosolo and Pierpaolo Zanchetta (Regione Friuli Venezia Giulia), Giorgio Fontolan and Annelore Bezzi (DiGe University of Trieste) for their support, the data and information they made available. We acknowledge Carlo Reggiani (University of Manchester) for the useful comments and suggestions. The usual disclaimer applies, and all conclusions, observation, and comments must be referred exclusively to the authors.

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Nautical tourism, carrying capacity and environmental externality in the Lagoon of Marano and Grado¹

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DRAFT, June 2013

Abstract

Tourism and environmental preservation are often conflicting activities, mainly in areas such as coastal lagoons, where seaside mass-tourism comes into contact with a very sensitive ecological system. In this paper we deal with a classical problem of both environmental and tourism economics, the internalization of environmental costs of tourism, focusing on the nautical fruition of the Lagoon of Marano and Grado (North-Eastern Italy, Friuli Venezia Giulia Region).

Using different instruments, both theoretical (Carrying Capacity framework, Polluter-Payer principle, Coase compensation) and empirical (Cluster analysis, Log-log regression, Forecasting model, cost and benefit calculation through actual market values), we get the result that a standard Coasian equilibrium (unit external cost equal to unit private benefit) doesn't hold, and a higher coverage of the local berths endowment (i. e. a higher vessels transit in the Lagoon) is more effective for nature conservation than a tempered fruition. Another interesting result is that the best available solution to internalize environmental externality is a mixed one, comprehensive of a command and control rule (a speed-limit prescription), and a compensation scheme.

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1. Introduction and Background

Many natural sites throughout the World suffers from externality *à la* Siebert (1990), i. e. a contention on the use of environmental asset. The disputation is even harder in Europe, where the notion of wilderness is a *de facto* non-sense, since the natural heritage is a result of many centuries of interaction between environmental phenomenon and the human being work.

This is a common situation for coastal lagoons, where the precious landscape and the sensitive environment, natural habitat for aquatic species and birds, must find a *modus vivendi* with man activities such as tourism, fish-farming, hunting, and terrestrial agriculture and industry, that dump their pollutants and nutrients in the lagoon through the water stream network.

In this paper we focus on an Italian site, the Lagoon of Marano and Grado, showing so many features characterizing a problematic lagoon shield (see Section 2), to be a perfect archetype of many other similar cases throughout the world.

Nowadays, the main contention in Marano and Grado is about the intrusiveness of tourism activities, more precisely the impact in terms of saltmarshes' erosion of the waves generated by the large number of nautical boats and vessels moored in the marinas and little ports of the Lagoon, and the related disturbance to fauna. The local environmental and planning authority (Friuli Venezia Giulia Regional Government) wonders on the best way to preserve the Lagoon habitat from artificial erosion, calculating a Tourism Carrying Capacity (TCC) and imposing a regulation to vessels allowed to moor and transit in the Lagoon. In this context, we evaluate both the Region's proposals and other instruments.

Since its appearance in the first 1980ies, the concept of TCC has been interpreted in many ways. For some destination (protected areas, natural parks, sea beaches) the identification of capacity is related to crowding, meaning the number of people present in the site at a given time. When applied to a larger geographical area (such as a country or a tourist district), the concept acquires a broader significance to express a maximum acceptable tourist development, on the basis of the capacity of the resources to support tourism activity (Coccosis and Mexa, 2004). One of the most important definitions of tourism carrying capacity is provided by World Tourism Organization: "TCC is the maximum number of people that may visit a destination simultaneously without causing destruction of the physical, economic and socio-cultural environment, and generating an unacceptable decrease in the quality of visitor satisfaction" (WTO, 1981). Despite various definitions of TCC, it's hard to find one of them universally accepted. Most definitions combine two aspect: the capacity issue of a destination, how many tourists can be accommodated before negative impacts arise, and the perception of capacity issue, how many tourists are acceptable before a decline in the level of satisfaction and ensuing decline in tourism) (Coccosis and Mexa, 2004).

Because of the lack of accordance on both definition and calculation methodologies, the concept of TCC received plenty of criticisms by many sides of the international scientific community. Lindberg, McCool and Stankey (1997) summarize three principal criticisms: the first being that carrying capacity definitions often provide little guidance for practical implementation; the second relates to the perception of carrying capacity as a scientific objective concept; the third to the fact that carrying capacity issue typically focuses on use levels or numbers of visitors, while management objectives typically relate to conditions. According to Seidl and Tisdell (1998) the concept of carrying capacity becomes operational only if the question about the desired conditions is asked to local stakeholders, so that the sociopolitical, economic and subjective components are taken into account, and concerned parties are involved.

In the following pages we adopt a strictly scientific concept of Carrying Capacity, related to the minimal size of saltmarshes necessary to support avifauna (Section 2), that gives the threshold beyond which the transit of vessels becomes ecologically unsustainable. Running then an econometric regression to understand the actual effect of boats transit on saltmarshes erosion, and using it to forecast the future evolution of the naturalistic asset at the current use (Section 3), we identify the most problematic saltmarshes to be intervened.

Section 4 is dedicated to compare different viable solutions to reduce the environmental impact in the Lagoon. To do this, we calculated environmental costs of sandbank loss, and the net revenue of the nautical activity in the area using standard assumption on the production function and market price of re-nourishment and boating service. This is an original contribution if compared with standard literature on lagoons and environmental places attended by tourists, where usually monetary values are estimated applying indirect (parallel markets) and direct (artificial markets) evaluation methods, such as hedonic prices and contingent evaluation².

Another peculiarity of the analysis is that the base assumptions and the effective calculation of costs and revenues yield to refuse the standard convexity for the total private costs function. This affects the Coasian compensation scheme, leading to a counter-intuitive result that claims for a full occupancy of the Lagoon Marina's berths endowment as the solution that maximise total local welfare.

All the technical theoretical and empirical derivations are reported in Appendix 1 (Pressure Parameter Calculation), Appendix 2 (Benefit and Cost Calculation), and Appendix 3 (Data set and Econometric Tests).

2. This must be the place

The Lagoon of Marano and Grado plots down the coastal profile of Friuli-Venezia Giulia, a Northeastern region of Italy situated between the Alps and the Adriatic Sea. Delimited by rivers Isonzo and Tagliamento, the whole area is a Natura 2000 SAC/SPA³ given by the two watersheds of Marano Lagoon and Grado Lagoon. The total surface area is 160 squared km along a coast of 32 km around; the middle distance between the coastal line and the barrier islands is around five km.

The complex hydrodynamics of the lagoon is subject to continuous human pressures. After a bulk of activities that produced meaningful changes in lagoon waters circulation, because of pollution in 1998 has been implemented a law that blockaded the dredging of the channels, reducing the average deepness of the channel network. The sea-water affluence comes through six tidal inlets (Lignano, Sant'Andrea, Buso, Morgo, La Fosa of Grado and Primero), that conduct to as many basins (Marano, Sant'Andrea, Buso, Morgo, Grado and Primero).

In the lagoon there are many saltmarshes, which are typical structures in the upper coastal intertidal zone between land and open salt water, regularly flooded by the tides. They have a fundamental role in the lagoon ecosystem. From a morphological point of view, they catch suspended sediments and the relative sea loss; from the naturalistic one, they are a place of ecological excellence for the roosting and growth of many kinds of birds. Moreover, widest saltmarshes host some "casoni", the typical wood and rush huts that sheltered local fishermen in pre-industrial fish times, nowadays abandoned or recovered as tourism chalet (both low and high cost).

In last years, the development of the harbor tourism and increase in motor boats traffic had a negative impact on the lagoon's environment and local habitats, mostly because of increase in the wave motion by vessels passage and of the related erosion generated in saltmarshes. In most serious cases, saltmarshes vanished or are next to vanish. The most relevant source of pressure for the internal habitat of the lagoon is the boats and vessels transit. We calculated 10,537 mooring places all across the Marano and Grado watershed, a figure arising from official harbour plans, field enquires and aerial photo analysis. More specifically, 6,000 posts are provided by the local 17 Marinas, while the others are located in official city-harbours and authorized landfalls.

² For a complete review of issues and methods in lagoons valuation, see Enjolras and Boisson (2010).

³ The acronyms stand respectively for Special Area of Conservation (referring to Habitat Directive, 92/43/EEC), and Special Protected Area (referring to Birds Directive, 79/409/EEC, renewed by 2009/147/EC).

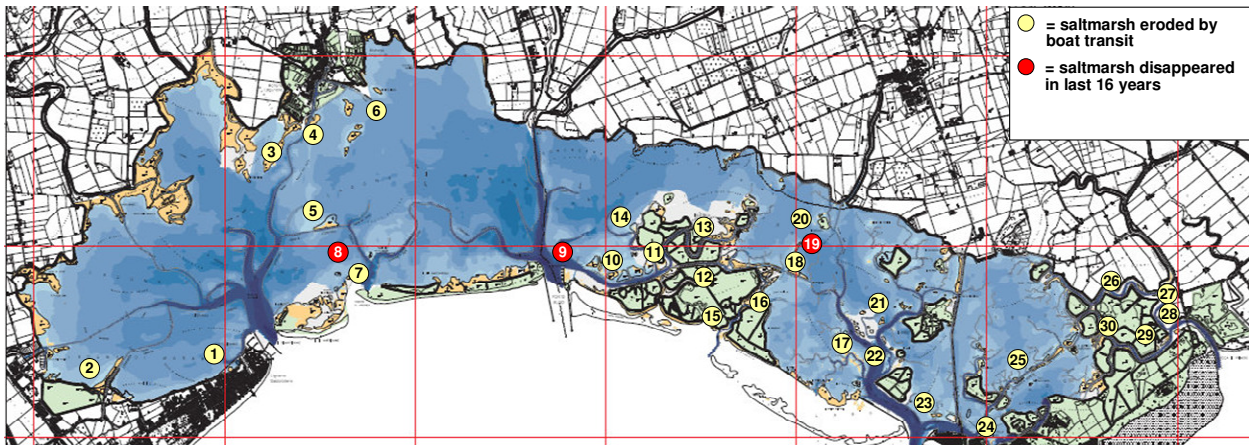


Figure 1: Localization of saltmarshes with vessels generated erosion. Source: Sinergheia and eco&eco (2012) on Triches et alia (2011)

Defining a unique measure of carrying capacity in a dynamic environment as a lagoon is a problematic exercise: the current geomorphologic conditions are shaped by centuries-run man activities; watercourses (Stella and Natissa, Tagliamento and Isonzo rivers, other minors streams) carry sediments and interact with both anthropic and natural erosion, the former mostly due to boat transit, the latter induced by wind and tide; finally, naturalistic engineering actions, such as nourishments and piles, change local conditions and could restore satisfactory conditions for saltmarshes and the lagoon environment.

In a very strict sense, any erosive evidence attests the overcoming of carrying capacity, and unless an artificial nourishment to restore initial conditions, it would claim for a blockade of boats transit throughout the Lagoon. It's easy to see it's a drastic measure, difficult to maintain from a social and economic perspective. Moreover, because of the trivial nature of the considered item – a saltmarsh made of marine sand – the loss of surface is technically replaceable with other marine sand excavated from the sea floor.

Besides of the Lagoon landscape, the main naturalistic emergency in the protected area of Marano and Grado is related to birds, that use to nest and roost in the local saltmarshes and sandy islands. Many aquatic species needs a space of at least 0.4 hectares to spawn and breed (Scarton 2010). For these reasons, we decided to take this value as a threshold of “minimal health” for saltmarshes in the Lagoon.

3. Set up of the model, estimation and forecasting

To capture the carrying capacity of nautical tourism in the Marano-Grado Lagoon, we take the state of the local saltmarshes as indicator of ecological pressure.

The Department of Land Science (Dipartimento di Geoscienze, DiGe) of the University of Trieste surveyed the state of saltmarshes inside the Lagoon of Marano and Grado, evaluating by aerial photos the modification of their extension occurred between 1990 and 2006 and – studying the morphology and the history of the Lagoon - associating the change in each saltmarsh to one or more main causes. Surveyed saltmarshes are 92, six of them disappeared in the considered time interval (Fontolan *et alia*, 2012). The complete encoded list of erosion sources is the following: drowning for the effects of subsidence and sediment deficit (E1); clearance margins/fragmentation to swell (E2); clearance Eyelash for waves generated by the passage of vessels (E3); retreat of the margin/submersion of sand/opening washover for coastal dynamics/wave (E4); elimination of saltmarshes by dredging or reclaiming (E5).

Since we are interested in the tourism pressure on the local habitat, in this paper we focus exclusively on 30 saltmarshes encoded with E3, searching for a direct impact on them of the transit of vessels, mostly nautical and tourists, in the internal channels of the Lagoon.

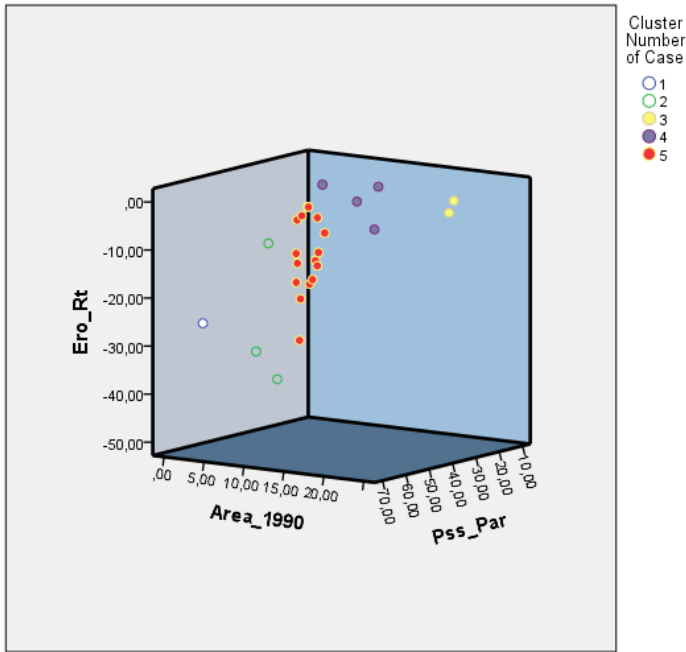


Figure 2: Spatial representation of cluster analysis of saltmarshes

Initially, we make a cluster analysis to find homogeneous groups of saltmarshes respect to area in 1990, pressure parameter and rate of erosion registered between 1990 and 2006. We exclude saltmarsh no. 24 (see *infra*), no. 8, no. 9, no. 19 (because they disappear between 1990 and 2006). Saltmarshes can be divided into five groups: the first group contain only saltmarsh no. 1, due to the high pressure parameter; the second group include saltmarshes no. 6, no. 17 and no. 23 (small area and an high pressure parameter); saltmarshes no. 2 and no. 3 set up the third group (big area with medium pressure parameter and an erosion rate very small); the fourth include saltmarsh no. 4, no. 10, no. 13 and no. 30 (medium area with a small erosion rate) and the others 16 saltmarshes form the last group (small saltmarshes with a small pressure parameter). We use k-means clustering method to distribute observations into five clusters in which each observation belongs to the cluster with the nearest mean.

We concentrate on the existing relationship between the erosion suffered by this group of sandbanks and the Lagoon traffic through a multiple regression model. Multiple regression is particularly useful because it allows to describe the relationship between the observed event (erosion) and independent variables; in fact, not only the traffic of vessels causes the erosion of a saltmarsh, but there are other con-causes to be taken into account. According to this, we initially selected four variables: the rate of erosion registered between 1990 and 2006 (*Ero_Rt*) as dependent variables, and three independent ones represented by the initial size of the saltmarsh (*Area_1990*), a pressure parameter (*Pss_Par*) calculated *ad hoc* using [1b] and deeply described in Appendix 1, and the average bathymetric level (*Bath*) of the Lagoon channels saltmarsh in the nearness of any considered saltmarsh. The functional form of the model is:

$$Ero_Rt = e^k Area_1990^\alpha * Pss_Par^\beta * Bath^\gamma \quad [1]$$

With the variables built as follows:

$$Ero_Rt = \frac{|Area_1990 - Area_2006|}{Area_1990} * 100 \quad [1a]$$

Where: $Area_1990$ = registered saltmarsh extension in 1990
 $Area_2006$ = registered saltmarsh extension in 2006

$$Pss_Par = \sum_{i=1}^n \sum_{j=1}^6 N_i * WM_{H,M,L} * WR_{H,M,L} \quad [1b]$$

Where: n = number of waterways affecting the considered saltmarsh
 N = number of boats belonging to one of the six dimensional classes transiting in the Lagoon (see Appendix 1);
 WM = parameter for wave motion produced, labeled with a qualitative indicator (High, Medium or Low) and then expressed in a quantitative value through a numerical transformation (respectively 6, 4, and 2);
 WR = water return due to the transit (same quali-quantitative scale of WM)⁴;

$Bath$ = average bathymetric level nearby the saltmarsh (Triches et alia, 2011) [1c]

e^k = constant [1d]

The use of the rate of erosion instead of the absolute value of erosion is to avoid a “size effect”, so that the widest the sandbanks, the higher the eroded square meters, while the real significant dynamics is on the relative value, i. e. the proportional loss of land. The table below shows the main features of the data set completely described in Appendix 3 (Table A11):

	<i>min</i>	<i>Max</i>	<i>Mean</i>	<i>Standard deviation</i>
<i>Ero_Rt</i>	-1	-0.1	-0.2	0.2
<i>Area_1990 (ha)</i>	0.13	22.27	3.9	5.55
<i>Pss_Par</i>	18.22	118.39	25.33	19.88
<i>Bath</i>	-7	-1.4	-3.97	1.5

Table 1: Regressors and dependent variable summary data

Saltmarsh no. 24 has been dropped out from the dataset because it’s an outlier, with anomalous behavior: despite its reduced original area (1.18 hectares), and the outstanding value of the pressure parameter, this saltmarsh shows a very low rate of erosion (1%). This divergence is because, being located in proximity of Lagoon harbor La Fosa (see Figure 1), it suffers from the passage of many boats, but they pass quite far from the saltmarsh to direct rapidly to the open sea. As a consequence, the negative effects of boats transit is inappreciable.

The model used to study the relationship between the variables is the logarithmic-logarithmic regression model of [1], so to consider the relationship between independent and dependent variables in terms of percentage change:

⁴ From an hydrodynamic perspective, a boat transit generate two consequences, that differs according to size and speed of the boat: the creation of a direct wave (wave motion, WM) more related to size (length and tonnage), and an indirect wave (wave return, WR), more connected with speed.

$$\log \text{Ero_Rt} = k + \alpha \log \text{Area_1990} + \beta \log \text{Pss_Par} + \gamma \log \text{Bath} \quad [2]$$

After a first attempt, variable *Bath* has been eliminated because of its low significance level: t-test is equal to 0.12 and p-value is very high (see Appendix 3), meaning we can't reject the null-hypothesis (*erosion rate is not correlated with bathymetry*). The model would claim that for a bathymetry increase by 1% erosion rate increases by 4%. This counterintuitive outcome must be ascribed to non-significance of the variable, most likely because boats transit is forcedly limited to navigable waterways, so that once navigability is ensured, there is no further correlation between bathymetry and boat transit.

Once eliminated variable *Bath*, the equation of a regression model that predicts the value of rate of erosion based on the remained independent variables is:

$$\log \text{Ero_Rt} = k + \alpha \log \text{Area_1990} + \beta \log \text{Pss_Par} \quad [3]$$

$$\log \text{Ero_Rt} = -3.39 - 0.67 \log \text{Area_1990} + 0.59 \log \text{Pss_Par}$$

The main regression results are summarized by the following table:

	Coefficient	Standard Error	t	P > t	Confiance interval 95%	
<i>log Area_1990</i>	-0.67	0.10	-6.64	0.00	-0.87	-0.46
<i>log Pss_Par</i>	0.59	0.43	1.36	0.19	-0.30	1.47
<i>k</i>	-3.39	1.31	-2.58	0.02	-6.09	-0.69

	Sum of Squares	Degree of Freedom	MS
Model	20.59	2	10.30
Residual	12.00	26	0.46
Total	32.59	28	1.16

No. of obs.	29
F (2, 26)	22.31
Prob > F	0.00
R ²	0.63
Adjusted R ²	0.60
Root Mean Square Error	0.68

Table 2: Regression results, Model results, and Tests from equation [3]

According to the t-test, the fit is good for *log Area_1990*, while the pressure parameter is not statistically significant. This is due to the small sample size and to the non-normal distribution of variable *log Pss_Par*, verifiable through the Kolgomorov-Smirnov test (see Appendix 3).

Estimated coefficients indicate that a unit increase in the percentage of the saltmarshes' surface corresponds to a decrease in the erosion rate equal to 0.67%, while the same unit increase in the percentage of the pressure parameter generates a higher erosion rate of 0.59%. The constant assumes a negative value: in absence of external influences or explanatory factors, which we theorize to be the vessels' traffic and initial size of the saltmarsh, sandbanks would lose naturally 4% of their own surface. This values confirms the two initial hypothesis; the first one can be reframed as:

Remark 1

There's an inverse correlation between erosion rate and initial size of the saltmarsh.

Bigger sandbanks suffer less from erosion. This means that erosion phenomenon encompasses a kind of “snowball” effect, according to which the rate of erosion in absence of any external intervention increases at a geometrical pace of 1.5 (reciprocal of 0.67); but this even means, on the other hand, that a direct artificial intervention such as bank-building or nourishment, can succeed in stopping or curtailing further saltmarshes loss. This point will be considered in Section 5.

The second hypothesis is:

Remark 2

There’s a direct correlation between erosion rate and pressure parameter.

The model confirms that where the associated pressure parameter is higher, a higher saltmarsh erosion is observed. More specifically, almost a 60% of the increase in this pressure index passes through and is transformed in erosion rate. It’s worth noticing that, according to [1b], the environmental pressure of vessels traffic can be smoothed reducing both the number of boats passing in the Lagoon channels, and the transit speed.

Since one of our main goals is to identify a carrying capacity of the Marano and Grado Lagoon related to the vessels transit, a measure of the pace of erosion of the saltmarshes at the current rate is needed. To this goal, we use the estimated model to forecast the future evolution of the area. Plugging the results from the regression model into [1], once omitted non-significant regressors, we get the following equation and the results depicted in Figure 3 (see Appendix 1, Table A6):

$$Ero_Rt = e^{-3.39} Area_1990^{-0.67} * Pss_Par^{0.59} \quad [4]$$

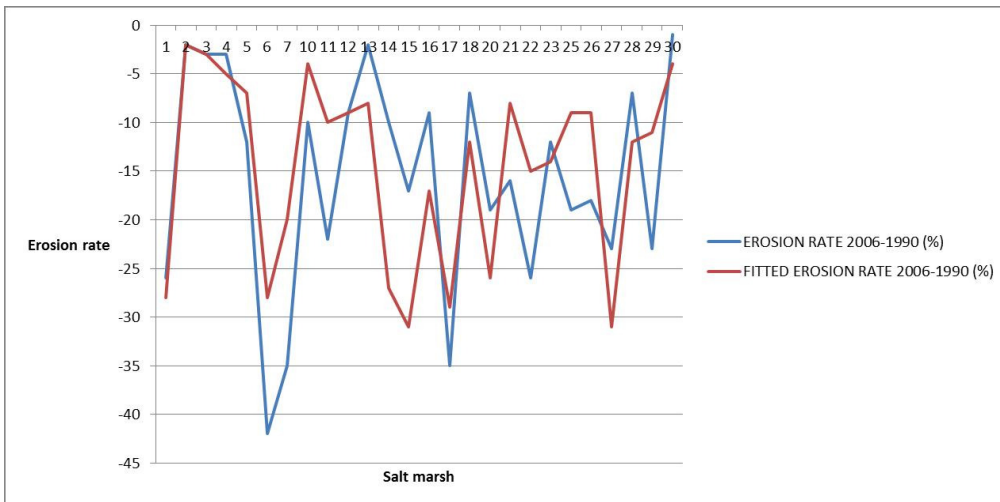


Figure 3: Comparison between observed and forecasted values for the Erosion rate 1990-2006.

Equation [4] allows to calculate the process of erosion suffered by any single saltmarsh. We’re interested in the year when the surface of a saltmarsh reaches the lower bound limit of 0.4 hectares, i. e. the fixed carrying capacity threshold.

Keeping unchanged the independent variables and using the appraised parameters to run the forecasting model, and leaving apart saltmarshes no. 8, 9 and 19, just disappeared in 2006, we observe that a relevant part of the saltmarshes are bound to trespass the threshold in a span of time that goes from now to 2100 (see Appendix 3)⁵.

⁵ The year of disappearance of a saltmarsh has been calculated in a mechanical way, assuming as constant the surface of saltmarsh lost each year, i. e. dividing the forecasted loss of surface for the 17 years of the considered span of time. The

Year of threshold trespassing	Saltmarsh code
≤ 2006	15, 27
2006-2030	6, 14, 17, 20
2031-2055	1, 7,
2056-2080	16
2081-2120	22, 23, 28
2121-2200	11, 18, 26, 29
> 2200	2, 3, 4, 5, 10, 12, 13, 21, 25, 30

Table 3: Year of trespassing of the 0.4 hectares threshold at the current use according to the forecasting model

Saltmarshes with similar characteristics and belonging to the same group according to the previous cluster analysis will trespass the carrying capacity threshold at the same time: no. 6 and no. 17 (second group) will pass respectively in 2021 and 2027 (no. 23, the other saltmarsh of this group, will pass in 2113), while no. 4, no. 10, no. 13 and no. 30 (fourth group) will pass the threshold beyond 2200, the same result of No. 2 and no. 3 (third group).

But what is most important, at the current use many saltmarshes are bound to lose their capability to be a nesting places for aquatic birds, i. e. an important ecological role.

Remark 3

Without any regulation, a third part of the whole group of considered saltmarshes will lose its ecological role within 50 years from the last survey.

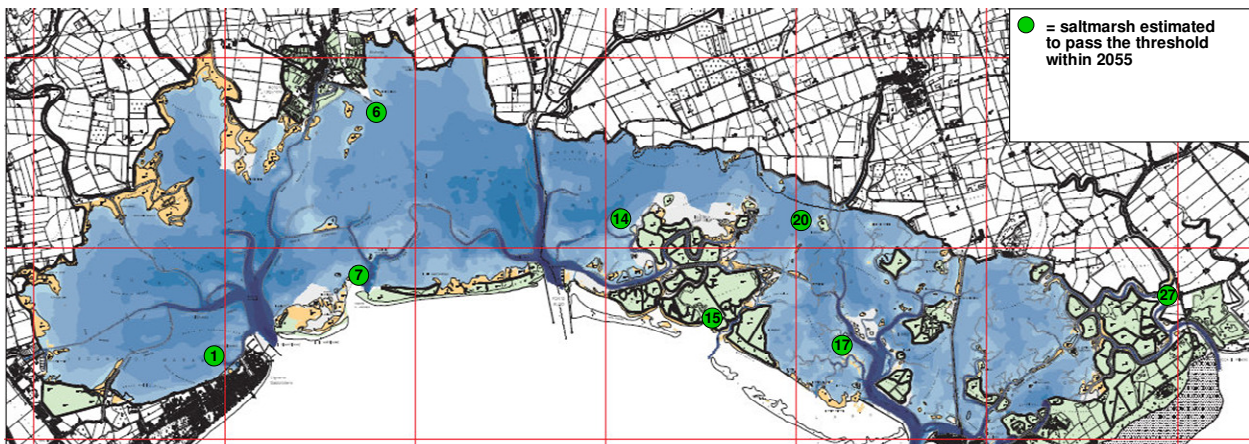


Figure 4: Localization of saltmarshes for which the threshold is trespassed within 2055. Source: Sinergheia and eco&eco (2012) on Triches et alia (2011)

4. Capacity threshold, externalities and internalization

Following the literature on externalities, there exist different tools to comply with a carrying capacity threshold. In this section we compare a command and control rule aimed at limiting the transit of vessels, and of a compensation scheme, observing that last one is more effective in terms of total welfare. But even that mixing up both solutions allows to get a better result.

4.1 Command and Control regulation

Once identified the transit of vessels as the main source of environmental externality in the area, a drastic rule to deal with the problem is to cut down the number of allowed mooring places in the

ratio allows to get the number of hectares to be diminished from the initial value, until the complete vanishing of the saltmarsh.

Lagoon. The rationale is quite evident: reducing the harbour endowments implies a lower circulation through lagoon waterways and a lesser wave generated by the passage of vessels.

According to official documents and field experience, a standard transit speed of vessels within the Lagoon is normally included between 20 km per hour for boats of length under 6 meters, and 7 km per hour for sail boats. All previous estimations and forecasts have been run assuming those values.

A reduction of the allowed speed to eight km/h for all types of vessels will ensure a crucial extension of saltmarshes' time of disappearance, through a reduction of the Pressure Parameter, in almost all cases far beyond the 2076 threshold (see Appendix 1)

The result of this rule in term of missed erosion is equivalent to a cutback in mooring places from current 10.537 to 5.901 (56%); but contrary of this, it wouldn't encompass an analogous reduction in revenues from the nautical sector (see *infra*).

Remark 4

Enforcing a speed-limit in the internal waterways of the Lagoon has the same positive environmental impact than cutting down a relevant number of vessels allowed to moor in the Lagoon marinas.

4.2 Compensation

Imposing a cutback both in the number of vessels allowed to station inside the Lagoon, or in the permitted speed of transit is a solution that may stir up social reactions from local community and boaters. Since the environmental impact considered is the loss of sandbanks, easily restorable with an action of replenishment using sands dredged in the sea floor, the same result could be reached with a compensation scheme such that the responsible for externalities gives back the resources to cover internalization costs, according to the common polluter-payer principle.

For this reason, it's worth exploring a negotiation scheme *à la* Coase (1960), where profit gainers from economic activity can compensate the induced loss of wildlife.

To follow this line, we calculated on one hand the private benefit (i. e. revenues minus costs) for different theoretical numbers of vessels mooring in the Lagoon (from 10 to the actual value of 10,537), and on the other hand the external costs induced by the same number of vessels being the source of traffic in the Lagoon, namely a monetary quantification of the lost sandbanks expressed in terms of total cost of nourishment to re-establish the original surface (see Appendix 2).

The application of the negotiation scheme in this exercise, must deal with a particular condition, out of shape with respect to a standard Coase design: an increasing monotonic function for private benefits, instead of a reversal-u shape. A second nother singularity with respect to standard Coase Theorem is that, once empirically calculated, the unit external costs are decreasing with the number of vessels, instead of increasing: this because, even tough the marginal impact of an additional vessel transiting in the Lagoon is positive, the total costs of replenishment of damaged saltmarshes increases at a lower rate than the number of vessels. The final outcome is the following:

No. of mooring places	External Costs	Private Benefit	Unit (Average) External Costs (AC _E)	Unit (Average) Private Benefit (AB _P)
5,710	1.076.816	165,00	290,85	0,03
6,000	1.101.687	1,243,097	283,06	207,18
6,110	1,711,915	1,714,554	280,20	280,60
7,000	1,823,543	5,529,071	260,51	789,87
8,000	1,942,887	9,815,045	242,86	1,226,88
9,000	2,057,233	14,101,018	228,58	1,566,78
10,537	2,170,219	20,688,559	206,00	1,963,42

Table 4: External cost and private benefit empirical functions, total and average values at the current use

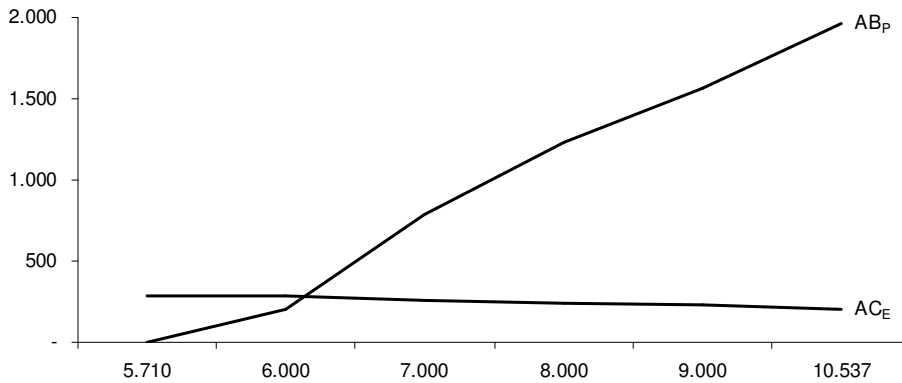


Figure 5: External average cost and private average benefit empirical functions at the current use

The graph illustrates two pivotal values for the number of mooring places: the minimal number of vessels allowing to recover the sunk private costs and generating a nil private benefit (5,710), and the minimal number of vessels allowing to compensate the external cost with private benefit (6,110 vessels, $AC_E = AB_p = 280.2$ €). From that value on, the local nautical sector's gain is higher than the impact produced by vessels on the Lagoon natural system. This means that with a simple transfer scheme from gainers to institutions delegated to nature preservation – e.g. a fee to be paid at the moment of renewing the annual licence by Marinas runners – the whole external cost could be internalized.

But, what's more relevant, because of the shape of the two curves, there's no unit cost equal to unit benefit rule: the higher the number of boats allowed to moor in the Lagoon, the higher the potential total benefit, and the revenues to be addressed to natural reconstruction.

Remark 5

When a compensation scheme is enforced, a full coverage of available mooring places is desirable, no matter what the TCC Threshold is.

4.3 Mixed solution

In last section we introduced three different solutions to the problem of saltmarsh erosion: a cutback in the number of vessels allowed to transit throughout the Lagoon; a speed-limit for all vessels, but no number restriction; a compensation scheme to the benefit of saltmarsh nourishment.

The cutback comparable with the eight km/h speed-limit asks for a maximum of 5,901 vessels hosted in the local facilities. For both options, the environmental cost, expressed by a monetary measure of the loss of saltmarshes, is the same, but they differ for two other items: the not-negligible cost of monitoring when a speed-limit is applied, and the higher profit for nautical activities achieved, directly related to the hosted number of vessels.

The monetary measure of environmental cost is given by the nourishment costs to be implemented to restore the 2006 saltmarsh surface, a value estimated to be near 1.5 millions of euro. According to market evaluations, the monitoring system is meant to cost 4,878 euro per year, while the private profit assessed is roughly 800,000 euro with the vessels' cutback, and more than 20.6 millions euro with free entrance. The reason for such a disparity in profits is that the local nautical system is built up to host 10,537 vessels, and the costs side incorporates the same construction costs in both cases. All of this values are calculated according to market prices of the considered services, and assumptions on occupancy ratio of Marinas supported by field interviews to practitioners and insiders (see Appendix 2 for details in values and methods).

The compensation design considers the same number of vessels than the speed-limit one, meaning the same profits of 20.6 millions euro, no monitoring costs, and – because of the higher pressure and the direct consequence on erosion of saltmarshes with respect to the speed-limit case - a more than 2.1 millions euro environmental cost to be compensate. The following table summarizes the relevant values for each option, both in absolute and unit (average) values⁶:

	Cutback	Speed-limit (8 km/h)	Compensation
No. of mooring places	5,901	10,537	
External Costs (1)	1,449,469,72		-
Monitoring Costs (2)	-	4,878,20	-
Compensation Costs (3)	-	-	2,170,218,87
Private Benefit (4)	818,786	20,688,559	
Total Welfare (4-[1+2+3])	- 630,684	19,234,212	18,518,341
External Costs (1)	245.63	137.56	-
Monitoring Costs (2)	-	0.46	-
Compensation Costs (3)	-	-	205.96
Private Benefit (4)	138.75	1,963.42	
Total Welfare (4-[1+2+3])	- 106.88	1,825.40	1,757.46

Table 5: Different kinds of Costs, Private Benefits and Welfare with the three prospected solutions, Absolute and unit values

The cutback of the mooring places is a solution to disregard, since the total impact is negative or, put in another way, it doesn't allow to generate enough revenue to compensate the external costs.

The comparison between the other efficient solutions, Speed-limit at 8 km/h and Compensation, seems to tip in favor of the first option, since the difference in terms of unit external costs to be compensated (€ 68.44, equal to the difference between 205.96 € to be compensated when no speed-limit is imposed, and 137.56 € of external costs in speed-limit regime) is not offset by the almost negligible costs of monitoring that only the command and control instruments requires.

It's worth noticing that mixing both solutions, i. e. applying a speed-limit together with a compensation scheme, will ensure the best outcome in terms of environmental target (the total restoration of the saltmarshes) at the best price, being the external cost to be covered lower. In addition, imposing a speed-limit reduces from 6,110 to 5,961 the number of vessels necessary to cover the external cost, since the new Unit External Cost function is lower. As a consequence, the intersection between External Costs function and Private Benefit function is at $AC_E = AB_P = 179.6$ €, instead of 280.2 € (see Section 4.2).

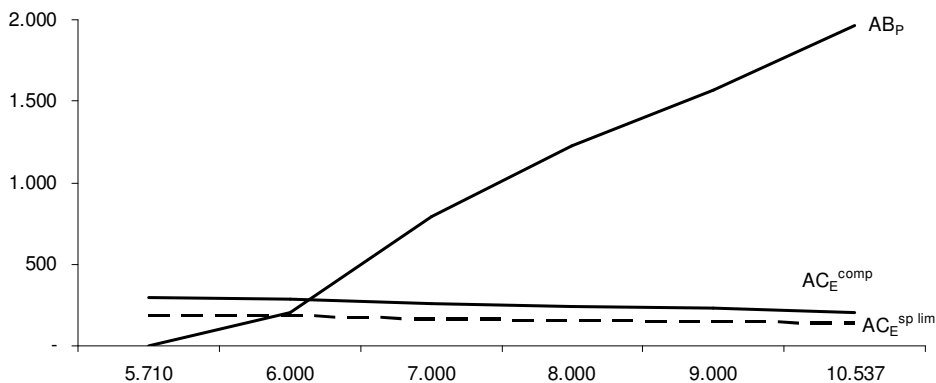


Figure 6: External average cost and private average benefit empirical functions at the current use and with speed-limit

⁶ With the Compensation solution, we decided to label the External Costs as Compensation Costs, since when used to re-nourish lost saltmarshes' soil, the External Costs disappear.

Moreover, the enforcement of a speed-limit is important to moderate the environmental impact in case the occupancy ratio of the mooring places is not high enough to ensure compensability.

Notice further that the application of a speed-limit introduces not only the costs of the indispensable monitoring system, but even the opportunity to levy fines to transgressors. Exceeding limits means most likely to pass through the internal waterways at the usual speed, i. e. having the standard erosive impact on saltmarshes instead of the temperate one. For this reason, and recalling that external costs are assumed as a monetary measure of environmental damage, it's correct to design the fine as an annual extra-cost, set equal to the difference between the unit external cost in the two cases. In this way, each fine charged to a transgressor covers exactly the higher environmental costs of transgression.

The mixed solution is not only more efficient, but even more equitable, because allows each kind of boater to choose the size of external cost to cover, according to his personal evaluation of the time required to go through the Lagoon waterways.

Remark 6

A mixed solution (speed-limit plus compensation of external costs) is the most efficient and equitable instrument to deal with the impact of nautical traffic in the considered natural site.

Conclusions

In this paper we concentrate on a site of the European network Natura 2000 (IT3320037) suffering from transit of boats and vessels lodged in the lot of harbours and marinas covering the Lagoon. The environmental impacts of this transit are bird roosting and nesting disturbance, crumbling of traditional fish farms' embankments, and mostly saltmarshes consumption, that has a direct negative effect on both Lagoon landscape and – again - bird roosting and nesting.

The main question affects the feasibility of the notion of carrying capacity, and the opportunity to allow just a restricted number of vessels to transit in the Lagoon waters. The practical calculation of a precise capacity threshold is always a problematic issue, since many variables are involved. In a strict sense, any wave generated by boat passage is potentially harmful, while the sediments coming from local streams would have to be addressed by the human action to benefit the compromised saltmarsh, going otherwise to fill the internal waterways and inducing the burial of the whole Lagoon. For these reasons, we decided to set a carrying capacity threshold in terms of minimal size of saltmarshes necessary to ensure their role as bird roosting and nesting habitat, and to calculate the year of probable overcoming of that threshold. This carrying capacity measurement is a first milestone to enlighten more problematic saltmarshes and to prospect solutions aimed at widen the span of time beyond the threshold. This is a reduction of allowed speed in the Lagoon from the usual 30-20 km per hour to a limit of eight km per hour, a rule with an impact comparable to a cutback of 44% of berths' endowment. In addition, the application of a Coasian compensation procedure leads to some remarkable results in terms of complete internalization of environmental costs, even with the full exploitation of the mooring places in the Lagoon.

The proper application of a speed-limit joint with a compensation scheme leads to the most efficient and equitable results, since it allows the full internalization at the lower cost, and selects boaters according to their tolerance to low speed and to their attitude for environment.

Finally, the speed-limit is the only way to reduce the environmental impact when the occupancy ratio of the mooring places is not high enough to ensure compensability. A relevant issue for any Italian nautical district, considering the actual crisis in the sector and the competition from the other bank of Adriatic Sea.

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Appendix 1: Pressure Parameter Calculation

The formula to calculate the Pressure Parameter is the following (see *supra* [1b]):

$$P_{ss_Par} = \sum_1^n \sum_1^6 N_i * WM_{H,M,L} * WR_{H,M,L} \quad [1b]$$

Where:

- n = number of waterways affecting the considered saltmarsh
- N = number of boats belonging to one of the six dimensional classes transiting in the Lagoon;
- WM = parameter for wave motion produced, labeled with a qualitative indicator (High, Medium or Low);
- WR = kind of water return due to the transit (same quali-quantitative scale of WM);

As reported in the summation notation, we consider six classes of boats:

Classes of vessels	Average transit speed (km/h)	Wave motion (WM)	Water Return (WR)
<6 m	20	4 (H)	2 (L)
6-15 m	16	6 (H)	4 (H)
>15 m	13	4 (H)	6 (H)
Commercial <10 m	8	4 (H)	4 (H)
Commercial >10 m	12	2 (L)	6 (H)
Sailboats	7	2 (L)	4 (H)

Table A1: Classes of vessels, usual transit speed in the internal waterways, wave motion and water return (qualitative and quantitative scales). Source: Sinerghia and eco&eco (2012)

Since there's no systematic registration of the real size of vessels going through the Lagoon, we operated an assessment based upon field researches (revising the official mooring places supply of Marinas, studying local port plans when existing, analyzing satellite and aerial photos), and interviews.

Starting from the berth endowment (10,537 mooring posts), the number of vessels belonging to each class is estimated parting them at first in two categories: the flow of vessels using the most direct waterway from the marina/port to the open sea, and the group of boats going around to visit the Lagoon.

The first group is assigned to the straightest waterway among the existing five connecting the marina with the open sea (Videra Canal, Marano Canal, Taiada-Mee Canal, Belvedere Canal, and Grado Canal). It's assumed that just 13.5% of the total endowment will move at the same time, with different weights according to the capacity of marinas of departure (Sinerghia and eco&eco, 2013). The second group is related to the usage of the waterway called *Litoranea Veneta*, a recreational canal cutting transversely the Lagoon and connecting it via river and waterways to other places throughout North-eastern Italy. This group is joined exclusively by the vessels that can circulate in the narrow and shallow internal channels, i. e. the 7,314 boats (69.5%) whose length is lower than six meters; we assume that just 2% of this group will go out simultaneously, augmented of a rough 29% ascribed to boats coming from outside to visit the Lagoon. The first step outcome is the following:

Waterways	K_i
Litoranea Veneta	$N*69.5%*2%*129*$
Marano Canal	$N*2.9%$
Grado Canal	$N*5.8%$
Belvedere Canal	$N*0.1%$
Taiada-Mee Canal	$N*1.2%$
Videra Canal	$N*3.4%$

Table A2: Number (K_i) of total moors (N) assigned to each internal waterway in peak moment. Source: Sinergheia and eco&eco (2012)

The second step to get N_i is assigning to any single waterway the number of units belonging to each class of vessels. Again, we set a percentage according to technical literature, size of the canals, capacity of the marinas, and specific information gathered at the local level. The final picture is the following:

Waterways	<6 m	6-15 m	>15 m	Commercial <10 m	Commercial >10 m	Sailboats
Litoranea Veneta	$K_1*89%$	$K_1*10%$	-	-	-	$K_1*1%$
Marano Canal	$K_2*61%$	$K_2*6%$	$K_2*1%$	$K_2*2%$	$K_2*22%$	$K_2*8%$
Grado Canal	$K_3*26.5%$	$K_3*42%$	$K_3*9%$	$K_3*18%$	$K_3*3,45%$	$K_3*1%$
Belvedere Canal	$K_4*80%$	$K_4*20%$	-	-	-	-
Taiada-Mee Canal	$K_5*42,68%$	$K_5*31,25%$	$K_5*7,62%$	$K_5*17,92%$	-	-
Videra Canal	$K_6*26,7%$	$K_6*46,39%$	$K_6*9,15%$	$K_6*17,9%$	-	-

Table A3: Number of boats transiting through each internal waterway in peak moment for class of vessels. Source: Sinergheia and eco&eco (2012)

The third step is the calculation of a Pressure Parameter of each waterway, according to the formula: $W_n Pss_Par = \sum_1^6 N_i * WM_{H,M,L} * WR_{H,M,L}$

The fourth step contemplates to get the Pressure Parameter for any single saltmarsh, summing up the value obtained for the waterways that affect them, according to the geographical localization. The final picture is the following.

Saltmarsh code	Waterways	Pss_Par	$Pss_Par^{sp_lim}$
1	Videra Canal	62.15	33.57
2	Litoranea veneta	18.22	7.77
3	Marano Canal	27.39	22.19
4	Marano Canal	27.39	22.19
5	Litoranea veneta	18.22	7.77
6	Marano Canal	27.39	22.19
7	Litoranea Veneta	18.22	7.77
8	Litoranea Veneta	18.22	7.77
9	Litoranea Veneta	18.22	7.77
10	Litoranea Veneta	18.22	7.77
11	Litoranea Veneta	18.22	7.77
12	Litoranea Veneta	18.22	7.77
13	Litoranea Veneta	18.22	7.77
14	Litoranea Veneta	18.22	7.77
15	Litoranea Veneta	18.22	7.77
16	Litoranea Veneta	18.22	7.77
17	Litoranea Veneta + Taiada-Mee Canal	37.08	17.97
18	Litoranea Veneta	18.22	7.77
19	Litoranea Veneta	18.22	7.77
20	Litoranea Veneta	18.22	7.77

21	Litoranea Veneta + Belvedere Canal	19.34	8.27
22	Taiada-Mee Canal + Belvedere Canal	19.98	10.70
23	Litoranea Veneta + Taiada-Mee Canal + Belvedere Canal	38.20	18.47
24	Litoranea Veneta + Grado Canal	118.39	64.94
25	Litoranea Veneta	18.22	7.77
26	Litoranea Veneta	18.22	7.77
27	Litoranea Veneta	18.22	7.77
28	Litoranea Veneta	18.22	7.77
29	Litoranea Veneta	18.22	7.77
30	Litoranea Veneta	18.22	7.77

Table A4: Combination Saltmarsh-waterways-Pressure Parameter

Pressure parameter depends also on vessels' speed: through the Froude value, there is a direct correlation between wave motion (*WM*), and speed⁷. This means that imposing a speed-limit at eight km/h reduces directly the Pressure Parameter for all saltmarshes, since the previous calculation has been done considering the average transit speed reported in Table A5, i. e. with speeds in four cases out of six higher than the imposed limit.

Because of the mentioned direct proportionality between speed and wave motion, the adjustment of the pressure parameters in the new prospected situation of speed-limit has been obtained at a first step calculating a Conversion Factor according to the ratio $CF = \text{Average transit speed} / \text{Speed-limit}$ for each class of vessels:

Classes of vessels	A. Average transit speed (km/h)	B. Speed-limit (km/h)	Conversion Factor (CF =A/B)
<6 m	20	8	2,5
6-15 m	16	8	2
>15 m	13	8	1,625
Commercial <10 m	8	8	1
Commercial >10 m	12	8	1,5
Sailboats	7	Not operative	-

Table A5: Conversion Factor for each class of vessels when a speed-limit is enforced

And than applying the following formula: $W_n P_{ss_Par}^{sp_lim} = \sum_1^6 N_i * CF_i * WM_{H,M,L} * WR_{H,M,L}$

The final outcome is the new Pressure Parameter for any saltmarsh, reported in the last column of Table 10.

Saltmarsh code	Area_1990 (ha)	Pss_Par	Fitted erosion rate 2006-1990	Observed erosion rate 2006-1990
1	1,61	62,15	-0.28	-0.26
2	20,19	18,22	-0.02	-0.02
3	22,27	27,39	-0.03	-0.03
4	10,75	27,39	-0.05	-0.03
5	4,04	18,22	-0.07	-0.12
6	0,78	27,39	-0.28	-0.42
7	0,88	18,22	-0.20	-0.35
10	10,26	18,22	-0.04	-0.10
11	2,52	18,22	-0.10	-0.22
12	3,12	18,22	-0.09	-0.09

⁷ The Froude Value (Fr), from the British hydrodynamic engineer William Froude, in its simplest formula is given by: $Fr = S/\sqrt{L}$, where *S* = boat speed, and *L* = boat length.

13	3,75	18,22	-0,08	-0,02
14	0,58	18,22	-0,27	-0,10
15	0,47	18,22	-0,31	-0,17
16	1,17	18,22	-0,17	-0,09
17	0,96	37,08	-0,29	-0,35
18	2,01	18,22	-0,12	-0,07
20	0,62	18,22	-0,26	-0,19
21	3,58	19,34	-0,08	-0,16
22	1,52	19,98	-0,15	-0,26
23	2,82	38,20	-0,14	-0,12
25	3,11	18,22	-0,09	-0,19
26	2,87	18,22	-0,09	-0,18
27	0,48	18,22	-0,31	-0,23
28	1,88	18,22	-0,12	-0,07
29	2,14	18,22	-0,11	-0,23
30	10,75	18,22	-0,04	-0,01

Table A6: Independent variables data for the forecasting model, and comparison between observed and forecasted values. Source: Fontolan et alia (2012), and Our computation

Appendix 2: Private Benefits and External Costs calculation

Private benefit is the market profit generated by the nautical accommodation in ports and marinas of the Lagoon. We considered three kinds of boaters: the ones leasing a berth in the marina (48%); the ones leasing a berth in cheaper nautical shelters, such as city ports, other mooring places (43%); and passing boaters, staying just for one night in the marina/port and leaving the day after (9%). This three kinds of users show different consumption profiles. For each category, we sketched the following list of annual expenditures per single user, based on official tariffs and market prices, to the benefit of local economy:

	Cat. 1	Cat. 2	Cat. 3
Lease	4,060	2,000	-
Dockyard	1,500	750	-
Day expenditures	5,000 (=200 € x 25 days)	1,250 (=50 € x 25 days)	875 (=35 € x 25 days)

Table A7: Annual average income (€) classified for type of revenue and for category of customer

The costs aimed at providing the requested goods and services (private costs) are estimated as follows:

	Cat. 1	Cat. 2	Cat. 3
Dockyard	1,000	500	-
Day expenditures	3,250 (=130 € x 25 days)	875 (=35 € x 25 days)	525 (=21 € x 25 days)
Sunk costs (facilities)	24,472,744		

Table A8: Annual average cost (€) classified for type and for category of customer

The calculation of external costs is made in terms of cost of restoring the saltmarsh to the current state through nourishment.

We calculate an average cost of replenishment of € 500 per square meter and multiply this value for the number of square meters lost each year according to the forecasting model.

The computations of both costs and benefits repeated for different numbers of potential users (from 10 to 10,537) give a total and a unit private benefit (i. e profit) function, a total and unit external costs function identified by the following table (partially reported in Table 4):

No. of mooring places	External Costs	External Costs w/ speed-limit	Private Benefit	Unit External Costs AC_E^{Comp}	Unit External Costs w/ speed-limit $AC_E^{Sp\ lim}$	Fine for trespassed speed-limit	Unit Private Benefit AB_P
10	54,918	46,508	- 24,429,884	5,492	4,651	841.03	- 2,442,988
100	249,464	175,657	- 24,044,147	2,495	1,757	738.07	- 240,441
200	375,504	237,134	- 23,615,549	1,877	1,186	691.85	- 118,078
400	559,499	352,914	- 22,758,355	1,399	882.29	516.46	- 56,896
500	604,717	382,940	- 22,329,757	1,209	765.88	443.55	- 44,659
1,000	911,610	577,234	- 20,186,771	911.61	577.23	334.38	- 20.187
2,000	1,104,900	707,180	- 15,900,797	552.45	353.59	198.86	- 7.950
3,000	1,272,856	819,298	- 11,614,823	424.29	273.10	151.19	- 3.872
4,000	1,425,109	920,553	- 7,328,850	356.28	230.14	126.14	- 1.832
5,000	1,566,079	1,044,610	- 3,042,876	313.22	208.92	104.29	- 608.58
5,710	1,076,816	1,076,816	165	290.85	188.58	102.27	0.03
6,000	1,101,687	1,101,687	1,243,097	283.06	183.61	99.45	207.18
6,110	1,711,915	1,111,015	1,714,554	280.20	181.84	98.35	280.60
7,000	1,823,543	1,184,525	5,529,071	260.51	169.22	91.28	789.87
8,000	1,942,887	1,263,409	9,815,045	242.86	157.93	84.93	1,227
9,000	2,057,233	1,338,935	14,101,018	228.58	148.77	79.83	1,567
10,537	2,170,219	1,449,470	20,688,559	206.00	137.56	68.44	1,963

Table A9: External cost and private benefit empirical functions, absolute and average values

Finally, the cost to monitor and enforce the respect of the speed-limit is computed assuming the implementation of a video remote controlled system, with six location in strategic sites of the Lagoon, each one equipped with a supporting pole where to set two video-cameras, a sim-card to transmit data, and a PV module to give energy.

Including a software to process data, the total market price of the a system working for 10 years is € 28,190. Adding € 2,288 per year for replacement pieces in the following nine years, the total cost is € 48,782, i. e € 4,878.20 per year.

	1 st year		2 nd -10 th year	Total Cost
	Unit Cost	Units	General Costs	
Remote videocamera	250	6	-	1,500
Control videocamera	300	6	-	1,800
Sim-card	50	6	-	300
PV Module	1,500	3	-	4,500
Software	12,000	1	-	12,000
Overhead costs	1,333	6	1,400x9	20,600
Replacement cost			750x9	6,750
Other costs	90	-	138x9	1,332
Total costs				48,780

Table A10: Monitoring and speed-limit enforcement costs, total values. Source: Sinergheia and eco&eco (2012)

Appendix 3: Data set and Econometric Tests

The Data set is given by the total surface of 30 saltmarshes affected by vessels' transit wave motion erosion, registered in 1990 and in 2006 (Fontolan *et alia*, 2013):

Saltmarsh code	<i>Ero_Rt</i>	<i>Area 1990 (ha)</i>	<i>Area 2006 (ha)</i>	<i>Pss_Par</i>	<i>Pss_Par^{sp_lim}</i>	<i>Bath</i>
1	-0.26	1.61	1.19	62.15	33.57	-3.0
2	-0.02	20.19	19.87	18.22	7.77	-2.8
3	-0.03	22.27	20.96	27.39	22.19	-3.8
4	-0.03	10.75	5.81	27.39	22.19	-3.5
5	-0.12	4.04	3.57	18.22	7.77	-3.8
6	-0.42	0.78	0.45	27.39	22.19	-1.4
7	-0.35	0.88	0.57	18.22	7.77	-3.5
8	-1.00	0.34	0	18.22	7.77	-2.1
9	-0.50	0.22	0	18.22	7.77	-2.1
10	-0.10	10.26	8.22	18.22	7.77	-4.5
11	-0.22	2.52	1.40	18.22	7.77	-4.5
12	-0.09	3.12	2.63	18.22	7.77	-3.8
13	-0.02	3.75	3.66	18.22	7.77	-5.5
14	-0.10	0.58	0.52	18.22	7.77	-2.5
15	-0.17	0.47	0.39	18.22	7.77	-4.0
16	-0.09	1.17	1.06	18.22	7.77	-2.5
17	-0.35	0.96	0.62	37.08	17.97	-5.3
18	-0.07	2.01	1.87	18.22	7.77	-2.0
19	-0.50	0.13	0	18.22	7.77	-3.0
20	-0.19	0.62	0.39	18.22	7.77	-3.8
21	-0.16	3.58	2.40	19.34	8.27	-5.0
22	-0.26	1.52	0.73	19.98	10.70	-4.0
23	-0.12	2.82	2.12	38.20	18.47	-4.2
24	-0.01	1.18	1.17	118.39	64.94	-5.0
25	-0.19	3.11	2.53	18.22	7.77	-2.6
26	-0.18	2.87	1.81	18.22	7.77	-7.0
27	-0.23	0.48	0.26	18.22	7.77	-7.0
28	-0.07	1.88	1.5	18.22	7.77	-6.5
29	-0.23	2.14	1.15	18.22	7.77	-6.5
30	-0.01	10.75	10.66	18.22	7.77	-4.0

Table A11: The Data set. Source: Fontolan *et alia* (2012), Triches *et alia* (2011), and Our computations

Saltmarsh code	Forecasted year of 0.4 hectares trespassing (current)	Forecasted year of of 0.4 hectares trespassing (speed-limit)
1	2041	2065
2	Beyond 2200	Beyond 2200
3	Beyond 2200	Beyond 2200
4	Beyond 2200	Beyond 2200
5	Beyond 2200	Beyond 2200
6	2021	2025
7	2039	2073
10	Beyond 2200	Beyond 2200
11	2162	Beyond 2200
12	Beyond 2200	Beyond 2200
13	Beyond 2200	Beyond 2200
14	2010	2024
15	1998	2004
16	2065	2115
17	2027	2047
18	2128	Beyond 2200
20	2014	2030

21	Beyond 2200	Beyond 2200
22	2087	2133
23	2113	2182
25	Beyond 2200	Beyond 2200
26	2186	Beyond 2200
27	1999	2005
28	2119	Beyond 2200
29	2139	Beyond 2200
30	Beyond 2200	Beyond 2200

Table A12: Forecasted year of Carrying Capacity threshold trespassing (0.4 hectares) at the current use and with a speed-limit enforcement

We run two kinds of regressions with these data: the first one is considering a bathymetry level value:

Regressors	Coefficient	Standard Error	t	P > t	Confiance interval 95%	
log <i>Area_1990</i>	-0.67	0.11	-6.33	0.00	-0.89	-0.45
log <i>Pss_Par</i>	0.59	0.44	1.34	0.19	-0.32	1.50
log <i>Bath</i>	0.04	0.34	0.12	0.90	-0.66	0.74
<i>k</i>	-3.46	1.45	-2.38	0.03	-6.44	-0.47

	Sum of Squares	Degree of Freedom	MS
Model	20.60	3	6.87
Residual	11.99	25	0.48
Total	32.59	28	1.16

No. of obs.	29
F (2, 26)	14.32
Prob > F	0.00
R ²	0.63
Adjusted R ²	0.59
Root Mean Square Error	0.69

Table A13: Regression results, Model results, and Tests from equation [2]

Once dropped out the regressor *Bath*, we run a second and final regression, based upon equation [3]:

	Coefficient	Standard Error	t	P > t	Confiance interval 95%	
log <i>Area_1990</i>	-0.67	0.10	-6.64	0.00	-0.87	-0.46
log <i>Pss_Par</i>	0.59	0.43	1.36	0.19	-0.30	1.47
<i>k</i>	-3.39	1.31	-2.58	0.02	-6.09	-0.69

	Sum of Squares	Degree of Freedom	MS
Model	20.59	2	10.30
Residual	12.00	26	0.46
Total	32.59	28	1.16

No. of obs.	29
F (2, 26)	22.31
Prob > F	0.00
R ²	0.63
Adjusted R ²	0.60
Root Mean Square Error	0.68

Table A14: Regression results, Model results, and Tests from equation [3]

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