ECOlogical observing System in the Adriatic Sea: oceanographic observations for biodiversity

Priority Axis 3: Environment and cultural heritage

Specific Objective 3.2: Contribute to protect and restore biodiversity

D3.4.1 Report on the ecosystem services to be used for monitoring ecological processes within the Natura 2000 sites

WP3 – Design of the Ecological Observing System in the Adriatic Sea (ECOAdS)

A3.4 – Relationships between ecological status and Ecosystem Services

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CONTENTS

1. INTRODUCTION

The ECOSS project focuses on the integration of ecological and oceanographic research with conservation programs, with the aim to contribute to the improvement of the conservation status of the Adriatic Sea and the Natura 2000 sites located therein. Within this context, the concept of ecosystem services (ES), defined as the contributions of ecosystem structure and function to human well-being (Burkhard et al., 2012), assumes a great importance, by making explicit the connection between the well-being of our society and the ecosystem and its functioning. The broad set of ES provided by ecosystems is generally organized into four main categories: regulating services (the benefits obtained from the regulation of ecosystem processes), provisioning services (the products obtained from the ecosystems), cultural services (the non-material benefits people obtain from the ecosystems), and habitat/maintenance services (the importance of ecosystems to provide living space for resident and migratory species) (TEEB, 2010). Table 1 provides a comprehensive list of ES and their description, according to the classification from TEEB (2010) and adapted to marine and coastal ecosystems following Bohnke-Henrichs et al. (2013).

The knowledge on the ES provided by marine and coastal ecosystems is quite limited if compared to the terrestrial ones (Liquete et al., 2013; Townsend et al., 2018), and the Adriatic Sea makes no exception to this. Indeed, the available literature on ES in this area is limited to a qualitative assessment based on EUNIS seabed habitats (European Union Nature Information System) (Depellegrin et al., 2017), and a spatial assessment of supporting ES (Manea et al., 2019). This highlights a great knowledge gap concerning ES in the Adriatic Sea, calling for further research on this topic. A proper knowledge at the basin scale is crucial also when the management is focused on the local scale. It is not possible to manage an ecosystem locally without taking into consideration the ecological and social context in which it is situated. This is indeed stressed by the ECOSS project itself, in which the conservation of the selected Natura 2000 is faced by considering the importance of connectivity among habitats and species in coastal and offshore waters. For this reason, a multi-scale approach is adopted in this deliverable, which considers both the basin scale and the local scale.

The aim of this deliverable is to advance the knowledge on the multiple ES provided by the marine and coastal ecosystems of northern-central Adriatic Sea, and to analyze their links with underling ecological structures and processes. The objectives are threefold:

(i) to elaborate a conceptual model that represents how ES are connected with ecological structures and processes, and how they emerge from the interactions occurring between the ecosystem and society;

(ii) to provide a quantitative assessment of a subset of ES at the basin scale. Three cultural ES related to recreational activities have been selected (Table 1). This choice is based on two criteria, namely, the relevance in the Natura 2000 sites upon which the project is focused, and the manageability of the ES. With respect to the first criterion, we expect that habitat/maintenance ES and cultural ES are the most relevant in these sites. The first have been already mapped at Adriatic basin scale by Manea et al., 2019, therefore here we focus on cultural ones. With respect to the second criterion, given the overall ambition of the project to contribute to the management of the sites, we have chosen ES whose flow requires human activities ("mediated" ES *sensu* Rova and Pranovi, 2017) that can be directly addressed by management interventions;

(iii) to characterize the multiple ES provided in the Natura 2000 sites selected by the ECOSS project.

The deliverable is structured as follows:

- Section 2 presents the conceptual model that has been developed to represent how ES are generated within social-ecological systems and how they depend upon the ecological status and other variables. Based on the conceptual model, the "response goals" from an ES perspective are discussed and connected with management approaches;

- Section 3 contains the assessment of the selected ES, performed at the basin (Northern-Central Adriatic) scale. The indicators, methods and results of the assessment are presented, and connected with the conceptual model;

- Section 4 presents the assessment of the relative importance of multiple ES in the project's Natura 2000 sites, based on expert judgement.

Table 1. ES classification according to TEEB (2010) and adapted to marine and coastal (including the terrestrial part) ecosystems following Bohnke-Henrichs et al. (2013). The three ES selected for the basin scale assessment are highlighted through a grey background. The D/M column specifies which ES are "direct" (D) and "mediated" (M) (*sensu* Rova and Pranovi, 2017).

Ecosystem services			**General description**	**D/M**
Provisioning	Food	Industrial fishery	Fish and seafood extracted through industrial fishery activities	M
		Artisanal fishery	Fish and seafood extracted through artisanal fishery activities	M
		Aquaculture	Seafood from aquaculture	M
	Water		Water extracted for human use	M
	Raw materials		Extraction of materials for human use (excluding those covered by Ornamental resources ES)	M
	Genetic resources		Provision/extraction of genetic material for human use (excluding medicinal and research-related uses covered by Medicinal resources and Information for cognitive development ES)	M
	Medicinal resources		Material extracted for its ability to provide medicinal benefit	M
	Ornamental resources		Material extracted for use in decoration, handcrafts, souvenirs, etc.	M
Regulating	Air purification		Purification of air (e.g. removal of fine dust and particular matter)	D
	Climate regulation	Local climate regulation	Contribution to the maintenance of a favorable local/regional climate (e.g. through an impact on the hydrological cycle)	D
		Global climate regulation	Contribution to the maintenance of a favorable global climate through the sequestration of climate-influencing substances (e.g. carbon sequestration)	D
	Disturbance prevention/coastal protection		Contribution to the dampening of the intensity of environmental disturbances such as storm floods	D
	Regulation of water flows		Contribution to the maintenance of localized current structures	D
	Waste treatment/water purification		Mediation of waste and nutrient/pollutant loads	D
	Erosion prevention		Contribution to the prevention of coastal erosion/sediment transport processes	D

Ecosystem services			General description	D/M
	Maintaining soil fertility[1]		Soil formation and contribution to the maintenance/improvement of soil quality	D
	Pollination[1]		Contribution to plant pollination and seed dispersal	D
	Biological control		Contribution to the maintenance of natural healthy population dynamics to support ecosystem resilience through maintaining food web structure and flows	D
Habitat/ maintenance	Lifecycle maintenance		Contribution to migratory species' populations through the provision of essential habitat for reproduction and juvenile maturation (e.g. nursery function)	D
	Gene pool protection		Contribution to the maintenance of viable gene pools	D
Cultural	Recreation and tourism	Tourism	Provision of opportunities for tourist recreation linked with marine/coastal ecosystems (visiting, bathing, diving)	M
		Recreational navigation	Provision of opportunities for recreational navigation with leisure boats in marine/coastal ecosystems	M
		Recreational fishing	Provision of opportunities for recreational/sport fishing in marine/coastal ecosystems	M
	Aesthetic information		Contribution of marine/coastal ecosystems to a landscape/seascape that generates a noticeable emotional response with the individual observer	M
	Information for cognitive development		Contribution of marine/coastal ecosystems to education, research, etc.	M
	Inspiration for culture, art and design		Contribution of marine/coastal ecosystems to the existence of environmental features that inspire elements of culture, art and/or design.	M
	Spiritual experience		Contribution of marine/coastal ecosystems to formal religious experiences	M

[1] Only applicable to coastal terrestrial ecosystems

2. CONCEPTUAL MODEL

This section presents a conceptual model, developed within the activity 3.4 of the ECOSS project, which aims to represent how ecosystem services (ES) are generated within social-ecological systems, arising from the interactions and feedbacks occurring among ecosystem, society and governance system.

The conceptual model has been developed starting from two conceptual bases.

First, the viewpoint proposed by Rova and Pranovi (2017), which distinguishes between the ES that are generated directly through ecosystem functions and do not generate side-effects (*direct ES*, generally corresponding to regulating and maintenance ES), and the ES whose provision is mediated by some type of human input that can produce some side-effects on the system (*mediated ES*, generally corresponding to provisioning and cultural ES). This viewpoint makes use of a social-ecological systems perspective, highlighting both the ecological and social elements involved in ES provision, and facilitates the conceptualization of the interactions occurring among multiple ES.

Second, the distinction between the potential to provide a service (*ES capacity*) and the actual production of that service experienced by people (*ES flow*) (Villamagna et al., 2013). Especially in the case of mediated ES, this distinction is crucial to connect the use of ES, which occurs through some human activity, with the ecological structures and processes upon which it is based, and thus facilitates an analysis from a sustainability perspective.

Building upon these concepts, we propose here a conceptual model constructed as a Causal Loop Diagram (Fig. 1), which represents the causal relationships between the variables involved in the capacity, flow and management of ES. The Causal Loop Diagram graphical notation consists of variables connected by arrows (*causal links*), which denote causal influences among the variables. Each link shows a polarity, either positive or negative:

- A positive link means that a variation in the causal variable is expected to produce an effect of the same sign (increase/increase or decrease/decrease) on the affected one;
- A negative link means that a variation in the causal variable is expected to produce an effect of the opposite sign (increase/decrease or decrease/increase) on the affected one.

This notation is particularly suitable for the representation of the feedback structure of systems, which we deem crucial for understanding the dynamics of ES under different scenarios of environmental and management conditions. Important loops can be highlighted by a loop identifier, which shows whether the feedback is positive (self-reinforcing) or negative (balancing).

The whole conceptual model is shown in Figure 1, along with a description of all the model variables (Table 2).

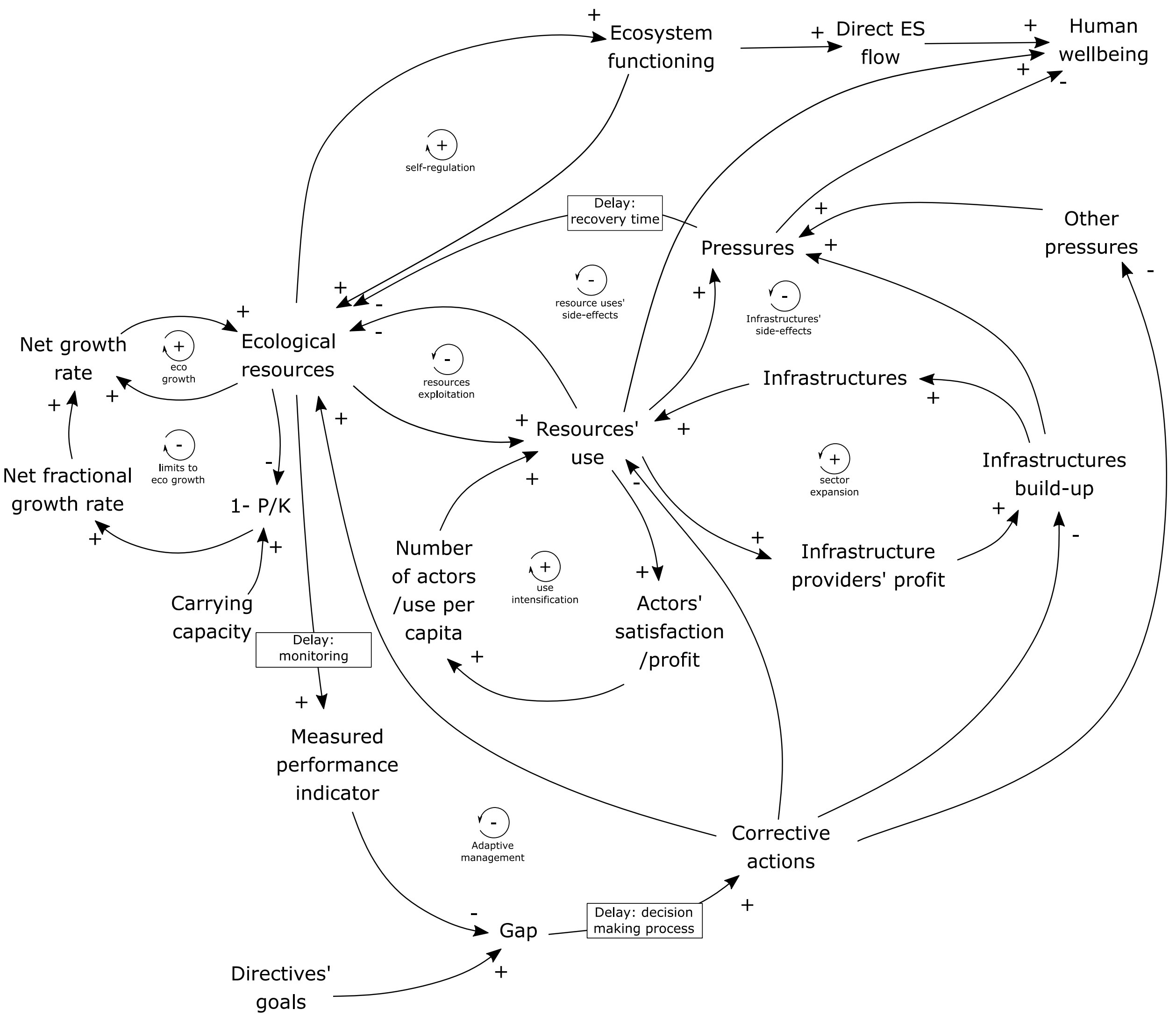

Figure 1. Conceptual model representing the generation of ES in socio-ecological systems. The model is developed as a Causal Loop Diagram, in which arrows denote causal links between variables. A positive link between two variables X and Y means that if X increases, Y is expected to increase (and vice versa); a negative link between two variables X and Y means that if X increases, Y is expected to decrease (and vice versa).

Table 2. List of variables and descriptions (in alphabetic order).

Variable name	Description
Endogenous variables	
Actors' satisfaction/profit	The well-being of the users deriving from the resource use, measured either in monetary terms or in terms of satisfaction
Carrying capacity	Amount of ecological resources that can be sustained by the ecosystem
Corrective actions	Management interventions to fulfill the EU directives
Direct ES flow	Actual 'use' of direct ES (e.g. reduction of nutrients loads, reduction of exposure to natural hazards)
Ecological resources	Ecological structures and processes of the ecosystem (e.g. surface of a certain habitat; abundance of a certain species or group of species, water circulation)
Ecosystem functioning	Energy, matter and information flows and storage within the ecosystem. The capacity of direct ES (e.g. ecological processes such as pollutants/nutrient retention, accumulation of organic carbon, the capacity of habitats to reduce the severity of storm floods, etc.) is part of the ecosystem functioning
Gap	Difference between the directives' goals and the measured performance indicators
Human well-being	A state characterized by availability of basic materials for a good life, health, good social relations, security and freedom of choice and action (after Millennium Ecosystem Assessment, 2005)
Infrastructures	Infrastructures, services and other factors involved in the resources' use (e.g. tourist infrastructures, aquaculture farms)
Infrastructures' build-up	Rate at which infrastructures are built up
Infrastructures providers' profit	Profit of the firms involved in infrastructures. Please note that in some cases this may correspond to the profit of resource users, e.g. in the case of the aquaculture.
Measured performance indicator	Indicators of environmental status whose measurement is prescribed by EU directives (e.g. indicators of MSFD descriptors)
Net fractional growth rate	Net growth rate per unit of ecological resource. $Net\ fractional\ growth\ rate = r\left(1-\frac{P}{K}\right)$, where r= intrinsic rate of increase, K=carrying capacity, P=population of ecological resource
Net growth rate	Rate of change of the ecological resource (derivative of the ecological resources with respect to time). $Net\ growth\ rate = r\left(1-\frac{P}{K}\right)P$, where r= intrinsic rate of increase, K=carrying capacity, P=population of ecological resource
Number of actors / use per capita	N. of actors (stakeholders) involved in the resources' use (e.g. n. of fishermen, n. of tourists), and/or the rate of use per capita (e.g. hours of fishing per capita, frequency of visits per capita)
Pressures	Anthropogenic or natural pressures that alter the state variables (e.g. nutrient loads, emissions of climate-influencing substances, land use change)
1- P/K	Normalized distance between the carrying capacity and current amount of ecological resources

Variable name	Description
Resources' use	The use of ecological resources, corresponding to the flow of mediated ES. The use can occur through the physical removal of resources from the ecosystem (e.g. fish catches) or through the experiential use of resources (e.g. tourist visits).
Exogenous variables	
Directives' goals	Environmental targets prescribed by the EU directives (e.g. good environmental status for MSFD descriptors).
Other pressures	Other pressures insisting on the ecosystem, which are not resulting from the modeled processes/activities (e.g. nutrients and pollutants loads from other areas, extreme events).

To explain the rationale behind the model structure, the following sections provide a step-by-step description of the four main model components: first the sub-model representing direct ES; second the one representing mediated ES; third, the one representing the generation of ecological resources, and fourth, the one representing ecosystem monitoring and management.

2.1. Direct ES submodel

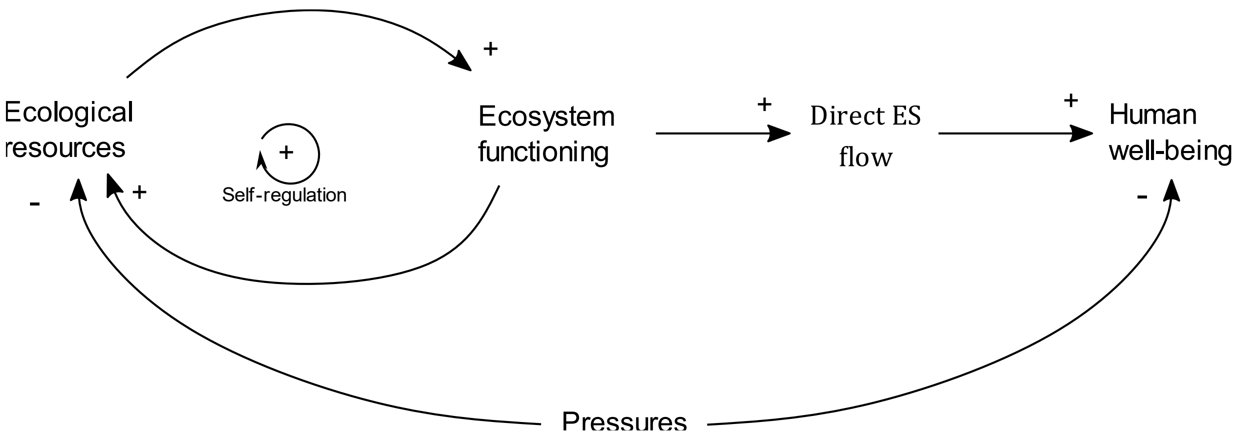

Figure 2. Submodel representing direct ES

The ecological resources (e.g. the mosaic of habitats and the community living therein), altogether, make up an ecosystem with certain functional properties (*ecosystem functioning*, e.g. energy flow and matter cycling). This functioning regulates the ecosystem and determines its resilience (self-regulation loop) (Figure 2). Some of these functions correspond to the potential of the ecosystem to provide ES (*ES* *capacity*, e.g. attenuation of extreme events), which is expressed as an ES flow when/where human well-being is or can be threatened by anthropogenic and natural pressures (e.g. settlements exposed to extreme events). Pressures can also negatively affect the ecosystem. Within certain threshold levels, these negative effects can be offset by the ecosystem self-regulation capacity.

2.2. Mediated ES submodel

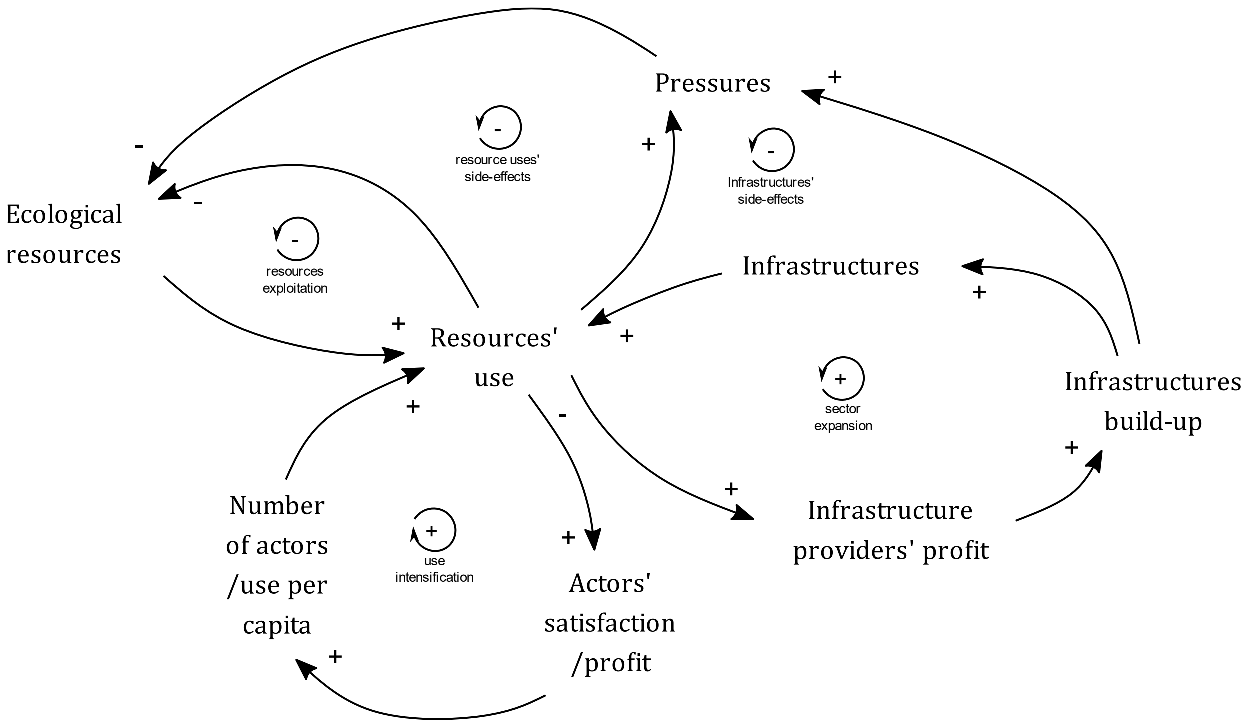

Figure 3. Submodel representing mediated ES.

The use of resources (e.g. fishing yield) depends on the state of ecological resources (e.g. a fish stock) and can impact the resources in two ways: directly, through the removal of units of the exploited resources (resources exploitation loop); and indirectly, by creating pressures that in turn negatively affect the ecological resources (resources uses' side effects loop) (Figure 3). Depending on the ES, these loops can be active or not, stronger or weaker. For the ES that involve the physical extraction of resources from the ecosystem (e.g. fishing) the resources exploitation loop is always occurring, whereas the resources uses' side effects loop is relevant only if the resource use produces negative side effects on the ecosystem (e.g. fishing with gears that damage the seafloor, overexploitation of the resources). For the ES that occur through the experiential use of the ecosystem (e.g. recreational fruition of the landscape) the resources exploitation loop is generally not active (resources are not consumed by the use) but the resources uses' side effects loop can be active if the resource use produces pressures on the ecosystem (e.g. if visiting damages the ecosystem).

The increasing use of resources increases the profit/satisfaction of the actors involved, which in turn attracts new actors or increases the per capita use (use intensification loop) (e.g. the more I catch the more I fish, or, if I visit a beautiful place I will return more often or suggest it to others).

For some ES, the resource use is not only dependent on the amount of ecological resources and on the number of actors/per capita use, but it may also depend on other inputs, here called infrastructures. Let us make two examples in which this is the case: (i) recreational ES, where the visitation rate depends also on the presence of infrastructures (e.g. roads, parking, food and accommodation facilities) that facilitate the arrival of visitors, and (ii) aquaculture ES, where the seafood production requires that the ecological resources (the suitable environmental conditions) are present and that aquaculture farms are installed. The dynamics of infrastructures also follows a positive feedback (sector expansion loop) whereby the greater the resource use, the greater the infrastructure build-up. However, the infrastructures' build-up does not come at any cost. In many cases, in fact, an increase in infrastructures produces pressures that have negative effects on the ecological resources (infrastructures' side effects loop, e.g. land use change).

Furthermore, the presence of infrastructures may weaken the coupling between the state of the ecological resources and their use, as it may allow the resource use to increase even when the ecological resources are declining.

Please note that in this case the ES capacity corresponds to the amount of ecological resources, whereas the flow corresponds to the resources' use.

2.3. Submodel representing the generation of ecological resources

The generation of ecological resources follows the typical CLD structure of an S-shaped growth (logistic growth in ecology, Figure 4), in which two feedbacks occur jointly: on the one hand, the positive feedback between the population size and its net growth rate (growth loop), whereby the greater the population of ecological resources, the higher the net growth rate. This loop dominates the initial phases of the growth, in which the carrying capacity is distant and the population grows nearly exponentially. On the other hand, the logistic growth is characterized by the presence of a balancing feedback related to the approaching of the carrying capacity (limits to growth loop), due to the presence of limited energy amount: the greater the population of ecological resources, the smaller the distance to the carrying capacity (1-P/K), and the smaller the growth rate per unit of ecological resource (net fractional growth rate), which in turns implies a smaller net growth rate. This loop becomes stronger and stronger as the carrying capacity is approached, becoming dominant in the later phases of the population growth.

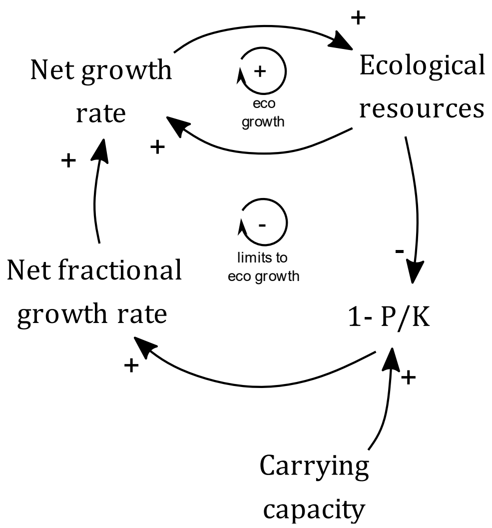

Figure 4. Submodel representing the generation of ecological resources

2.4. Ecosystem monitoring and management submodel

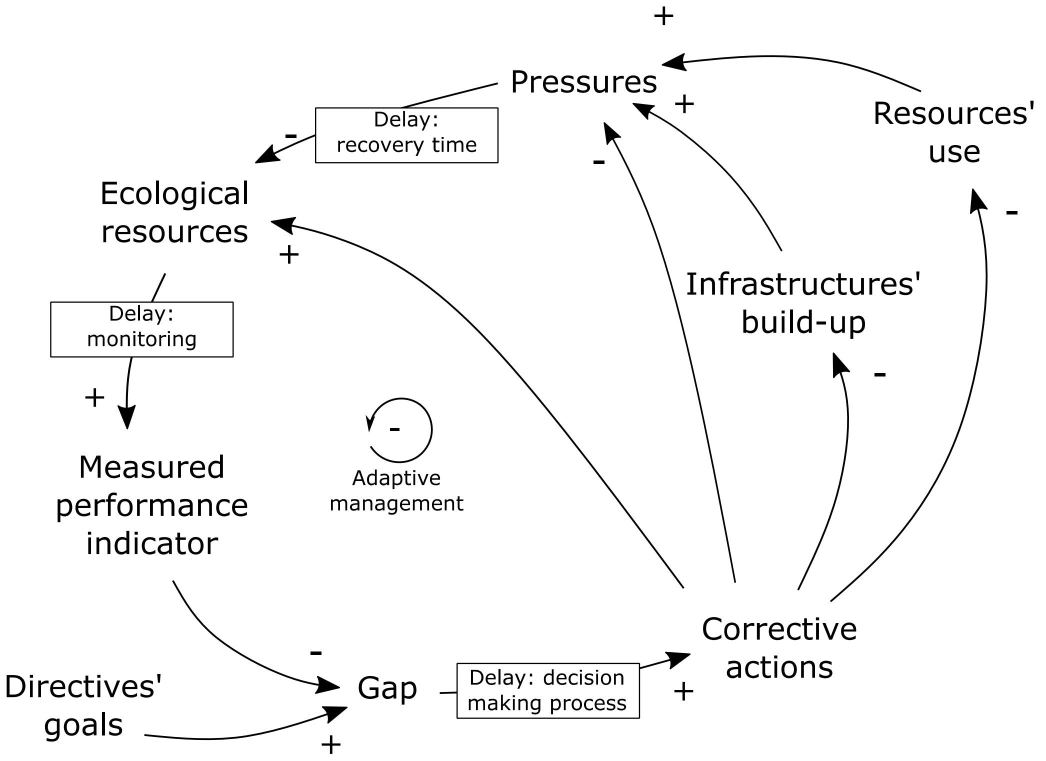

Figure 5. Submodel representing ecosystem monitoring and management

Monitoring of ecological resources can allow the measuring of a set of performance indicators, prescribed by EU directives, whenever present (Figure 5). The better the state of ecological resources, the better the measured performance indicators. The management evaluation is based on the comparison between the goal prescribed by the Directives and the actual condition. If a gap is identified, then corrective actions are put in place, which either conserve/restore the ecological resources, or reduce the resources' use, the build-up of infrastructures or other pressures. This pressures reduction has positive effects on the ecological resources, which will be again monitored, and so on. This whole process is a negative "goal-seeking" feedback (adaptive management loop) whereby the ecosystem should reach an overall desirable condition while the socio-economic development continues to be supported. However, there is a series of delays that threaten the effectiveness of this loop. First, a delay between the change in state of the ecological resources and the measurement of this change through monitoring activities, mainly dependent on the frequency with which monitoring takes place and/or possible threshold effect on the ecological side. Second, and probably most importantly, a delay between the appraisal of the gap and the implementation of corrective actions, that is related to the complexity of the decision making process, which entails the choice between alternative actions and has to take into account factors not directly related with the implementation of EU environmental directives (e.g. political influences and other socio-economic factors). Finally, a delay between the reduction of pressures and the improvement in the state of ecological resources, depending on different degrees of resilience of the ecosystem. These delays can weaken (or in some cases neutralize) the effectiveness of the adaptive management process in reaching the goals of EU Directives.

It is worthy to note that an ecosystem provides, at the same time, a broad set of multiple ES, of which the conceptual model attempts to provide a synthetic representation. All the ES listed in Table 1 could be potentially provided by a single ecosystem, which means several direct ES with the submodel structure of section 2.1, and several mediated ES with the submodel structure of section 2.2. All of them interact with each other, generating a very complex network of feedbacks, which represent, although in a very simplified way, the complexity of the interactions occurring in a real social-ecological system.

2.5. Monitoring, management targets and management strategies from an ecosystem services' perspective

Based on the conceptual scheme presented above, how can ES help improve the management process? Which variables should be measured, and which should be the "response goals" and the targets?

2.5.1. Monitoring

Monitoring should include the assessment of indicators of ES capacity and flow over space and time, to characterize the potential of the ecosystem, the current uses and benefits obtained.

Monitoring the capacity of direct ES requires choosing indicators that reflect functional aspects of the ecosystem, connected with ES provision. Just to make few examples, these include the sequestration of CO2, the dissipation of energy, the nursery role of habitats. Clearly, these are not easy variables to monitor as they require in many cases physical and ecological models to be assessed, as exemplified by Liquete et al. (2016). However, keeping in mind their functional value, they can be assessed using more easily quantifiable proxies, such as habitats' distribution and associated environmental parameters.

On the other side, as highlighted by Villamagna et al. (2013) the flow can be evaluated as the negative effects of pressures that are prevented thanks to the ES capacity. Again, this is not an easy task. For some ES it can be done by applying proxy methods widely accepted in literature (e.g. Arkema et al., 2013; Paracchini et al., 2014), for other ES it requires complex modelling tasks (e.g. water purification in Liquete et al., 2016). From our perspective, although the assessment of direct ES flow is useful to show the benefits for human wellbeing, the monitoring of capacity is of greater importance as it reflects the underpinning ecological functioning and should be thus given a priority.

Concerning mediated ES, defining and assessing capacity indicators for mediated ES requires understanding and quantifying the connection between the uses of the ecosystem and the ecosystem variables upon which these uses depend. The flow instead is a “simpler” measure of the uses/outputs (fish harvested, visitation rate, etc.).

2.5.2. Targets

The overall response goal should be a healthy marine ecosystem that delivers ES to people now and in the future. From this perspective, the key “performance indicators” are indicators of ES capacity. The management target here suggested is based on a temporal approach: avoiding the decline of ES capacity over time. Preserving the ES capacity means in fact to preserve the current and future delivery of them.

Looking at direct ES, the capacity can be seen as our insurance against environmental pressures, ranging from CO2 accumulation in the atmosphere to water pollution and natural hazards. An insurance that includes not only the current flow of these direct ES, that contributes to preserve human wellbeing in the face of current (known) environmental pressures, but also (and most importantly) the resilience of the ecosystem and its ES in the face of known and unknown pressures. For this reason, management should target at preserving the ES capacity, regardless of whether it is currently expressed as an ES flow or not, because the capacity allows to project the management results to the future.

Concerning mediated ES, the capacity corresponds to the stock of ecological resources that sustain our uses of the ecosystem. These range from the fish stocks exploited by fishing activities to the features of the ecosystem which are enjoyed through different cultural ES. Also in this case it is crucial to target the maintenance of the ES capacity instead of the flow, for two reasons, highlighted by the conceptual model: first, the resources’ use can produce negative effects which may undermine future uses and other ES, and second, because other inputs (“infrastructures” in the model) can decouple the trend of the uses from the trend of the resources exploited. Targeting the ES capacity thus allows overcoming these limitations and focusing on a sustainable provision of ES, in which ES are maintained in the long run.

2.5.3. Management

Looking at EU directives, such as the Water Framework Directive (WFD) (2000/60/EC) and the Marine Strategy Framework Directive (MSFD) (2008/58/EC), a major challenge is moving from monitoring to implementation. These directives in fact require the achievement of a good ecological status, but do not provide clues on how to get there. The result is that, taking for example the WFD, by 2015 the good status has not been achieved in about half of EU surface waters (Voulvoulis et al., 2017). Looking at the conceptual model, this challenge is represented by the decision-making process delay, which highlights the difficulties of moving from the appraisal of the gap to the choice and implementation of corrective actions.

At least from a theoretical point of view, we believe that the approach we are proposing can contribute to overcome those difficulties, making the adaptive management process more effective. First, the analysis of the social-ecological system through the lens of the conceptual model facilitates the understanding of key interactions occurring between ecosystem and society; second, it underlines the importance of monitoring the ES capacity and flow over space and time, through indicators that represent functional aspects of the ecosystem and the benefits they deliver; third, it can contribute to identify the pressures that are outside the ecosystem's tolerance range. In other words, it facilitates the recognition of the causes that drive the system away from the desired state. This recognition, along with the understanding of the underlying ecological mechanisms, leads to the correct response. These pressures, including those deriving from the flow of mediated ES, should be mitigated to the point that the self-regulation capacity of the ecosystem and the generation of ecological resources (self-regulation loop and eco growth loop) can offset them. This could reduce the delay related with the decision-making process, by facilitating the choice of the appropriate correcting actions.

3. ECOSYSTEM SERVICES ASSESSMENT AT BASIN SCALE

In this section we present the assessment of three selected cultural ES: tourism, recreational navigation and recreational fishing (**Table 3**). These ES have been selected because, along with habitat/maintenance ES, which have been already assessed by Manea et al. (2019), they are likely to be among the most relevant ES in the project Natura 2000 sites and, more in general, in the whole Adriatic coastal areas. Furthermore, given the overall ambition of the project to contribute to the management of the sites, we have chosen to focus on mediated ES, whose flow can be directly addressed by management measures.

The assessment is structured following a capacity-flow approach, whereby the capacity refers to the potential to provide an ES and the flow to its actual production/use (Villamagna et al., 2013). Therefore, specific indicators have been defined and assessed for both the capacity and flow of each service (**Table 3**).

Table 3. ES included in the assessment and indicators.

ES	Description	Capacity indicator	Flow indicator
Tourism	Provision of opportunities for tourist recreation linked with marine/coastal ecosystems (visiting, bathing, diving)	Attractiveness of marine/coastal ecosystems to visitors	Number of visitors/km2/year
Recreational navigation	Provision of opportunities for recreational navigation with leisure boats in marine/coastal ecosystems	Attractiveness of marine/coastal ecosystems to boaters	Number of boat trips/km2/year
Recreational fishing	Provision of opportunities for recreational/sport fishing in marine/coastal ecosystems	Estimated biomass of target fish species	Catches (ton/year)

The assessment of these three ES has been performed at the basin scale. In fact, dealing with the capacity and flow of ES requires to adopt a spatial scale that embraces the whole basin, as the relationships between the two cannot be captured by looking at small-scale sites separately and in isolation from their ecological context. Therefore, in the perspective of contributing to the ecosystem-based management of the Adriatic Sea and of the Natura 2000 sites located therein, the assessment has been carried out considering the whole Northern-Central Adriatic Sea and the corresponding coastal area (Figure 6). In administrative terms, the study area includes the coastal and marine portion of Adriatic Croatia, and of the Italian regions of Friuli-Venezia-Giulia, Veneto, Emilia-Romagna and Marche. The reference year of the assessment is 2018.

The methods and results of each of the three ES are presented in Sections 3.1, 3.2 and 3.3, respectively, whereas a joint discussion is included in section 3.4.

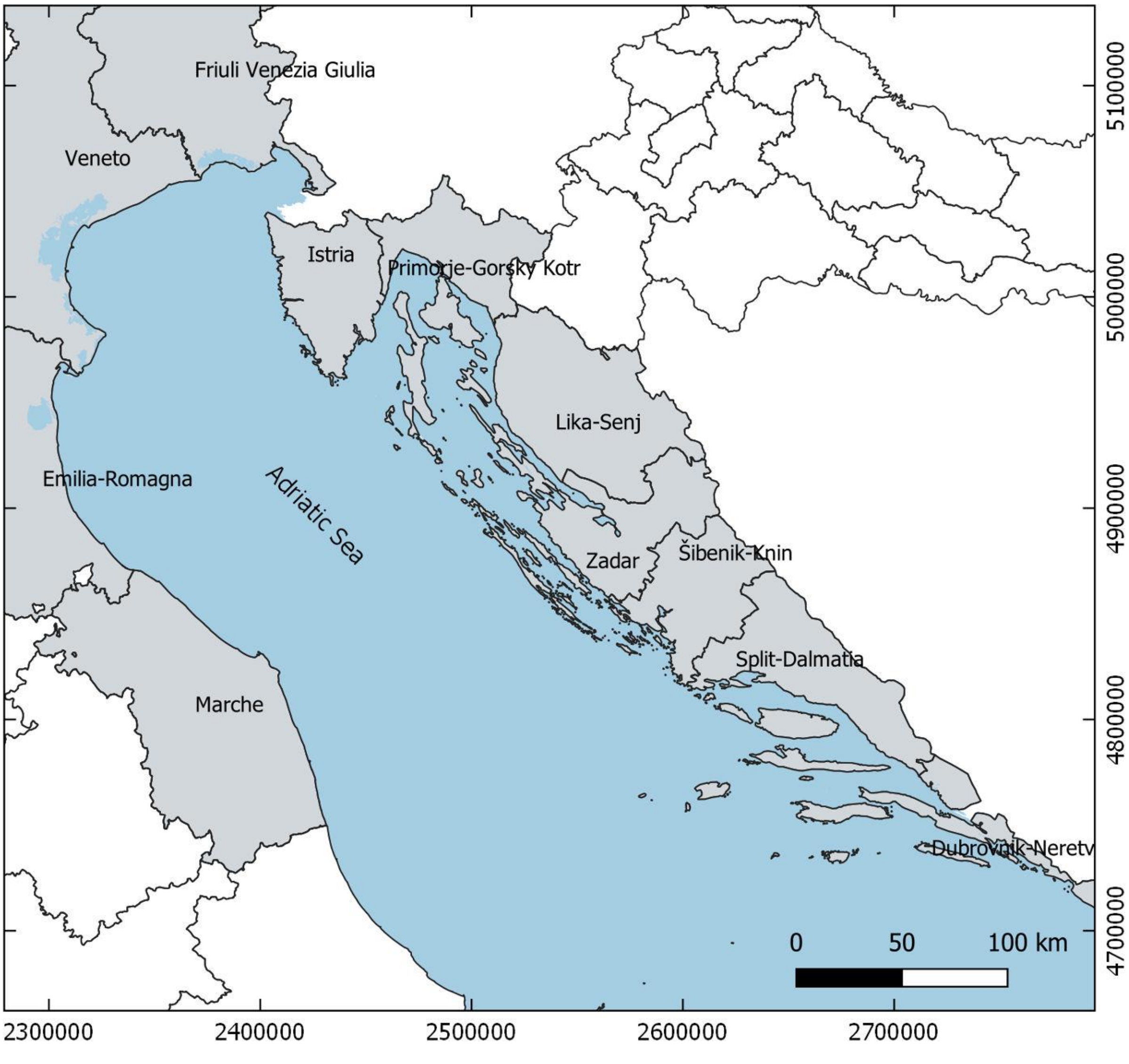

Figure 6. Study area of the ES assessment, that includes the marine and coastal areas of the Regions/Counties indicated in grey.

3.1. Tourism

This ES refers to the provision of opportunities for tourist recreation linked with marine and coastal ecosystems, such as visiting, bathing, diving, etc. Seaside tourism is a very developed sector in the study area, being one of its main economic drivers. By looking at these activities from an ES perspective, and especially doing so by adopting a capacity/flow approach, we attempt to analyze and quantify the linkages between these activities and the marine and coastal ecosystem.

3.1.1. Methodology of the capacity assessment

The indicator chosen to represent the capacity of this ES is the attractiveness of marine and coastal ecosystem, as perceived by the visitors of the coastal areas.

This indicator has been estimated through a survey addressed to the visitors of the northern-central Adriatic coast, conducted during the second semester of 2019. A specific questionnaire has been developed and administered to the visitors through both face-to-face interviews and self-administration. The latter has occurred in a variety of ways, which include mailing lists, posters and fliers displayed in tourist information offices and public places (hotels, restaurants, beach resorts, etc.), publication in websites and Facebook pages of tourism operators, and posts in social networks. In order to facilitate the distribution, the questionnaire has been prepared in 5 languages (Italian, Croatian, English, German and French) and a webpage has been created (link) where the questionnaires were made available to the public in the different languages.

The key aspect investigated is the relative importance attributed by the visitors to different factors of attractiveness. This is addressed in two questionnaire's sections: (i) a first one asking for the relative importance attributed to the natural environment with respect to other general factors, namely, cultural heritage, food and wine, tourist infrastructures and events, and (ii) a second part asking for the relative importance of different factors connected with the state and functioning of the coastal and marine ecosystem, namely, water quality, natural terrestrial habitats, marine habitats and fauna, cetaceans and protected areas. In both cases, the respondent could indicate the importance on a scale from not important to very important, and could specify other relevant factors of attractiveness not included in the list. Furthermore, the questionnaires ask for general information about the visiting trip (day-trip/overnight stay, place and duration of the stay, participation to naturalistic activities) and general data of the respondent (age, sex, place of residence, education).

The responses concerning the factors of attractiveness were coded on a 0-1 scale, where 0=not important and 1=very important, and then averaged for each factor, obtaining a coefficient that expresses the relative importance of each factor of attractiveness.

In order to map how the attractiveness varies within the study area, each factor related to the attractiveness of the ecosystem was mapped according to the methodology described in Table 4. The resulting maps were then aggregated through a weighted sum, the weights corresponding to the coefficients obtained from the questionnaires. The resulting map, normalized on a 0-1 scale, is used to represent the attractiveness of marine-coastal ecosystem to visitors.

3.1.2. Methodology of the flow assessment

The indicator used to represent the flow of this ES is the number of visitors per year in the coastal area.

This indicator has been quantified using official statistics of tourist arrivals (n. of visitors staying overnight) relative to the year 2018. Concerning the Italian coast, data at the municipality level were retrieved from the Italian National Institute of Statistics (ISTAT), and include all the coastal municipalities in the regions Friuli-Venezia-Giulia, Veneto, Emilia-Romagna and Marche. Concerning the Croatian coast, data at the county level was retrieved from the Croatian Bureau of Statistics and include all the coastal counties of Adriatic Croatia (Primorje-Gorski kotar, Lika-Senj, Zadar, Šibenik-Knin, Split-Dalmatia, Istra and Dubrovnik-Neretva).

In order to be comparable among areas of different extent, the indicator has been mapped as number of visitors/year/km^2, where the surface considered has been calculated differently for Italy and Croatia, due to the different input data used. For Italy, the surface of each municipality has been used. For Croatia, although the data provided is relative to the coastal counties, it has been assumed that tourists are mainly located in the coastal part of these counties, corresponding to the coastal municipalities. Therefore, the surface of all the coastal municipalities within each county has been used to calculate the mapped indicator.

Finally, it is important to highlight that the number of tourist arrivals is very likely to be an underestimate of the number of visitors, as a relevant number of day-trippers visit the area without staying overnight. The quantification of day-trippers is a very complex task because these visitors are not directly captured by any statistics. We have made an attempt to provide an estimate of this phenomena by merging different sources of information: (i) available literature on this subject, (ii) interviews to beach resorts owners, tourist information offices and consortia of tourist operators located along the coast of Veneto and Friuli-Venezia Giulia, made in late summer/autumn 2019, and (iii) the composition of our survey's sample in terms of overnight stays and day-trippers.

Table 4. Methods used for mapping the factors of environmental attractiveness, and data sources.

Factor of environmental attractiveness	Mapping method and data sources	Scale
Water quality	Trophic Index (TRIX, Vollenweider et al., 1998) modelled for the Adriatic Sea by Fiori et al. (2016)	0-1 scale, where 0=bad, 0.33= mediocre, 0.66=good and 1=elevate trophic state according to the reference values from Rinaldi and Giovanardi (2011)
Presence of natural terrestrial habitats	Proportion of natural habitats within segments of coast approx. 10 km long and 10 km wide. Natural habitats have been extracted from Corine Land Cover 2018 (CLC[2]), corresponding the following land-cover types: all forest types (CLC code 31*); all scrub and/or herbaceous vegetation associations (CLC code 32*); among open spaces with little or no vegetation (CLC code 33*), the classes beaches dunes and sand, and sparsely vegetated areas (CLC codes 331 and 332 respectively); all wetlands, both inland and marine (CLC code 4**).	0-1 scale, corresponding to the ratio between the surface of natural habitats and the surface of the coastal segment.
Presence of marine habitats and fauna	Distribution of *Posidonia oceanica* from habitat suitability model (retrieved from EMODnet[3]). This species has been chosen to represent this factor of attractiveness because it constitutes one of the most important shallow habitats in the Mediterranean Sea, associated with high biodiversity and high environmental quality.	Presence/absence (0/1) of the meadows, obtained from the modelled probability of presence using a 0.5 cutoff
Opportunity to watch cetaceans	Distribution of bottlenose dolphins, one of the most common species of cetaceans in the study area, based on aerial surveys (Fortuna et al., 2018).	Presence/absence (0/1), where 1 corresponds to the areas with predicted density above average, as identified by (Fortuna et al., 2018)
Presence of protected or valuable natural areas	Marine protected areas, Ramsar sites and Natura2000 sites, retrieved from MAPAMed[4], and a marine site of community importance currently being established for the protection of dolphins and sea turtles, facing the coast of Veneto and Emilia Romagna[5]	Presence/absence (0/1)

[2] Copernicus Land Monitoring Service, https://land.copernicus.eu/pan-european/corine-land-cover
[3] European Marine Observation and Data Network, https://www.emodnet.eu/emodnet-maps-catalogue
[4] MArine Protected Areas in the MEDiterranean, https://www.mapamed.org/
[5] http://ambiente.regione.emilia-romagna.it/it/notizie/attualita/2019/febbraio/accordo-tra-le-tre-regioni-del-distretto-alto-adriatico-per-unarea-marina-a-tutela-di-delfini-e-tartarughe

3.1.3. Results of the capacity assessment

A total of 424 compiled questionnaires have been collected. The respondents are 58% male and 42% female, with the age-class distribution shown in Figure 7. The majority has completed upper secondary and higher education (43% and 38%, respectively), while the remaining 17% and 1% have completed lower secondary and primary education, respectively. Among those who have provided their place of residence, the greater share are Italians and Germans (58% and 19%, respectively), 5% are Croatians, 13% from other EU countries and 5% from non-EU countries. Among Italians, most respondents are from Veneto (61%), followed by Lombardia (18%), Emilia-Romagna (11%), Piemonte (4%), and Friuli-Venezia Giulia (4%).

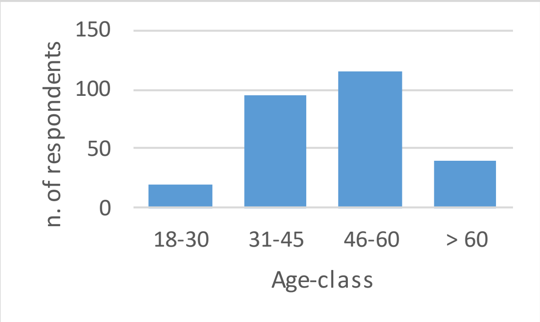

Figure 7. Age-class distribution of the visitors who have taken part to the survey

The geographical area covered by the survey comprises both the northern-central Italian coast (83% of the sample) and the Croatian coast (17% of the sample). Concerning Italy, the sampling has been mainly focused on tourist areas situated along the coast of Veneto region (which sum up to 93% of the Italian sample). The rationale of this focus are both the very high tourist fluxes that characterize this coastal area and logistic reasons related to the questionnaires administration. The distribution of the sample has been designed to be representative of this region, with a relative distribution approximately in line with the distribution of tourist arrivals (Figure 8). The other regions covered are Emilia-Romagna, Friuli-Venezia Giulia and Marche (5%, 2% and 1% of the Italian sample, respectively). Concerning Croatia, most of the questionnaires derive from the counties of Split-Dalmatia and Dubrovnik-Neretva (50% and 42% of the Croatian sample, respectively). Most of the visitors have been reached through face-to-face interviews (63%) or word-of-mouth (19%), the remaining through flier, tourist information offices, social media and mailing list (7%, 5%, 4%, and 2%, respectively).

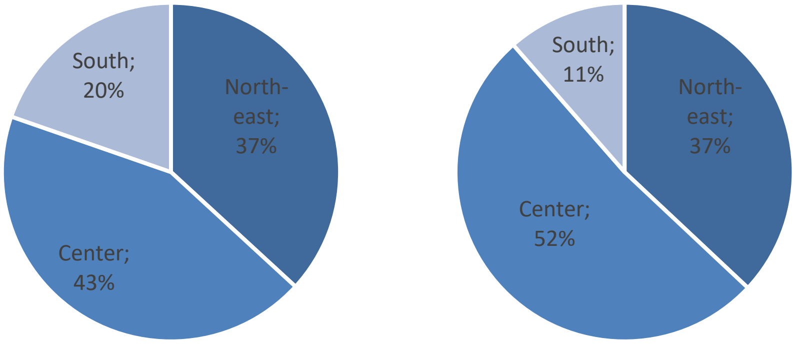

Figure 8. Relative distribution of the questionnaires collected (left) and of tourist arrivals in 2018 (right), in the coastal municipalities of the Veneto region. Municipalities have been grouped as north-eastern portion (munucipalities of Caorle, San Michele al Tagliamento, Eraclea), central portion (municipalities of Jesolo and Cavallino) and southern portion (municipalities of Chioggia, Rosolina, Porto Tolle, Porto Viro and Ariano Polesine) of the coast. The arrivals in the municipality of Venice have been exluded from the computation not being directly connected with the Adriatic Sea.

The first result that emerges from the analysis of the questionnaires is the relative importance of the general factors of attractiveness (Figure 9). According to the preferences expressed by the interviewed visitors, all the factors have, on average, a medium-high score (corresponding to moderately important or higher), except ‘events’, which has a lower score. This suggests that all of them, together, concur to determine the overall attractiveness of a coastal area. Among them, the natural environment appears to be the factor with the highest score, highlighting the key role played by marine and coastal ecosystems in attracting visitors to our coastal areas, and confirming that seaside tourism can be indeed considered an expression of a service provided by the ecosystem.

Focusing on the natural environment, the relative importance of different factors connected with the marine and coastal ecosystems is shown in Figure 9. Water quality and natural terrestrial habitats have been attributed a higher importance, followed by protected areas, marine habitats and fauna and cetaceans. Other factors mentioned include quality of air, the cleanliness of the area and the warmth of the locals, each mentioned by about 1% of the interviewed. By combining this information with the spatial distribution of the environmental factors of attractiveness, mapped as specified in Table 4, we obtained the map of natural attractiveness shown in Figure 10. This map depicts the capacity of this ES, that is the contribution of the ecosystem to the overall tourist attractiveness. The overall attractiveness, whose mapping is out of scope in this study, will result from the interplay between the environmental and the other general factors of attractiveness.

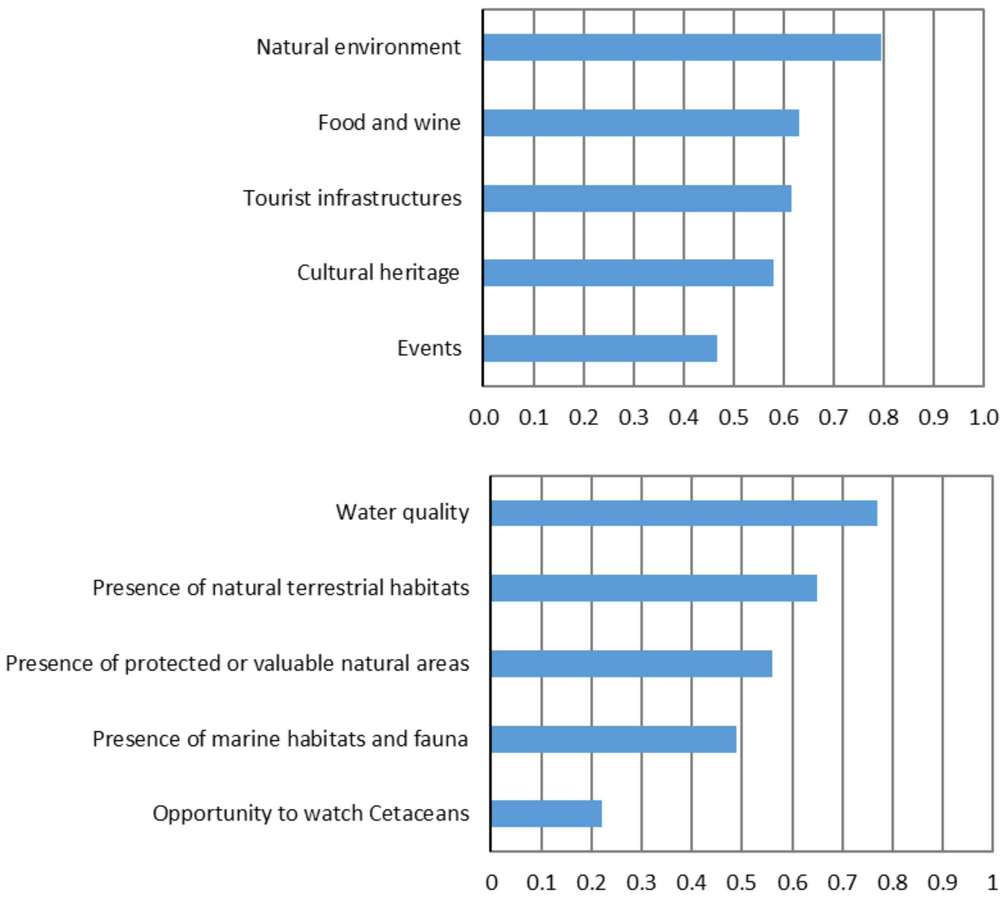

Figure 9. Relative importance attributed by visitors to general factors of attractiveness (top) and to factors of attractiveness related to marine and coastal ecosystems (bottom), expressed on a 0-1 scale where 0=not important, and 1=very important.

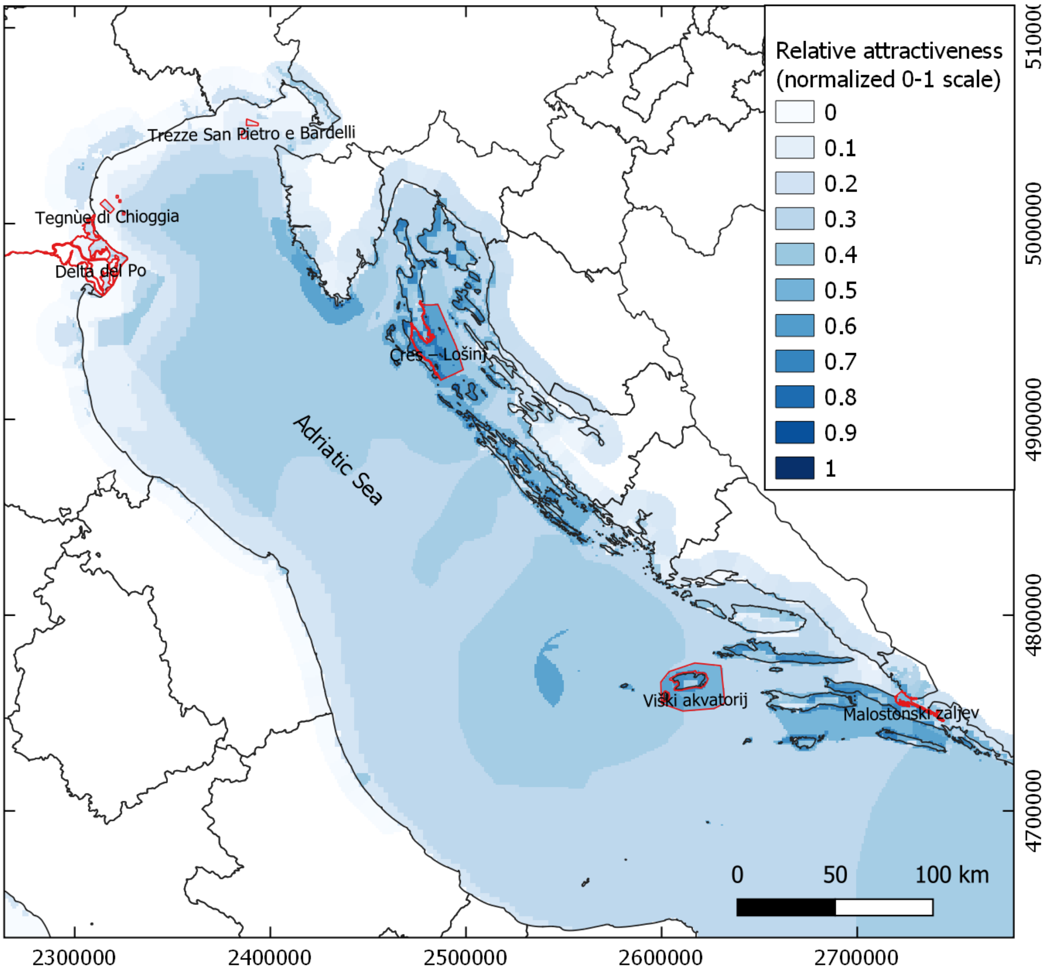

Figure 10. Capacity of the tourism ES, corresponding to the relative attractiveness of marine and coastal ecosystems of northern-central Adriatic Sea, as perceived by the visitors of the coastal areas, expressed on a normalized 0-1 scale. The location of the Natura 2000 sites selected by the project is also indicated.

3.1.4. Results of the flow assessment

The number of tourist arrivals in the coastal municipalities in the regions Friuli-Venezia Giulia, Veneto, Emilia-Romagna and Marche (data from ISTAT, year 2018) are shown in Table 5, whereas those referred to the counties of Adriatic Croatia (data from Croatian Bureau of Statistics, year 2018) are shown in Table 6. Figure 11 maps the number of visitors per square Km for the whole study area.

Concerning the estimate of day-trippers, the information collected is the following:

- The stakeholders that have been interviewed (beach resorts owners, tourist information offices and consortia of tourist operators) have been asked for an estimate of the fraction of visitors paying a daily entrance vs. the total number of visitors that access the resorts. The rationale being that it is more likely that tourists that are staying overnight will pay an entrance pass valid for more days, whereas day-trippers will pay for a single-day entrance. The interviews revealed a fraction of daily entrances ranging between 30% and 80% of the total entrances in the beach resorts, with an average of about 55%.
- A report covering seaside tourism in Italy (CISET, 2011) highlights the use of beach resorts by non-registered excursionists, corresponding to about 30% of total users.
- The composition of our survey's sample consists of about 75% overnight stays and 25% day-trippers.

Considering these data, and applying a conservative approach, we estimate that day-trippers could correspond to about 1/3 of the total visitors, whereas visitors registered as tourist arrivals could correspond to the remaining 2/3. By applying these ratios to the tourist arrivals statistics in the Italian municipalities located along the northern Adriatic coast, we provide an estimate of the potential number of day-trippers and total visitors in the Italian portion of the study area (Table 5). Please note that the information collected is mainly referred to the Veneto region and are extrapolated to the four Italian regions considered here, to provide a rough estimate of the magnitude of this phenomenon that must be taken with great care, given the related uncertainties. We cannot provide a similar estimate for the Croatian coast, as we could not retrieve enough information.

Table 5. Number of tourist arrivals in the coastal municipalities of the four Italian regions facing northern-central Adriatic Sea (data from ISTAT, year 2018) and estimate of the number of day-trippers.

Region	Tourist arrivals (ISTAT, 2018)	Day-trippers estimate	Total (arrivals + day-trippers)
FRIULI-VENEZIA-GIULIA (Municipalities: Muggia, Trieste, Duino-Aurisina, Monfalcone, Staranzano, Grado, Marano Lagunare, Lignano Sabbiadoro)	1 524 884	762 442	2 287 326
VENETO (Municipalities: San Michele al Tagliamento, Caorle, Eraclea, Jesolo, Cavallino-Treporti, Venezia, Chioggia, Rosolina, Porto Viro, Porto Tolle, Ariano nel Polesine)	9 139 107	4 569 554	13 708 661
EMILIA-ROMAGNA (Municipalities: Goro, Codigoro, Comacchio, Ravenna, Cervia, Cesenatico, Gatteo, Savignano sul Rubicone, San Mauro Pascoli, Bellaria-Igea Marina, Rimini, Riccione, Misano Adriatico, Cattolica)	6 102 285	3 051 143	9 153 428
MARCHE (Municipalities: Gabicce Mare, Gradara, Pesaro, Fano, Mondolfo, Mondolfo, Montemarciano, Falconara Marittima, Ancona, Sirolo, Numana, Porto Recanati, Loreto, Potenza Picena, Civitanova Marche, Porto Sant'Elpidio, Fermo, Porto San Giorgio, Lapedona, Altidona, Pedaso, Campofilone, Massignano, Cupra Marittima, Grottammare, San Benedetto del Tronto)	1 472 171	736 086	2 208 257
TOTAL	**18 238 447**	**9 119 224**	**27 357 671**

Table 6. Number of tourist arrivals in the counties of Adriatic Croatia (data from Croatian Bureau of Statistics, year 2018).

County	Tourist arrivals (Croatian Bureau of Statistics, 2018)
Istra	4 332 752
Primorje-Gorski kotar	2 909 914
Lika-Senj	789 330
Zadar	1 664 467
Šibenik-Knin	965 203
Split-Dalmatia	3 474 145
Dubrovnik-Neretva	2 734 000
TOTAL	**16 869 811**

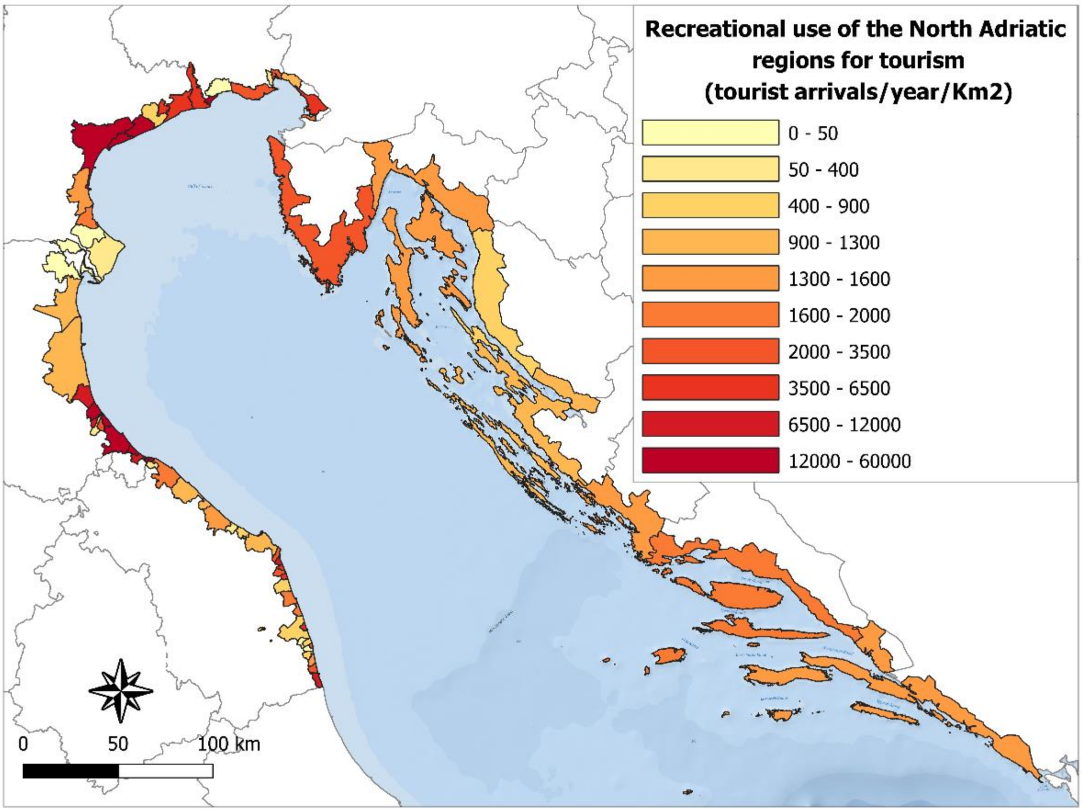

Figure 11. Flow of the tourism ES, corresponding to the number of tourist arrivals per year per km^2 in the coastal municipalities facing northern-central Adriatic Sea. For each county of Adriatic Croatia, data at the county level have been applied to the surface of the respective coastal municipalities as a whole.

3.2. Recreational navigation

This ES refers to the recreational navigation with leisure boats within the marine/coastal ecosystem of the northern-central Adriatic Sea. We mainly refer to navigation with privately owned boats, which is one of the most widely practiced recreational activities in the study area. An analysis of this activity from the ES perspective means to analyze the use of the marine seascape by boaters and the relationship with the marine/coastal ecosystem.

3.2.1. Methodology of the capacity assessment

The indicator chosen to represent the capacity of this ES is the attractiveness of the coastal and marine ecosystems as perceived by boaters.

Like the methodology applied for the tourism ES, this indicator has been estimated through a survey addressed to the boaters of the northern-central Adriatic coast, conducted during the second semester of 2019. A specific questionnaire has been developed and administered to the boaters through both face-to-face interviews and self-administration. The latter has occurred in a variety of ways, which include mailing lists, posters and fliers displayed in marinas, publication in websites and Facebook pages of marinas, and posts in social networks. In order to facilitate the distribution, the questionnaire has been prepared in 3 languages (Italian, Croatian, and English) and a webpage has been created (link) where the questionnaires were made available to the public in the different languages.

With respect to the capacity, the key aspects investigated are: (i) the relative importance attributed by the boaters to different activities that can be potentially practiced during boat trips (namely, go bathing and sunbathing, go fishing, visit the city centers, watching coastal and marine environment, and eat in restaurants or in the open air), and (ii) the relative importance of different factors connected with the state and functioning of the coastal and marine ecosystem, namely, natural terrestrial habitats, marine habitats and fauna, opportunity to observe cetaceans and presence of protected areas. The respondent could indicate the importance on a scale from not important to very important, and could specify other relevant factors of attractiveness not included in the list. Furthermore, the questionnaire asks if the frequency of their trips would change in case of deterioration of water quality.

The responses concerning the relative importance of activities and factors of attractiveness were coded on a 0-1 scale, where 0=not important and 1=very important, and then averaged for each factor, obtaining a coefficient that expresses the relative importance of each activity/factor.

In order to map how the attractiveness varies within the study area, each factor related to the attractiveness of the ecosystem was mapped according to the same methodology described for tourist attractiveness (Table 4). The resulting maps were then aggregated through a weighted sum, the weights corresponding to the coefficients obtained from the questionnaires. The resulting map, normalized on a 0-1 scale, is used to represent the attractiveness of marine-coastal ecosystem to boaters.

3.2.2. Methodology of the flow assessment

The indicator chosen to indicate the flow of this ES is the number of boat trips per km2 per year that represents the use of the marine ecosystem by boaters.

This indicator has been estimated by combining information on the individual behavior of boaters, collected through the questionnaires introduced in the previous section, and information on the number and spatial distribution of leisure boats in the study area.

3.2.2.1. Individual behavior from questionnaires

The questionnaires asked for information regarding the port of departure, the main destinations and the average distance travelled. Based on this information, we calculated the average frequency of the boat trips and the average distance covered during the trips, distinguishing between motorboats and sailboats. It must be pointed out that, among the respondents, some indicated trips with distances and destinations not compatible with a daily trip, that suggest the use of the boat for trips lasting more than a single day. Therefore, based on the questionnaires, we calculated the fraction of those who indicate only daily trips, the fraction of those who provide indications of both daily and longer trips, and the fraction of those who indicate longer trips only, distinguishing between types of boat (motorboat vs sailboat) and between classes of length. The average distance covered during the trips was calculated for the daily trips only.

3.2.2.2. Number and spatial distribution of leisure boats in the study area.

Regarding the number and spatial distribution of leisure boats in the study area, the data collected differ between Italy and Croatia.

Concerning the Italian coast, data on the number of leisure boats were retrieved from the Coast Guard registry, divided by maritime compartments ('Capitaneria di Porto'), relative to the year 2018. The dataset distinguishes between motorboats and sailboats, and specifies the distribution by classes of length. In order to obtain a greater detail in the spatial distribution of the boats, the location of ports and marinas located in each maritime compartment was retrieved from the website Tuttobarche.it[6], along with the number of boat places in each marina. For the small subset of the marinas for which the number of boat places was not available, this parameter was estimated based on the surface of the marina, following a regression between the surface of the marina and the number of boat places resulting from the data from

[6] https://www.tuttobarche.it/ricerca-rade-e-porti

the other marinas. Finally, the boats registered in each maritime compartment were distributed among the marinas located therein, according to the number of boat places available. For each marina it was assumed that the proportion of motorboats and sailboats, as well as the length distribution, correspond to the proportions reported for the respective compartment. In this way we obtained an estimate of spatial distribution of motor and sailboats in the Italian portion of the study area. It should be noted that the registration to the Coast Guard's registry for the boats with length <10 m is optional. Therefore, the number of boats registered is likely to be an underestimate of the total number of boats, especially regarding motorboats.

Concerning the Croatian coast, the number of leisure boats permanently moored in the nautical ports of the Croatian coast was retrieved from the Croatian Bureau of Statistics, relative to the year 2018. In this case, the dataset provides the total number of boats in each county of Adriatic Croatia, but unfortunately no further information on the type of boats and their precise location could be retrieved.

3.2.2.3. Mapping procedure

Based on these data, the use of marine space by boaters was estimated by applying the average individual behavior obtained from the questionnaires to the number of boats present in the study area. In particular, the analysis is focused on mapping the marine space used for daily trips, whose destination can be assumed to be the area facing the homeport.

Concerning the Italian coast, this was done by mapping a semi-circular marine area, centered on each marina, whose radius equals the average distance travelled by boaters, distinguishing between motorboats and sailboats. Since the boats registered include big vessels that are not likely to be used for daily trips, the number of boats used for daily trips in each marina was estimated based on the ratios derived from the questionnaires, distinguishing between type of boat and classes of length. For each marina (or groups of marinas in case of very close ones), the number of boat trips/km2/year was obtained by multiplying the number of boats by the frequency of trips, and then dividing by the surface of the semi-circular area.

Concerning the Croatian coast, as the information retrieved is less detailed, we used a buffer from the coast with a distance equal to the average distance travelled by respondents using motorboats and sailboats. No fractioning relative to the portion of boats making daily trips were applied here, due to the lack of information about the type of boats. For each county, the number of boat trips/km2/year was obtained by multiplying the number of boats by the frequency of trips, and then dividing by the surface of the coastal buffer.

The boat trips longer than one day were not mapped, as it was not possible to identify a general individual behavior, being the destinations and distances extremely variable. As a significant fraction of the respondents owning a sailboat have mentioned a cruise to Croatian coast at least once a year, we provide an estimate of the number of sailboats that make a cruise to Croatian coasts leaving from the Italian portion of the study area.

3.2.3. Results of the capacity assessment

A total of 220 compiled questionnaires has been collected, of which 73% own a sailboat and the remaining a motorboat. Most boaters have been reached through face-to-face interview (55%), followed by social networks (17%), mailing lists (15%), word of mouth (9%) and other methods. Most of the respondents are males (89%), with the age-class distribution shown in Figure 12. The majority has completed higher education (48%) or upper secondary education (45%), followed by lower secondary education (6%) and primary education (1%). Most of the respondents are Italian (86%), mostly from Veneto, Friuli-Venezia-Giulia and Emilia Romagna (56%, 30% and 10% of the Italians, respectively). 11% of the respondents are from Croatia, of which most from the Split-Dalmatia county.

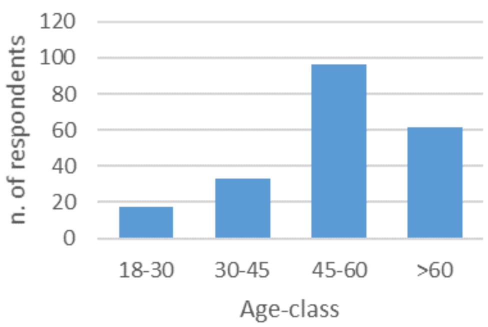

Figure 12. Age-class distribution of the boaters who have taken part to the survey

Concerning the importance attributed to different activities (Figure 13), the observation of the marine and coastal environment has been given the highest score, followed by going bathing and sunbathing. The different factors related to the ecosystem were given a similar relative importance (Figure 13), with terrestrial habitats and natural protected areas having a slightly higher score. Among the other factors mentioned, the most frequent was silence and calmness, mentioned by about 10% of the respondents. Finally, a hypothetical drastic deterioration of the water quality would not affect the behavior of nearly half of the respondents (Figure 14), suggesting that, once a boater has invested money on a boat, its use would be poorly affected by this variable.

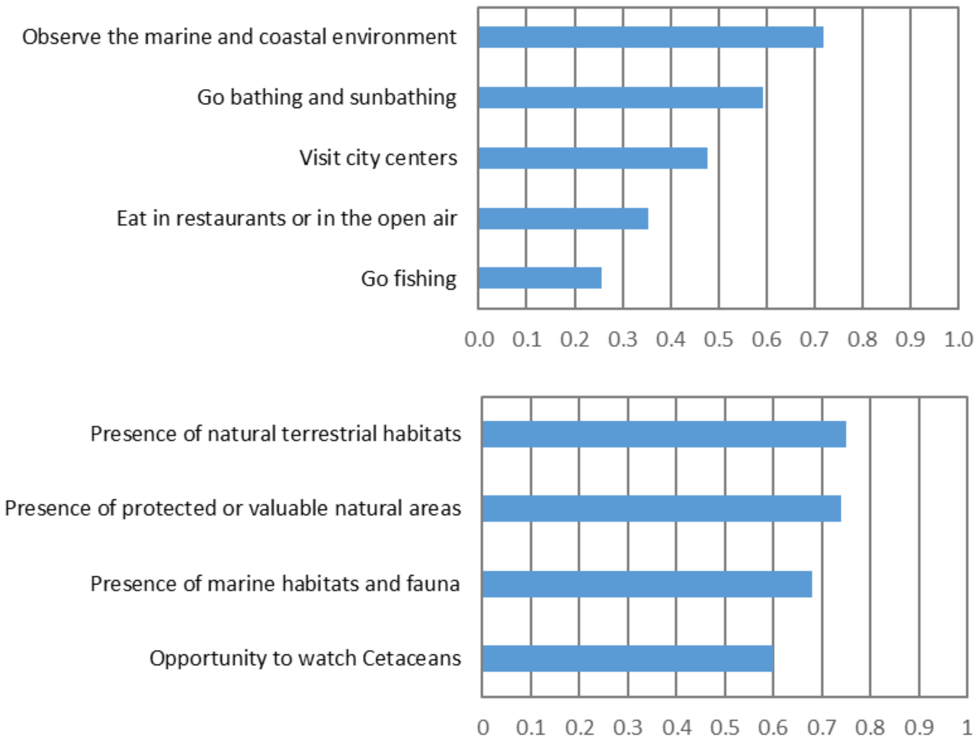

Figure 13. Relative importance attributed by boaters to different activities that can be potentially practiced during boat trips (top) and to different factors of environmental attractiveness (bottom), expressed on a 0-1 scale where 0=not important, and 1=very important.

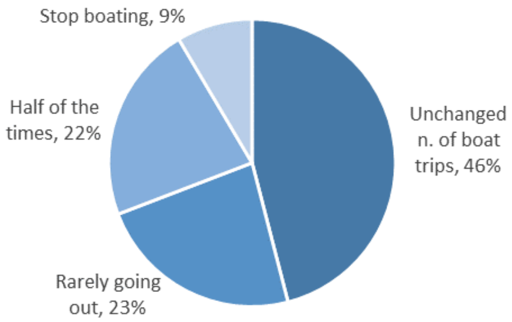

Figure 14. Change of trips' frequency due to a hypothetical drastic deterioration of water quality

By combining this information with the spatial distribution of the environmental factors of attractiveness, mapped as specified in Table 4, we obtain the map of natural attractiveness shown in Figure 15.

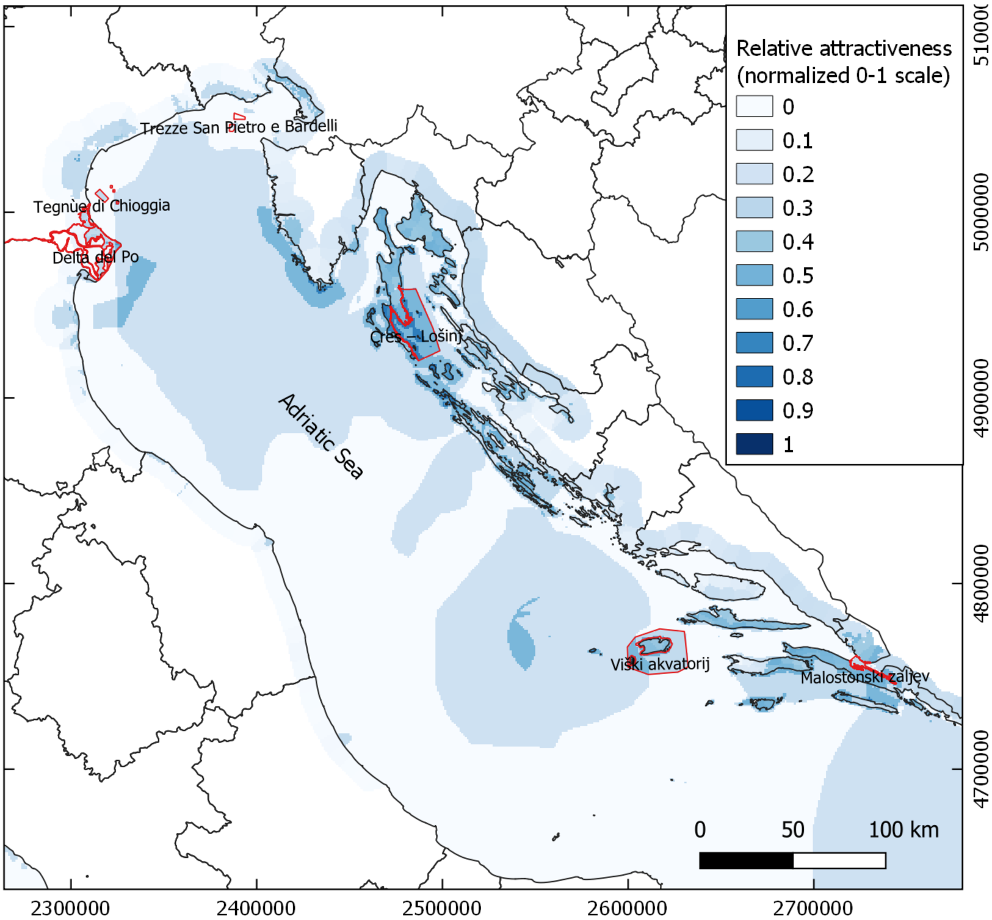

Figure 15. Capacity of the recreational navigation ES, corresponding to the relative attractiveness of marine and coastal ecosystems of northern-central Adriatic Sea, as perceived by the owners of leisure boats, expressed on a normalized 0-1 scale. The location of the Natura 2000 sites selected by the project is also indicated.

3.2.4. Results of the flow assessment

Concerning the individual behavior of the boaters, derived from questionnaires, the average frequency of trips is 27 trips/year, for both sailboats and motorboats. The average distance covered during daily trips is equal to 5 nm for motorboats and 6.5 nm for sailboats.

The number of leisure boats registered is equal to about 15 000 boats along the Italian coast ranging from Trieste to Ancona, and nearly 14 000 boats along the whole Croatian coast (no data available for the Lika-Senj County) (Figure 16). Concerning the Italian part, about 60% are motorboats and 40% sailboats.

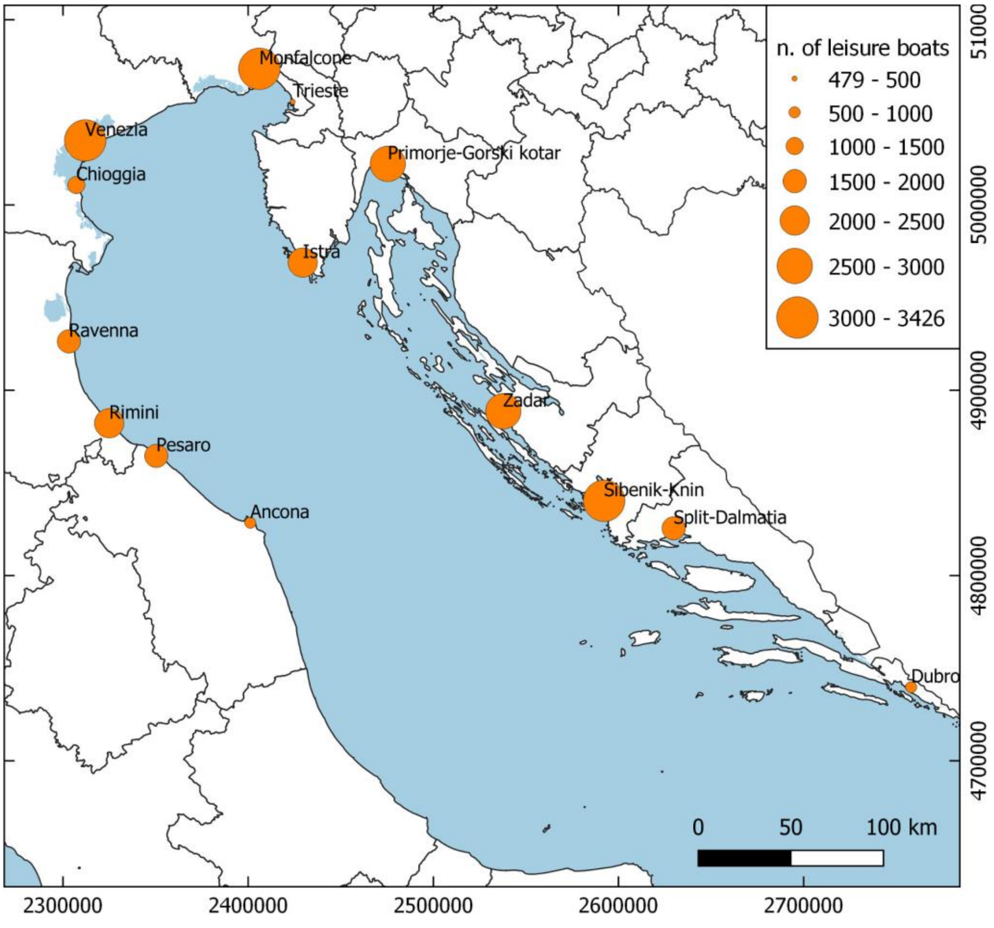

Figure 16. Number of registered leisure boats in the study area. For the Italian portion, the bubbles represent the n. of boats registered within the jurisdiction of each maritime compartment ('Capitaneria di porto'). For the Croatian portion, the bubbles represent the n. of boats in each County (no data available for the Lika-Senj County).

Concerning the use of boats for daily trips vs. longer trips, according to the questionnaires collected, it emerges that daytrips are practiced by all motorboats <10 m, and by a fraction of sailboats <18 m, fraction that decreases with increasing size-class (99% and 80% for classes <12 m and 12-18, respectively). Therefore, to estimate the use of the marine space for daily boat trips, the corresponding fractions of the boats registered were calculated.

The map of use of the marine space by leisure boaters, showing the estimated number of boat passages/km2/year referred to daily trips, is shown in Figure 17. In support of the choice of mapping the daily trips as a semicircle centered on the marina, according to the results of the questionnaires the most common destination is the marine space facing the marina (selected by 74% of the respondents), followed by ports and villages (41%) and bays (37%).

Regarding cruises to Croatia from the Italian portion of the study area, according to the questionnaires, the fraction of sailboats that make a cruise with a Croatian destination at least once a year is equal to about 1%, 20% and 100% of the boats belonging to the length classes <12 m, 12-18 m and >18 m, respectively. By applying these fractions to the sailboats registered, it emerges that Croatian coastal area could be visited by about 550 Italian private sailboats leaving each year from the northern-central portions of the Italian coast.

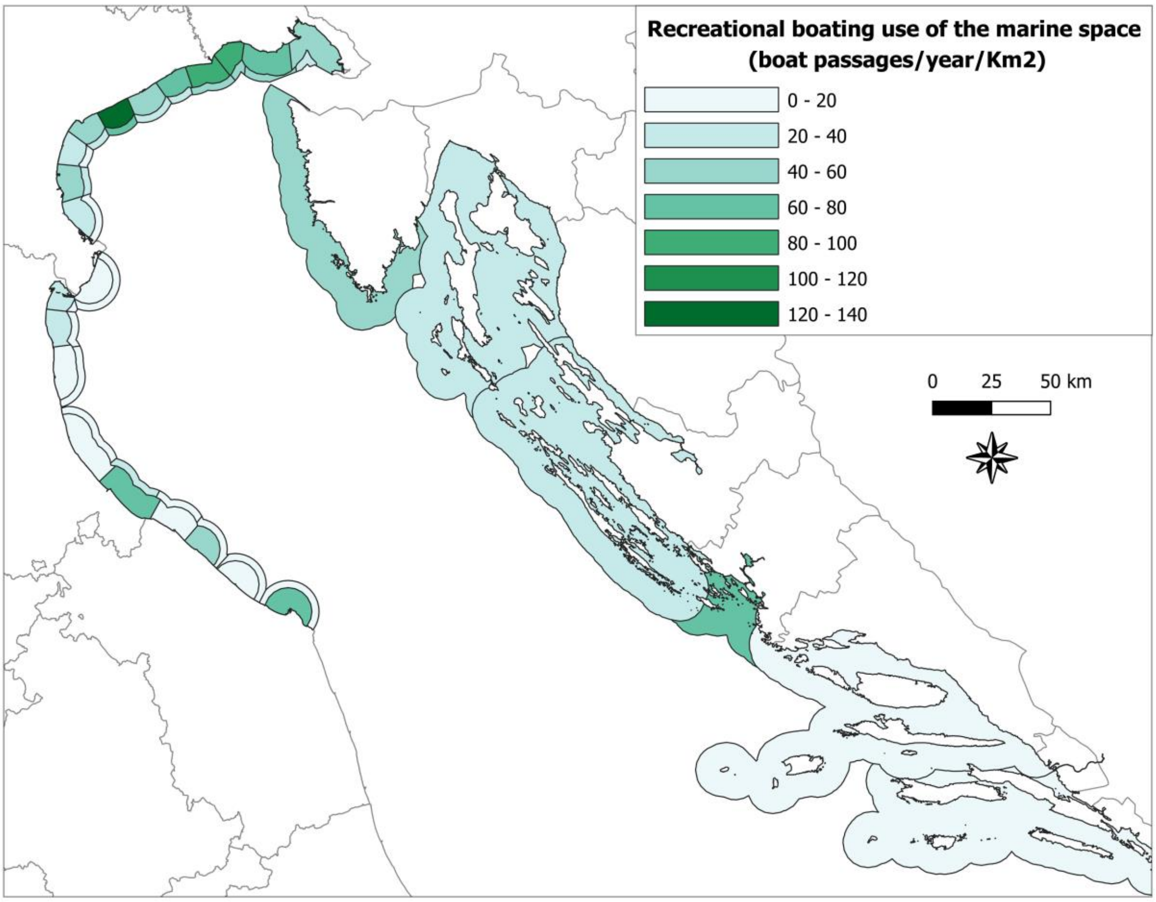

Figure 17. Flow of the recreational navigation ES, corresponding to the use of the marine space of northern-central Adriatic Sea for daily trips by leisure boaters of Italy and Croatia, expressed as number of boat passages/km2/year.

3.3. Recreational fishing

The ES refers to marine recreational fishing activities practiced in northern-central Adriatic Sea. Although being one of the most relevant and popular leisure activities in the study area, very little data are available that characterize these activities and their link and effects on the ecosystem. Therefore, this analysis from the perspective of ES capacity and flow aims to contribute to reduce these knowledge gaps.

3.3.1. Methodology of the capacity assessment

The capacity of this ES corresponds to the fish stocks upon which recreational fishing insist. The indicator chosen to represent this ES is the biomass of species targeted by recreational fishing.

This has been estimated based on a food-web model representing the northern-Adriatic Sea ecosystem, built in Ecospace-with-Ecosim (Libralato et al., 2015). The model is referred to the northern Adriatic, considering an area approximately coincident with the Gulf of Venice, and it is relative to the years 2007-2008. Although it is important to point out the discrepancy of the spatial and temporal correspondence between the food-web model and our study, we emphasize that these are the most suitable data available at the moment.

The target species have been selected based on the results of the survey administered to recreational fishermen (please see the next section). According to the foo-web model, these species are included in the following functional groups, whose biomass have been obtained from the model: nekton feeders, cephalopods, benthos feeders, planktivorous fish and bluefin tuna (Libralato et al., 2015). However, the species targeted by recreational fishery are only a subset of these functional groups, in which several other species are included. Therefore, the biomass of the species targeted by recreational fishing has been calculated as a fraction of the biomass of the respective functional groups. This fraction has been estimated on the basis of the ratio between the landings of the species of our interest and the landings of all the species of the respective functional group, based on data from the Chioggia fish market referred to the years 2007-2008.

3.3.2. Methodology of the flow assessment

The indicator chosen to represent the flow of this ES is the fish catch from recreational fishing.

Following the approach applied in a previous study conducted in the same area (Pranovi et al., 2016), this indicator has been estimated though a survey aimed at characterizing the activity of recreational fishermen in the northern-central Adriatic Sea, conducted during the second semester 2019.

A questionnaire has been developed and administered to the fishermen through both face-to-face interviews and self-administration. Fishermen have been contacted in a variety of ways, which include recreational fishing associations (part of the Italian Federation of Sport Fishing and Underwater Activities, FIPSAS), mailing lists, social networks (in particular Facebook groups), and through bait shops or tourist information offices. In order to facilitate the distribution, the questionnaire has been prepared in 3 languages (Italian, Croatian and English) and a webpage has been created (link) where the questionnaires were made available to the public in the different languages.

The main questions regard the fishing techniques, the preferences in terms of target species, catches and fishing effort (in terms of number of trips per week in the different seasons). Based on the data collected through the survey, we estimated the average fishing effort per fisherman (n. of fishing trips/fisherman/year), the catches per unit of effort (CPUE, g/fishermen/trip) for the main target species, and the fraction of fishermen that target a certain species. Questionnaires collected in Italy and Croatia have been analyzed separately.

In order to estimate the total catches, the total number of active fishermen have been estimated based on two separate sets of data, for Italy and Croatia.

Regarding Italy, the available data on the number of recreational fishermen mainly derive from the Ministry of Agriculture, Food and Forestry Policies (MIPAAF). In Italy, no license is required for recreational fishing in marine areas, but an optional registration (free of charge) is available for census purposes. According to this registry, the number of recreational fishermen active in marine waters in Italy in 2018 was 1 054 584. In order to estimate how many of them are active within our study area (regions Friuli-Venezia Giulia, Veneto, Emilia-Romagna and Marche) we used three different methods: (i) the incidence of recreational fishermen resident within the study area, recorded by a census by MIPAAF in 2014, indicating about 14% of the total number; (ii) the proportion of fishermen that have selected the regions of the study area as fishing areas, during the MIPAAF registration (2018 data), which corresponds to 20% (please note that this does not necessarily correspond to the region of residence, each fisherman could select more than 1 regions, in relation to this on average, each one selected 2.6 regions); (iii) the real number of fishermen that have selected the regions of the study area during MIPAAF registration (about 360 000). Being all three potentially valid methods, we decided to take the average value (240 000 fishermen). A different estimate of the number of fishermen really active in marine waters derives from a market survey conducted by the Italian federation of producers and sellers of sport fishing gears (FIPO[7]), which reports about 540 000 fishermen in the national territory. This different estimate suggests that only about half of the fishermen registered at MIPAAF is actively frequenting bait shops and fishing gears shops. Finally, a comparison between the total effort (n. fishing days/fisherman/year) reported by Hyder et al. (2018) and the one derived from our questionnaire, the first being about 3-4 times smaller than the

[7] FIPO, Il mercato della pesca sportiva, http://www.fipopesca.it/il-mercato

second, suggests that the sample of our survey reflects only the fraction of fishermen that are regularly active and not those which only fish occasionally and could not be reached by our survey. Therefore, in order to make a conservative estimate of the number of recreational fishermen which are regularly active, we consider both these alternative sources and we divide the number of fishermen derived from MIPAAF data by a factor 6. In this way we obtain an estimate of about 40 000 fishermen active in the coastal area of Friuli-Venezia Giulia, Veneto, Emilia-Romagna and Marche.

Concerning Croatia, the following data on the number of recreational fishermen are available: the range reported by Matić-Skoko et al. (2014) and Hyder et al. (2017) for the decade 2000-2010 (from 25 000 to 80 000 fishermen), and the number of licenses in 2011 reported by Soldo et al. (2018) (78 200 licenses for recreational and sport fishing). Based on this information and considered that most likely the number of fishermen did not decrease in the last decade, we adopt a conservative estimate of 80 000 recreational/sport fisherman active in marine and coastal areas.

3.3.3. Results of the capacity assessment

The estimated biomass of the species targeted by recreational fishery in northern Adriatic, derived from the food-web model of Libralato et al. (2015) is reported in Table 7. European seabass, cuttlefish and gilthead seabream are the most abundant species, which together sum up to more than 85% of the biomass of the targeted species. Please note that these estimates are referred to the Gulf of Venice and to the years 2007-2008.

Table 7. Estimated biomass of the main target species of recreational fishing, based on the food-web model of Libralato et al. (2015).

Species		**Functional group in the food-web model**	**Estimated biomass (ton)**
European seabass	*Dicentrarchus labrax*	Nekton feeders	4 541
Cuttlefish	*Sepia officinalis*	Cephalopods	3 421
Gilthead seabream	*Sparus aurata*	Benthos feeders	2 682
Atlantic bluefin tuna	*Thunnus thynnus*	Bluefin tuna	905
Atlantic mackerel	*Scomber scombrus*	Planktivorous fish	1 874
Leerfish	*Lichia amia*	Nekton feeders	114
European squid	*Loligo vulgaris*	Cephalopods	104
Sand steenbras	*Lithognathus mormyrus*	Benthos feeders	500

3.3.4. *Results of the flow assessment*

The results obtained for Italy and Croatia are reported separately, in order to reflect the differences in the behavior of fishermen in the two countries.

3.3.4.1. Italy

A total of 211 compiled questionnaires has been collected, covering fishermen active along the coast of Veneto, Friuli-Venezia-Giulia and Emilia-Romagna. Most of the fishermen have been reached through social networks (62%), fishing associations (14%), word-of-mouth (9%), face-to-face interview (8%), e-mail (7%) and flyer (1%). Most of the interviewed fishermen are male (96%), with the age-class distribution shown in Figure 18. The majority has completed upper secondary education (54%) or lower secondary education (29%), followed by higher education (16%). The residence of the respondents is almost equally distributed between the regions Friuli-Venezia Giulia (31%), Veneto (37%) and Emilia Romagna (31%), with a remaining 1% from Lombardia.

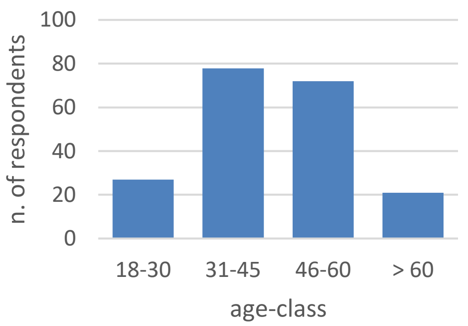

Figure 18. Age-class distribution of the fishermen who took part to the survey

Based on the questionnaires, the dominant fishing technique is the fishing rod (99%), with a variety of techniques among which the most widely used are surfcasting and spinning (44% and 29% of those using fishing rods, respectively). The remaining 1% practices underwater fishing. About 6% of those using the fishing rod also use other techniques, namely, underwater fishing (4%) and spear fishing (2%). Most respondents fish along the coast (55%), followed by those fishing both inshore and offshore (38%), and only offshore (7%). 58% of the respondents fish from land, 38% from the boat and 4% from both.

The CPUE data derived from the questionnaires for the main target species are shown in Table 8, along with the fraction of fishermen targeting each species. On average, the total catches are equal to 2.4 kg/fisherman/trip, the average fishing effort per fishermen being equal to 27 fishing trips/fisherman/year.

Please note that recreational fishing activities targeting Atlantic bluefin tuna (*Thunnus thynnus*) have been treated separately, due to the peculiar characteristics of this activity, which is subject to a Total Allowable Catch. This activity is discussed in section 3.3.5.

Table 8. Catches per unit of effort (CPUE, g/fisherman/year) for the main target species and fraction of fishermen targeting each species. These fractions do not sum up to 100% because many fishermen target more than one species.

Species		CPUE (g/fisherman/trip)			Fraction of fishermen targeting each sp.
		1st quartile	Median	3rd quartile	%
Gilthead seabream	*Sparus aurata*	500	625	1000	67%
Sand steenbras	*Lithognathus mormyrus*	1000	1000	1500	31%
European seabass	*Dicentrarchus labrax*	1000	1125	1500	27%
Cuttlefish	*Sepia officinalis*	425	1000	2000	16%
Atlantic horse mackerel	*Trachurus trachurus*	600	1000	2500	12%
Mullet	*Mugil spp.*	2000	2000	2000	11%
Atlantic mackerel	*Scombrus scombrus*	4000	5000	6500	10%
Bluefish	*Pomatomus saltatrix*	1000	1750	2000	9%
European squid	*Loligo vulgaris*	375	500	500	8%
Other		425	800	3900	23%

Table 9 reports the estimates of annual catches of marine recreational fishermen in the Italian portion of the study area, corresponding to the coast of Friuli-Venezia-Giulia, Veneto, Emilia-Romagna and Marche. The total catches sum up to about 2 600 tons/year (with 2 029 and 4 432 as 1^{st} and 3^{rd} quartiles, respectively). The catch composition is shown in Figure 19, with Atlantic mackerel, gilthead seabream, European seabass, and sand steenbras accounting for more than 60% of the total catches.

Table 9. Estimate of the annual catches from marine recreational fishing in the regions Friuli-Venezia Giulia, Veneto, Emilia-Romagna and Marche

Species		Annual catches (ton/yr)		
		1st qu.	Median	3st qu.
Atlantic mackerel	*Scombrus scombrus*	421	526	684
Gilthead seabream	*Sparus aurata*	361	451	722
European seabass	*Dicentrarchus labrax*	295	331	442
Sand steenbras	*Lithognathus mormyrus*	330	330	494
Mullet	*Mugil spp.*	238	238	238
Bluefish	*Pomatomus saltatrix*	98	172	196
Cuttlefish	*Sepia officinalis*	72	168	337
Atlantic horse mackerel	*Trachurus trachurus*	76	126	316
European squid	*Loligo vulgaris*	34	46	46
Other		104	196	957
TOTAL		**2 029**	**2 585**	**4 432**

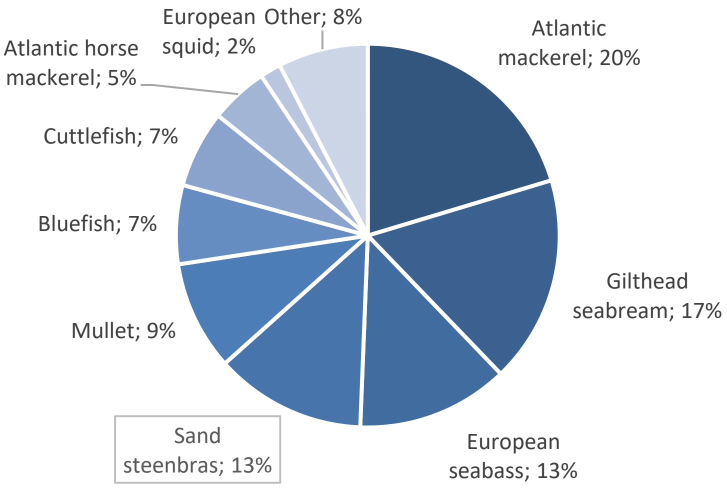

Figure 19. Catch composition from marine recreational fishing in the regions Friuli-Venezia-Giulia, Veneto, Emilia-Romagna and Marche.

3.3.4.2. Croatia

A total of 97 filled questionnaires has been collected. Most of the fishermen have been reached through social networks (53%), followed by face-to-face interview (37%), e-mail (3%), tourist information offices (3%), word-of-mouth (2%) or fliers (1%). Most of the interviewed fishermen are male (86%), with the age-class distribution shown in Figure 20. The majority has completed secondary education (68%) or higher education (31%). The distribution of the respondents by county of residence is dominated by four counties of Adriatic Croatia, namely Split-Dalmatia, Dubrovnik-Neretva, Primorje-Gorski-Kotar and Istria (Figure 20).

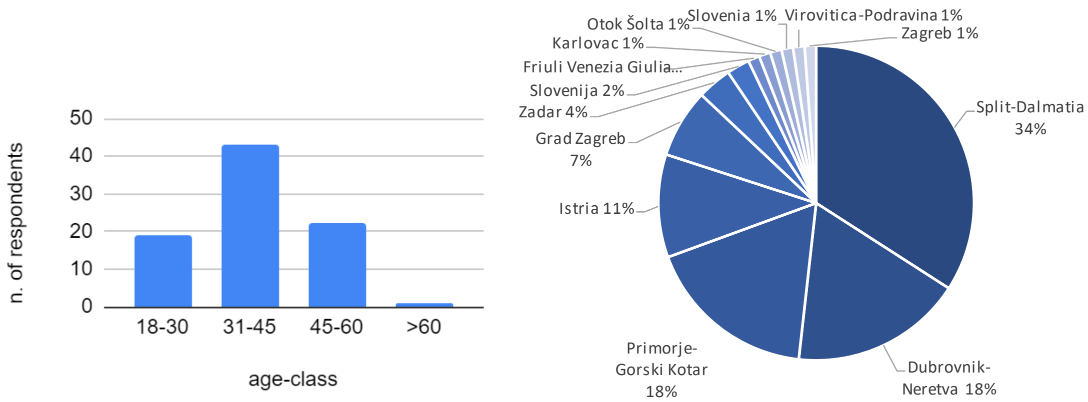

Figure 20. Age-class distribution (left) and county of residence (right) of the interviewed fishermen.

Based on the questionnaires, the dominant fishing techniques are fishing rods and fishing hooks (60% and 51%, respectively), followed by underwater fishing (28%). More than one third of the respondents uses more than one technique. Most respondents fish along the coast (96%), followed by those fishing both inshore and offshore (22%), and only offshore (4%). Generally, 53% of the respondents fish from land, 30% from the boat and 14% from both.

The CPUE derived from the questionnaires for the main target species are shown in Table 10, along with the fraction of fishermen targeting each species. On average, the total catches are equal to 2.4 kg/fisherman/trip, the average fishing effort per fishermen being equal to 24 fishing trips/fisherman/year.

Table 10. Catches per unit of effort (CPUE, g/fisherman/year) for the main target species and fraction of fishermen targeting each species. These fractions do not sum up to 100% because many fishermen target more than one species.

Species		**CPUE (g/fisherman/trip)**			**Fraction of fishermen targeting each spp.**
		1° quartile	**Median**	**3° quartile**	**%**
Gilthead seabream	*Sparus aurata*	500	1000	1000	49%
European seabass	*Dicentrarchus labrax*	800	1000	1000	34%
White seabream	*Diplodus sargus*	363	500	788	27%
European squid	*Loligo vulgaris*	350	1000	1500	24%
Bluefish	*Pomatomus saltatrix*	1125	1500	1875	15%
Mullet	*Mugil spp.*	500	550	925	15%
Atlantic mackerel	*Scombrus scombrus*	300	450	650	5%
Cuttlefish	*Sepia officinalis*	650	1000	1250	4%
Atlantic horse mackerel	*Trachurus trachurus*	269	313	356	4%
Leerfish	*Lichia amia*	1000	1000	1000	3%
Sand steenbras	*Lithognathus mormyrus*	425	450	475	3%
Other		1000	1600	2500	45%

The estimates of annual catches of marine recreational fishermen in Croatia are reported in Table 11. The total catches sum up to about 4 500 tons/year (with 2834 and 5902 as 1st and 3d quartile, respectively). The catch composition is shown in Figure 21, with gilthead seabream, European seabass, European squid and bluefish accounting for about 55% of the total.

These results are in line with the catches from marine recreational fishery reported by Matić-Skoko et al. (2014), corresponding to an average of 3 150 ton/year for the 2000-2010 decade, and 4 800 ton/year for the year 2010.

Table 11. Estimate of the annual catches from marine recreational fishing in Croatia.

Species		Annual catches (ton/year)		
		1st qu.	Median	3st qu.
Gilthead seabream	*Sparus aurata*	467	934	934
European seabass	*Dicentrarchus labrax*	519	649	649
European squid	*Loligo vulgaris*	163	467	701
Bluefish	*Pomatomus saltatrix*	321	428	535
White seabream	*Diplodus sargus*	188	259	409
Mullet	*Mugil spp.*	143	157	264
Cuttlefish	*Sepia officinalis*	51	78	97
Leerfish	*Lichia amia*	52	52	52
Atlantic mackerel	*Scombrus scombrus*	31	47	67
Atlantic horse mackerel	*Trachurus trachurus*	21	24	28
Sand steenbras	*Lithognathus mormyrus*	22	23	25
Other		856	1 370	2 141
TOTAL		**2 834**	**4 488**	**5 902**

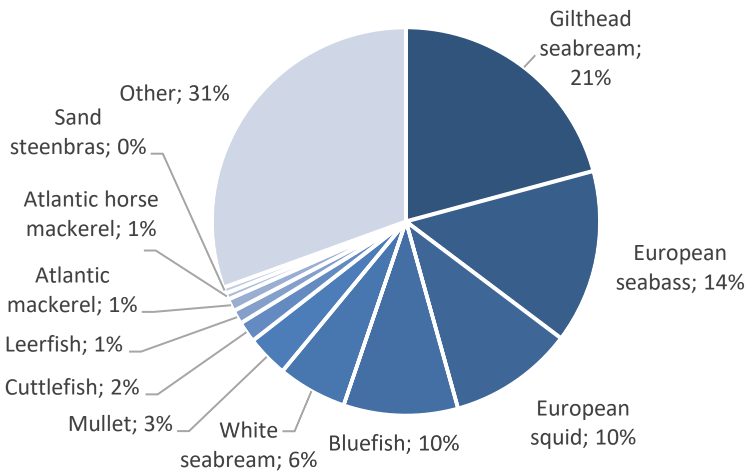

Figure 21. Catch composition from marine recreational fishing in Croatia.

If we sum up the results obtained for the two countries, the annual catches from marine recreational fishing in northern-central Adriatic Sea amounts to about 7 000 tons/year.

3.3.5. The case of tuna fishing

Tuna fishing represents a good example of the complexity of the interplay between ES capacity, flow and governance.

Atlantic bluefin tuna (*Thunnus thynnus*) is a species found throughout the Atlantic Ocean, the Mediterranean Sea and the Black Sea. Given the evidences of a decline of the eastern stock of this species, in 2006 the International Commission for the Conservation of Atlantic Tunas (ICCAT) established a multiannual recovery plan for bluefin tuna in the eastern Atlantic and Mediterranean, entering into force in 2007 and ending in 2022. This recovery plan regulates the fishing activities targeting this species in all the Member States. Each year, each Member State is assigned a Total Allowable Catch (TAC) defined by ICATT and is required to submit an annual fishing plan that allocates the quotas to the different gear groups, and, particularly, a specific quota for the purpose of sport and recreational fisheries must be allocated (Council of the European Union, 2016). Bluefin tuna sport and recreational fishing is permitted from 16 June to 14 October, with a minimum landing size of 30 kg or 115 cm fork length and no more than one specimen caught per vessel per day; catches must be recorded by local authorities and the selling is prohibited. Each Member State must regulate sport and recreational fisheries by issuing fishing authorizations to vessels for the purpose of sport and recreational fishing (Council of the European Union, 2016).

Given this premise, here we attempt to describe and discuss the phenomenon of tuna recreational fishing in the Northern Adriatic Sea. To do so, we have collected information on this type of fishing in two ways. On one side we use the questionnaires collected through our survey to derive the fishing effort (number of fishing trips per person per year) and the average weight of caught specimens. On the other side, we have made a series of interviews to the Coast Guard and to fishermen practicing this activity, in order to collect information on (i) the number of authorized boats that are effectively used to practice bluefin tuna fishing, (ii) the number of specimens caught and landed by each boat during the fishing season, (iii) the number of specimens caught and released by each boat during a fishing trip, and (iv) the fishing effort, which has then been averaged with that obtained from questionnaires.

The TAC for Italy for the year 2019 has been set in 4 308.36 tons, of which 20.23 tons have been allocated to recreational/sport fishing (MIPAAF, 2019). At the national level, the total number of boats authorized to practice bluefin tuna sport/recreational fishing amounts to about 6 500 vessels. It must be pointed out that the authorization is free of charge and it is linked to the vessel and not to who is using it. Therefore, the number of authorized boats corresponds to the boats *potentially* usable for tuna fishing, but not necessarily used for this purpose. Based on our interviews, it can be estimated that the number of boats actually used for bluefin tuna fishing corresponds to about 1/3 of the authorized boats (2167 boats), and that, on average, only 1/4 (542) of these boats catches (and registers) a tuna during the whole fishing season. Therefore, this fraction of boats corresponds approximately to the number of specimens landed. Considering 40 kg as an average weight of a tuna caught (according to the questionnaires collected), we obtain the about 20 tons of annual catches established by the quota. Downscaling this estimate to the regions included in our study area (Friuli-Venezia Giulia, Veneto, Emilia-Romagna and Marche), the number of boats authorized to bluefin tuna sport/recreational fishing is estimated in about 1 400 vessels. By applying the same rationale described above, the annual catches of bluefin tuna in these four regions amount to about 5 tons.

Outside the permitted period, and, in any case, once the quota has been reached, only *catch-and-release* practices are allowed. Based on our interviews, the number of catches/fishing trip varies depending on the season and Region, ranging between one specimen caught every 8-9 trips and 2 specimens/trip, with an average of about 1 specimen caught/boat per trip. Considering a fishing effort of about 30 trips/fisherman/year, we obtain about 30 specimens caught/boat/year, to which catch-and-release practices are applied. If we consider the number of boats that actually catch and land a tuna during the fishing season (542 boats), we obtain an estimate of 16 250 (no data about the probability of recapturing the same fish more than once) specimens caught-and-released/year. If we consider the number of active authorized boats (2167 boats), we obtain an estimate of 65 000 specimens caught-and-released/year. This means that, for each landed tuna registered by the Coast Guard, 30 - 120 specimens could be caught-and-released during the year.

These dynamics represent an interesting (and complex) case in which, in response to a dramatic decline in ES capacity -the decline of the tuna stock-, the governance system applies corrective actions that regulate the flow of two associated ES (commercial fishery and recreational fishery). In particular, the establishment of a TAC triggers at least two phenomena:

- The first, occurring *within* each ES, is a competition among fishermen for grabbing a share of the quota. Considering recreational/sport fishing, in fact, the quota is generally reached well before the end of the permitted fishing season (e.g. in 2019, at the beginning of August vs October), with fishermen complaining that they are ‘forced’ to go fishing almost every day in order to be able to catch and land a tuna before the quota is reached.
- The second, occurring *between* the flow of the two ES (commercial or recreational fishery), is a sort of conflict between the two sectors for the allocation of the quota, each sector demanding a greater share of the TAC. In a hypothetical situation without a TAC, the two types of fisheries would compete at sea by insisting upon the same, limited, resource. It is interesting how the

introduction of a TAC with quotas for specific sectors increase the lobbies' pressures on decision-makers.

Regarding recreational/sport fishing, we observe a differentiation in the way the ES flow takes place: landed specimens vs caught-and-released ones, the two having quite different effects on the resource capacity. In the first case all the caught specimens die (mortality rate of 100%), in the second, all specimens are caught but then released alive (according to Stokesbury et al., 2011 the post release mortality rate ranges between 3.4% and 5.6%). We could so conclude that the effects of the catch-and-release practice would be quite limited, but if considered in absolute terms, given the high number of specimens that are caught and released each year, catch-and-release could indeed represent a relevant source of mortality. Table 12 shows some preliminary estimates of how many specimens could die for catch-and-release practices for each specimen landed, under different assumptions of mortality rate and proportion of recapture of the same individual. These estimates, although very preliminary, highlight the need to deepen the limited knowledge available on the recreational removal of this species (Radford et al., 2018).

Table 12. Estimated ratio between the number of bluefin tuna specimens that could die for catch-and-release practices and the number of specimens that are caught and landed by recreational fishermen, per year, assuming different proportions of recapture and different mortality rates. The range refers to the two different estimates of the number of specimens caught-and-released each year presented in the text.

		N. of specimens that could die for catch-and-release practices for each specimen landed, under different mortality rates	
		Mortality rate = 3.4%	**Mortality rate = 5.6%**
Proportion of recapture	**100% of the specimens have been captured twice**	0.5 - 2.0	0.8 - 3.0
	33% of the specimens have been captured twice	0.8 - 3.1	1.1 - 4.5
	0% of the specimens have been captured twice	1.0 - 4.1	1.5 - 6.0

3.4. Discussion

The three cultural ES assessed can be discussed following the structure of the conceptual model presented in section 2.

First of all, all the three ES are 'mediated' ES (*sensu* Rova and Pranovi, 2017) whose flow necessarily occur through some human activities (the resource uses), namely, visiting, boating and fishing. These activities depend, at least to some extent, on some ecological resources (the ES capacity), that are, natural attractiveness to visitors and boaters and the stock of target species, respectively. We can analyze the results obtained from two perspectives:

- the relationships occurring '*within'* each ES (that is, between the capacity and flow of each ES),
- the relationships occurring *between* different ES, in terms of synergies and trade-offs (e.g. if the ecological resources upon which they depend are interdependent, and if the flow of an ES affects other ES).

3.4.1. Relationships 'within' ES

Regarding tourism ES, the final maps of capacity and flow (Figure 10 Figure 11Figure **15**) show a quite different pattern within the study area. The capacity (natural attractiveness) has higher values along the Croatian coasts with respect to the Italian ones. The flow (n. of visitors/km2) is instead quite balanced between the two countries, except for the particularly high values along the coast of the provinces of Venice and Rimini. This shows that the flow occurs also where the natural attractiveness is quite low. This discrepancy can be explained by the fact that, although important, the natural attractiveness is not the only factor of attractiveness. A series of other factors, among which cultural heritage, food and wine, tourist infrastructures and events, also contributes to the overall attractiveness. These factors can be assimilated to the 'Infrastructures' variable of the conceptual model: they concur to increase the resource use and, in some cases, can offset the low natural attractiveness. As pointed out by the conceptual model, both the visitation rate and the build-up of these 'Infrastructures' can produce negative impacts on the ecosystem (e.g. deterioration of the dunes due to visitors' passages, land use change due to the built-up of infrastructures). All this can result in a sort of decoupling between the capacity and flow of the ES, whereby the flow increases and the capacity decreases, with a loop that accelerates the deterioration of the coastal ecosystem. Finally, the day-trippers phenomena, although not captured by official statistics, is likely to exacerbate the situation in the areas with high population density, such as the regions on the West coasts. In this case, we expect that the users' selectivity with respect to the environmental conditions is traded off with proximity to home. Therefore, the high number of users seeking close-to home recreational opportunities may increase the number of visitors along the coast almost irrespectively to the environmental conditions, causing further development of tourist infrastructures, and degradation of the ecosystem.

However, the importance attributed by the visitors to the natural attractiveness should be a reason to reflect on these phenomena. How far can the anthropization of our coasts offset the loss of natural attractiveness? Which implications it has in terms of ecosystem resilience and associated ES flow? From an ES perspective, a coastal system whose attractiveness is 'optimized' for mass flows of visitors, with high levels of 'Infrastructures' replacing the natural attractiveness, is unlikely to be a resilient strategy, from both an ecological, and socio-economic perspective. An extreme (and tragic) situation such as the current coronavirus pandemic, with its consequences in the short, medium and long term, will dramatically test this hypothesis. Even just narrowly looking at tourism ES, we may expect the ecosystem to be the most resilient among the factors of attractiveness, the other factors requiring a strong rearrangement to adapt to the new rules on social distancing, with dramatic economic consequences. One more reason, if needed, to strive to sustainably manage coastal natural resources.

Regarding recreational navigation, similarly to what has been observed for tourism, the maps of capacity and flow present quite different spatial patterns. The relationship with the ecosystem appears indeed quite controversial also from the outcomes of the questionnaires. Boaters in fact rank the observation of the marine environment as the most important activity, but nearly half of them state they would not change the frequency of their trips in case of a hypothetical deterioration of the water quality. This could be explained by the fact that the natural attractiveness of the marine and coastal ecosystem are important factors that drive the overall decision of buying a boat, but then, once the boat is purchased, its 'everyday' use is only weakly linked with the state of the ecosystem, being instead strongly dependent on the place where the boat is normally moored and on the idea that it would be possible to look for better environmental conditions moving around the coastal area, thus avoiding the most degraded portions.

Concerning recreational fishing, only a rough comparison between capacity and flow is possible, because of the different spatial and temporal scales of the assessments. The catches corresponding to the area of the Gulf of Venice, that is, the area considered by the food-web model, can be estimated to be about half of the catches in the Italian portion of the study area (based on both the regional census of MIPAAF 2014 and the selection of fishing regions of the fishermen registered to MIPAAF in 2018). We have no means to subset the Croatian catches geographically therefore we will include only the Italian ones. A rough comparison suggests that recreational fishery represents a relevant source of mortality for the target species, the catches being on average about 10% of the biomass of the respective species. This highlights the importance to take into account marine recreational fishery in the management of the northern-Adriatic Sea.

Within this context, as can be seen from Figure 10 andFigure **15**, Natura 2000 sites contribute to create a network of areas characterized by high capacity of multiple ES, which, especially along the Italian coast, are often embedded in areas with relatively low capacity. This suggests that the efforts aiming at preserving habitats, communities and ecological processes within these sites could play a crucial role for the resilience of the ES provision in the whole coastal area.

3.4.2. Relationships 'between' ES

By adopting a perspective that considers the co-production of multiple ES we can analyze, at least conceptually, the relationships occurring between the different ES assessed.

If we look at the capacities of the three ES, it appears quite clear that they are positively related. Considering the attractiveness for tourists and boaters, the ranking attributed to the natural factors is the same. In both cases, the high ranking attributed to terrestrial habitats suggests that the naturalness of the emerged landscape is of primary importance for both categories of users. Regarding recreational fishing, the functioning of the food-web (and thus the status of the stocks of target species) can be assumed to be positively related to most of the variables used to map the factors of attractiveness. In other words, at least conceptually speaking, we can identify a synergy among the capacities of the three ES, a synergy that depends on a well-functioning ecosystem and on its self-regulation.

If we look at the flows of the three ES, the situation changes. The 'use' of the three ES, as already discussed, produces impacts on the ecosystem and thus on the other ES produced. Tourism has an effect, among others, on the land use, decreasing the naturalness of the terrestrial landscape that we have seen to be appreciated by both tourists and boaters. Boating with motorboats produces underwater noise, which affects the health and distribution of the marine community. Considering recreational fishing, similar to what has been discussed for the case of tuna fishing, we can identify an interaction between commercial and recreational fisheries. If we compare the catches from recreational fishing (by subsetting the fraction that could be ascribed to the Veneto region, that is, about 1/4 of those assessed for the four Italian regions) with the landings at the Chioggia fish market, we can observe that for some species (namely Atlantic mackerel, European seabass, gilthead seabream and sand steenbras) the catches from recreational fishing are higher than those from commercial fisheries.

These considerations highlight the complexity of the interactions between society and the marine/coastal ecosystem, and the importance to adopt a holistic perspective that includes the quantification and integrated analysis of multiple ES. In this context, monitoring the dynamics of ES capacity and flow over time would allow to observe the evolution of both the ecological functioning and the uses of the ecosystem, and to gain a deeper understanding of their interrelations. This could play a crucial role in supporting the definition and the implementation of integrated management strategies for marina and coastal ecosystems of the Adriatic Sea.

4. ECOSYSTEM SERVICES IN THE SELECTED NATURA 2000 SITES

This section presents the results of the expert judgement concerning the multiple ES in the six Natura 2000 sites selected as case study areas of the ECOSS project (Figure 22, please refer to D4.1.1 for their characterization):

- Delta del Po, IT3270023, and Delta del Po: tratto terminale e delta veneto, IT3270017,
- Tegnùe di Chioggia, IT3250047,
- Trezze San Pietro e Bardelli, IT3330009,
- Cres – Lošinj, HR3000161,
- Malostonski zaljev, HR4000015,
- Viški akvatorij, HR3000469.

The expert judgement was conducted as follows. Based on Table 1, the reference person for each site was asked to provide a score from 0 to 5 for each ES (according to Burkhard et al., 2009), where 0 = no relevant provision, 1 = very low relevant provision, 2 = low relevant provision, 3 = medium relevant provision, 4 = high relevant provision and 5 = very high relevant provision of each ES in the respective N2000 site. In case they had no means to provide a judgement on that ES, they were given the option to indicate "unknown". Furthermore, they were asked to provide a brief description of how each ES applies to the Natura 2000 site under their responsibility, along with a brief argumentation of the score assigned. In order to keep the request simple, no distinction between capacity and flow has been done. Due to their similar characteristics, a joint expert judgement has been provided for the sites Tegnùe di Chioggia and Trezze San Pietro Bardelli.

The results of the expert judgement are summarized in Figure 23, whereas Table 13Table 14, Table **15**, Table **16**, and Table **17** report the descriptions of the ES with highest provision (scores 3, 4 or 5) within each site, as provided by the reference person for each site.

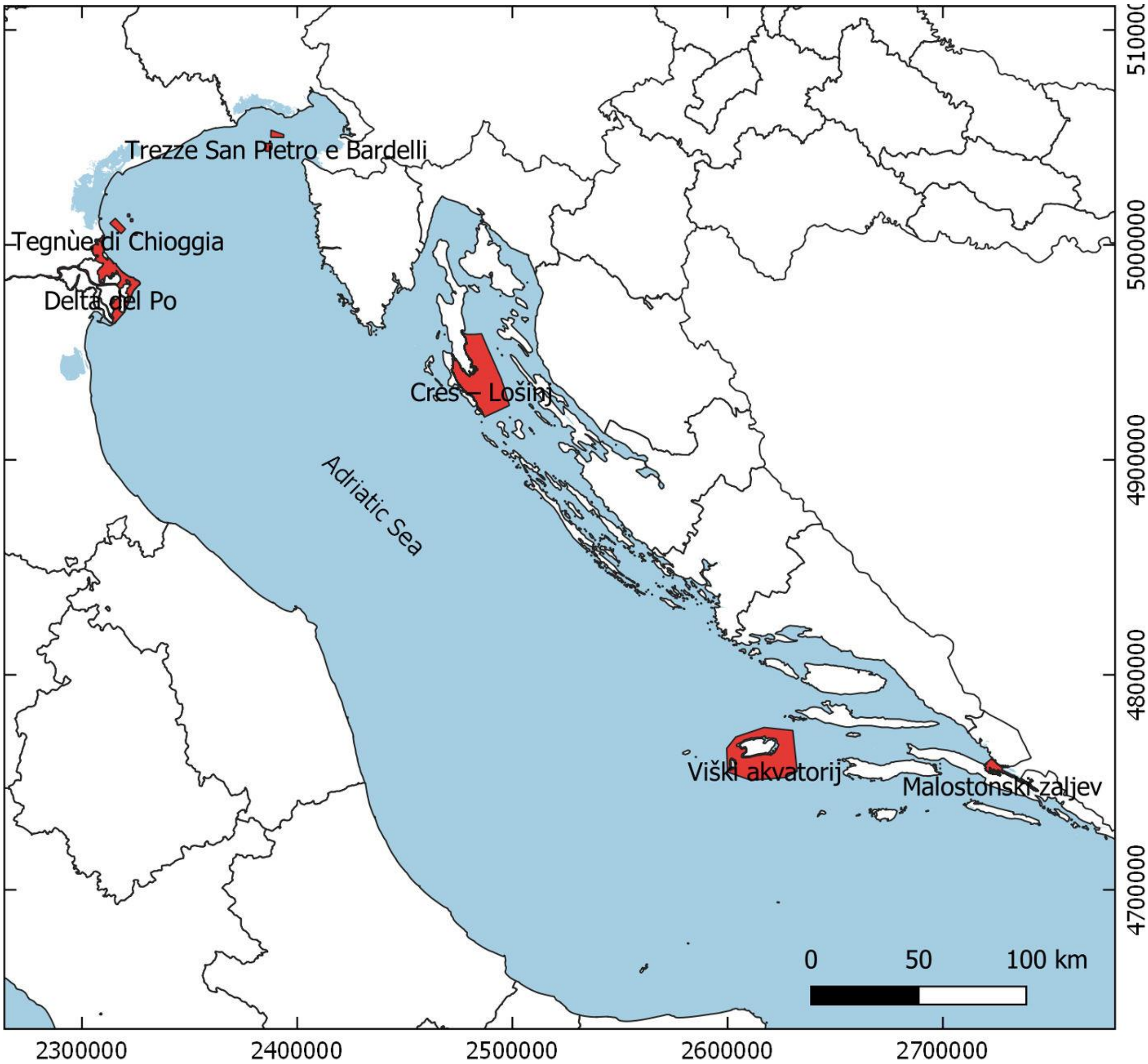

Figure 22. Natura 2000 sites selected as case study areas of the ECOSS project.

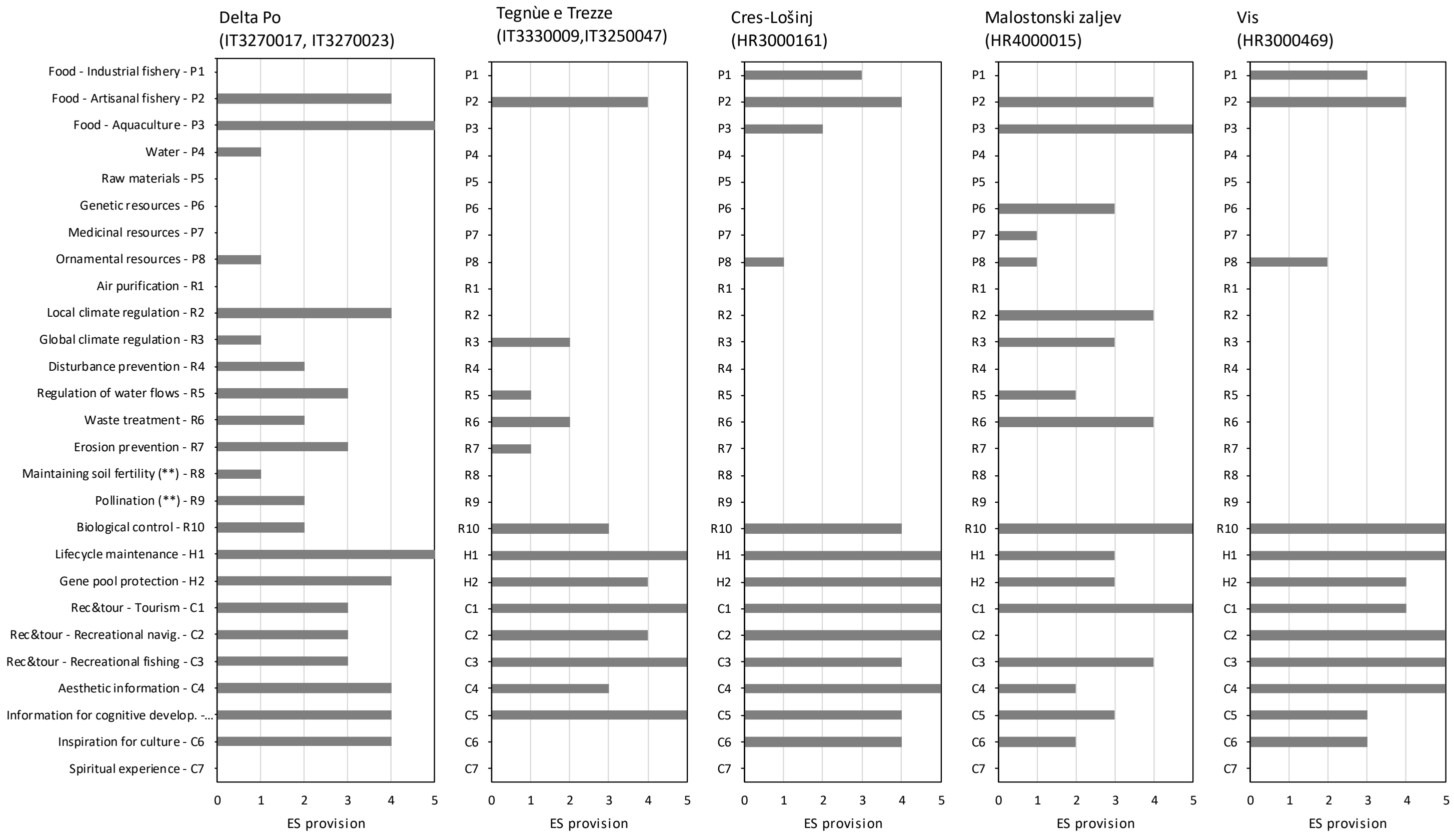

Figure 23. Results of the expert judgment concerning the multiple ES in the Natura 2000 sites selected as case study areas of the ECOSS project. ES provision is expressed on a 0-5 scale, where 0 = no relevant provision and 5= very high relevant provision

Table 13. Description of the ES with highest provision (scores 3, 4 or 5) in the Delta del Po site. Abbreviations: P=provisioning ES, R=regulating ES, H=habitat/maintenance ES, C=cultural ES.

Cat.	Ecosystem services	Score	Context-specific description
P	**Food - Aquaculture**	5	The lagoons area is extremely important for the production of shellfish, especially *Ruditapes philippinarum*. It is one of the most important areas in Italy.
H	**Lifecycle maintenance**	5	Thanks to their characteristics of large wetlands, the two N2K are important areas for the recruitment, refuge and food for many organisms, including commercial species, linked to aquatic environments. Adult individuals of migratory (and also breeding) species can move outside the protected sites and repopulate the surrounding unprotected areas (spillover effect).
P	**Food - Artisanal fishery**	4	The artisanal fishery activity in these areas is relevant and it is given by a local small size fleet is of medium-small size. The lagoons and Po river are areas historically used by local fishermen
R	**Local climate regulation**	4	The great abundance of waters favors the maintenance of the local climate
H	**Gene pool protection**	4	They are important source sites for spawning and dispersal of species, maintaining genetic connectivity in the network of rocky outcrops of the Northern Adriatic Sea, as demonstrated by Bandelj et al. (submitted).
C	**Aesthetic information**	4	The naturalness of many of the N2K sites lagoons generates strong emotions in visitors
C	**Information for cognitive develop.**	4	The presence of the 2 N2K sites allowed the realization of many dissemination projects at schools and research projects of the Universities of Ferrara, Padua and Venice
C	**Inspiration for culture**	4	The site locations have inspired numerous literary, photographic and cinematographic works
R	**Regulation of water flows**	3	The presence of the Po river delta allows to maintain localized current structures in the coastal area
R	**Erosion prevention**	3	The good presence of coastal dunes contributes to the hydro-morphological protection of lagoons and sediment transport processes
C	**Rec&tour - Tourism**	3	The naturalness, the abundance of fauna and flora, in particular of the lagoons and coastal areas of the N2K sites, attracts many visitors
C	**Rec&tour - Recreational navig.**	3	The richness of fluvial, lagoon and coastal waters allows a good possibility of tourist navigation
C	**Rec&tour - Recreational fishing**	3	The good presence of fish, especially in river and lagoon waters, allows an excellent possibility of sport fishing

Table 14. Description of the ES with highest provision (scores 3, 4 or 5) in the Tegnùe and Trezze sites. Abbreviations: P=provisioning ES, R=regulating ES, H=habitat/maintenance ES, C=cultural ES.

Cat.	Ecosystem services	Score	Context-specific description
H	**Lifecycle maintenance**	5	Thanks to their high complexity and tridimensionality, the biogenic reefs in the two N2K provide substrate for recruitment, refuge and food for many organisms, including commercial species, which live on rocky bottoms. Adult individuals of migratory species can move outside the MPAs and repopulate surrounding unprotected areas (spillover effect).
C	**Rec&tour - Tourism**	5	This kind of sites (hotspot of biodiversity) are important for tourist recreation, in particular for scuba diving with self-contained breathing apparatus. Note: Some publications report damage caused by air bubbles. The most evident effects of the attendance by scuba divers are related to sessile organisms of hard substrate with an erect shape and with calcified structure typical of the coralligenous.
C	**Rec&tour - Recreational fishing**	5	This kind of sites (hotspot of biodiversity) are important for sport (recreational) fishing. Note: One research concerning the coralligenous, highlighted the destructive effect of anchors at the level of some bioconstructors of the habitat (Bavestrello et al., 1997).
C	**Information for cognitive develop.**	5	Due to their specific wealth, the ecosystems of Trezze and Tegnùe represent a heritage of biodiversity to be protected and studied in terms of habitat, precisely due to the presence of species relevant for the purposes of international protection and conservation protocols.
P	**Food - Artisanal fishery**	4	The fishery activity in these areas is artisanal given that the local fleet is of medium-small size. Off-shore rocky outcrops are a hotspot of biodiversity in the Northern Adriatic Sea and these areas are historically used by local fishermen.
H	**Gene pool protection**	4	They are important source sites for spawning and dispersal of species, maintaining genetic connectivity in the network of rocky outcrops of the Northern Adriatic Sea, as demonstrated by Bandelj et al. (submitted).
C	**Rec&tour - Recreational navig.**	4	These sites represent a big opportunity for recreational navigation with leisure boats. They are a hotspot of biodiversity and therefore the boaters come to these sites for scuba diving and sport fishing. Note: One research concerning the coralligenous, highlighted the destructive effect of anchors at the level of some bioconstructors of the habitat (Bavestrello et al., 1997).
R	**Biological control**	3	The protected biogenic reefs act as reservoirs of organisms and sources of dispersal particles for non-protected reefs (spillover effect), and as refugia, spawning and nursery area of many pelagic and mobile species living in the Northern Adriatic Sea.
C	**Aesthetic information**	3	Especially for underwater tourism this particular marine ecosystem can generate some remarkable emotional responses.

Table 15. Description of the ES with highest provision (scores 3, 4 or 5) in the Cres – Lošinj site. Abbreviations: P=provisioning ES, R=regulating ES, H=habitat/maintenance ES, C=cultural ES.

Cat.	Ecosystem services	Score	Context-specific description
H	**Lifecycle maintenance**	5	Even though not a migratory species, the bottlenose dolphins here use the site for all life stages. Available studies regularly report presence of newborns, with notable proportion of them remaining resident in this area also in adulthood.
H	**Gene pool protection**	5	The site hosts a long-term resident sub-population of bottlenose dolphins, with stable abundance across years. The sub-population is not isolated, as numerous transient individuals are regularly reported here, possibly contributing to genetic diversity.
C	**Rec&tour - Tourism**	5	The developed touristic infrastructure on land along with a long tradition in tourism and a natural beauty, make this site a highly exposed touristic destination. Therefore, numerous touristic recreational services are developed, including diving trips, daily excursions, dolphin-watching, etc...
C	**Rec&tour - Recreational navig.**	5	Facilities on land supporting the recreational boating (marine gas stations, marinas) and numerous sheltered bays suitable for anchoring make this site a popular destination for recreational boaters.
C	**Aesthetic information**	5	Diverse coastline, clear sea and relatively large proportion of not-urbanized coastline makes this site visually attractive and popular touristic destination, known for its natural beauty
P	**Food - Artisanal fishery**	4	Artisanal fisheries are active year-round; a relatively small number of locals fish professionally and there is a notable number of locals and visitors fishing recreationally
R	**Biological control**	4	This site hosts diverse habitat types and the connected ecological communities, resulting in rich biodiversity. The target species of this site, the bottlenose dolphin is a top predator with a role in maintaining the ecological equilibrium.
C	**Rec&tour - Recreational fishing**	4	With rich biodiversity and available harbors, the site is popular destination for recreational fishermen, both from boat and from coast
C	**Information for cognitive develop.**	4	The Blue World Institute runs "Lošinj Marine Educational Centre" since 2003, hosting a permanent exhibition on marine biodiversity and conservation, providing educational programs for local school and numerous visiting school groups, specialized courses for graduate students. Furthermore, the BWI runs a long-term research project on bottlenose dolphins, focusing on this N2K site
C	**Inspiration for culture**	4	The local island community is traditionally strongly connected to this N2K site, yielding a number of artists that use the area as inspiration. This is reflected in numerous art galleries and rich cultural heritage
P	**Food - Industrial fishery**	3	Industrial-scale fisheries (purse-seiners) are occasionally active within or near this N2K site, depending on the season, e.g. availability of target species

Table 16. Description of the ES with highest provision (scores 3, 4 or 5) in the Malostonski zaljev site. Abbreviations: P=provisioning ES, R=regulating ES, H=habitat/maintenance ES, C=cultural ES.

Cat.	Ecosystem services	Score	Context-specific description
P	**Food - Aquaculture**	5	One of the most important economic sectors in the area. Marine protected area for oyster farming, the most important farmed species is European flat oyster *Ostrea edulis*, but there are also other species in local aquaculture, e.g. mussel (*Mytilus galloprovincialis*) and fish, European seabass (*Dicentrarchus labrax*) and gilthad seabream (*Sparus aurata*).
R	**Biological control**	5	The area is important as a habitat for autochthonous species European flat oyster (*Ostrea edulis*), and abundant population of noble pen shell (*Pinna nobilis*), both endangered and extinct from many other European sites. Oyster populations are bonamia free and noble pen shell populations are being decimated by a parasite. These two species inhabit different habitats- oysters are attached to the narrow rocky shore belt, but most of the oysters are attached to the farming installations. Contrary, pen shells are situated in predominant soft sediments which are sometimes covered with seagrass *Cymodocea nodosa*. Specific naturally moderately eutrophic ecosystem provides rich and diverse diet to many other different species of filter feeding organisms, especially suitable to oyster larvae which are being collected for the farming.
C	**Rec&tour - Tourism**	5	Along with agriculture and aquaculture, tourism is one of the most important economic sectors of the area. This is an example of successful attractive synergy of tourism and other sectors, all sharing common interest in preserving natural resources and clean environment.
P	**Food - Artisanal fishery**	4	Besides farming, shellfish are also collected from the wild. Local fishermen use traditional methods for shellfish collection (warty Venus, Noah's Ark shell, the bearded horse mussel, the smooth clam) and fishing (mostly sea bream, mullets, cuttlefish).
R	**Local climate regulation**	4	Local climate and air quality are influenced by regular winds which are season specific. Owing to surrounding karst area which is full of caves and karst sinkholes, there are a number of underwater freshwater springs which provide not only nutrients to the bay, but also moderating water temperature, especially in extremely hot summers or extremely cold winters.
R	**Waste treatment**	4	The ground water from karstic area which surrounds the bay together with waste waters from heterogeneous sources flow into marine environment which purifies all inflow.
C	**Rec&tour - Recreational fishing**	4	Recreational fishing is low scale activity in the area, but it improves the diversity of the diet of the local inhabitants. It also provides social events to the certain, mainly elder population groups.
P	**Genetic resources**	3	*Ostrea edulis* and *Pinna nobilis* populations present in Mali Ston Bay are important genetic resource of endangered species. Furthermore, there is also a possibility of further research on Bonamia resistant *O. edulis* strains.

Cat.	Ecosystem services	Score	Context-specific description
R	**Global climate regulation**	3	High production in the Mali Ston Bay means high biomass of the phytoplankton responsible for carbon sequestration in the water column.
H	**Lifecycle maintenance**	3	Mali Ston Bay is protected as a Special marine reserve in order to maintain biodiversity and good health of the ecosystem, which supports the most important human activity in this area - shellfish farming. There is a Special Protection Areas for birds (SPA) in wider coastal area.
H	**Gene pool protection**	3	This is a marine ecosystem with high biodiversity and some rare and endangered species are present.
C	**Information for cognitive develop.**	3	Since the Mali Ston area is rich with historical and cultural tradition which provides opportunity of in situ education, it is being visited by numerous educational institutions.

Table 17. Description of the ES with highest provision (scores 3, 4 or 5) in the Viški akvatorij site. Abbreviations: P=provisioning ES, R=regulating ES, H=habitat/maintenance ES, C=cultural ES.

Cat.	Ecosystem services	Score	Context-specific description
R	**Biological control**	5	This site hosts both coastal and open sea habitat types and the connected ecological communities, resulting in rich biodiversity. The target species of this site, the bottlenose dolphin is a top predator with a role in maintaining the ecological equilibrium.
H	**Lifecycle maintenance**	5	Even though not a migratory species, the bottlenose dolphins here use the site for all life stages. Available studies regularly report presence of newborns indicating the importance of the site as nursing grounds
C	**Rec&tour - Recreational navig.**	5	Facilities on land supporting the recreational boating (marine gas stations, marinas) and numerous sheltered bays suitable for anchoring make this site a popular destination for recreational boaters.
C	**Rec&tour - Recreational fishing**	5	With rich biodiversity and available harbors, the site is popular destination for recreational fishermen, both from boat and from coast
C	**Aesthetic information**	5	Diverse coastline, clear sea and relatively large proportion of not-urbanized coastline makes this site visually attractive destination, known for its natural beauty
P	**Food - Artisanal fishery**	4	Artisanal fisheries are active year-round; a relatively small number of locals fish professionally and there is a notable number of locals and visitors fishing recreationally
H	**Gene pool protection**	4	The site hosts a small long-term resident sub-population of bottlenose dolphins, with stable abundance across years. A larger proportion of individuals encountered here are transients that possibly play a role in genetic diversity
C	**Rec&tour - Tourism**	4	The touristic infrastructure on land is mainly oriented at family vacations in apartments and not big hotels exists, resulting in absence of mass-tourism. Nevertheless, services providing diving trips, excursions, visits to natural phenomena (Blue Cave at Biševo) are present
P	**Food - Industrial fishery**	3	The site encompasses a part of the fishing ground for bottom trawlers and purse-seiners that occasionally operate in the area
C	**Information for cognitive develop.**	3	Educational provisions mainly include field trips of local schools. The Blue World Institute runs a seasonal field station on the island of Vis, from which the research on bottlenose dolphins is conducted, along with opportunistic surveys on other species
C	**Inspiration for culture**	3	The local island community is traditionally strongly connected to this N2K site, yielding a number of artists that use the area as inspiration. This is reflected in numerous art galleries and rich cultural heritage.

If we look at the average values of each ES category in the different sites (Figure 24), we can observe that for all the sites the habitat/maintenance ES (lifecycle maintenance and gene pool protection) are those with the highest score, followed by cultural, regulating and provisioning ones, always with the same ranking. All this highlights the suggestion that all these sites could play an important ecological role not only locally but also with respect to the surrounding marine and coastal areas. On the other side, the high provision of cultural ES underlines the recreational importance of these natural areas, in which a variety of recreational activities is taking place. This confirms the correctness of the choice of the three recreational ES as focus for the basin scale assessment. Interestingly, among the sites there are examples of a positive integration between tourism and nature protection (as reported in the Mali Ston bay, where tourism is a key economic sector and does not enter in conflict with nature conservation nor with the provision of other ES, see Table 16) and examples of less positive integration (as reported in Tegnùe and Trezze, where relevant impacts of recreational activities on the ecosystem are highlighted, see Table 14). The relatively low score reported for regulating ES, whose provision is generally high in areas with good ecological conditions, could be due to the fact the it could be quite difficult even for the people directly involved in the nature conservation programs to recognize their presence. Finally, provisioning ES have the lowest average score, suggesting that we do not find several provisioning ES at the same time in the same site. However, if we look at Figure 23, we can see that in each site there is always one ES, either artisanal fishery or aquaculture, with high or very high provision. Again, in some sites a positive integration between provisioning ES and the other ES has been reported, as the case of oyster farming in Mali Ston bay.

If we look across the spatial scales (basin scale vs local scale), we find a good overall agreement between the assessment and the expert judgement concerning the three cultural ES. In particular, the basin scale assessment allows making some considerations on the sites. For example, if we consider tourism and boating, we can observe that the Tegnùe and Trezze sites are nearby some of the areas with the most intense flows of these ES within the whole Northern-central Adriatic. If we instead consider the capacity of these ES, we can see that these sites represent spots of relatively high natural attractiveness in areas where, in general, the natural attractiveness is relatively low. This could suggest that a relevant visiting pressure exists on these sites compared to the others, which explains the notes on the impacts of diving and boating activities reported by the reference person of these areas. If we instead look at the Mali Ston site, where a positive integration between mediated and direct ES has been reported, we can see that tourism flow has a medium provision respect to the rest of the study area, whereas boating has a very low flow. This suggests that, in order to achieve a sustainable integration of multiple ES, characterized by the conservation of nature and of the ES capacity, the provision of mediated ES should be balanced in a way that does not impair the provision of the other ES.

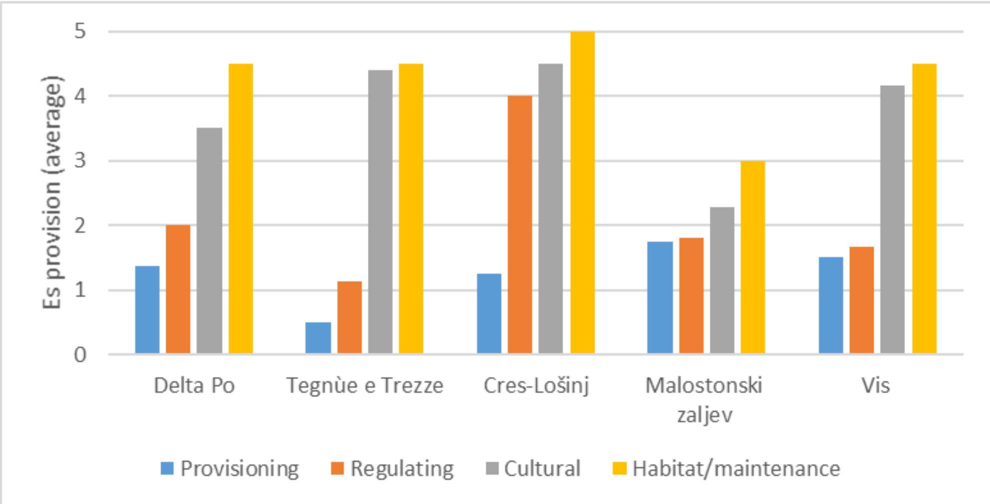

Figure 24. Average provision of each ES category in the Natura 2000 sites.

5. CONCLUSIONS

Marine and coastal social-ecological systems provide multiple ES, whose dynamics are characterized by high complexity. This deliverable contributes to advance the currently limited knowledge on the multiple ES provided by the northern-central Adriatic coastal area, through an approach that may support the implementation of monitoring schemes that include the assessment of ES. The work presented is contributing to the overall objective of the ECOSS project, that is, the establishment of the ECOlogical observing system in the Adriatic Sea (ECOAdS), that integrates the ecological and oceanographic research and monitoring with the conservation of the Natura 2000 sites.

A conceptual model is proposed that, although in a simplified way, attempts to depict how multiple ES emerge from ecological structures and processes, and from the complex feedbacks generated by the interactions between society and the ecosystem. Based on the conceptual model we discuss that, from an ES perspective, the goal is a healthy ecosystem that provides multiple ES both now and in the future. To achieve this goal, management should target the ES capacity rather than their flow and should do so with temporal perspective: to prevent that the ES capacity declines over time. Preserving ES capacity can be assimilated to the build-up of insurance for our future, as it would increase the resilience of the ecosystem and of the ES flow with respect to perturbations. Given a global context in which these perturbations are expected to increase dramatically (e.g. increasing frequency and intensity of extreme events due to climate change, but also the outbreaks of new diseases, as in the case of COVID19), the investment in ecological resilience could be the only way to adapt to an ever-changing situation. The analysis through the lens of the proposed conceptual model could facilitate this task by highlighting the mechanisms that underpin a decline in the capacity.

The ES assessment at northern-central Adriatic scale, structured as a quantification of ES capacity and flow, provides a relevant amount of data and information on three key cultural ES, namely tourism, recreational navigation and recreational fishery. This broad scale assessment is needed to characterize the context in which Natura 2000 sites selected by the project are located. Given a situation in which the available knowledge on ES capacity and flow in marine and coastal systems is very limited, this assessment represents a step forward towards the implementation of integrated management approaches such as that outlined above.

Finally, the deliverable presents the results of an expert judgement on the multiple ES in the Natura 2000 sites upon which the ECOSS project is focused. In all the sites it emerges that habitat/maintenance ES are, on average, the ES with the highest provision, followed, in order, by cultural, regulating and provisioning ES. Following what has been proposed above, from our perspective the management of the sites could target at balancing the flow of multiple ES in a way that the underpinning ES capacity is maintained, by adjusting the flow of those ES which produce impacts, and preserving the habitat and regulating ones.

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