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TOWARDS STRONG SUSTAINABILITY: A FRAMEWORK FOR ECONOMIC AND ECOLOGICAL MANAGEMENT OF MARINE PROTECTED AREAS

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NATURAL CAPITAL
BENEFITS
COST BENEFIT ANALYSIS
EMERGY ANALYSIS
SYSTEM ANALYSIS
BIOPHYSICAL METHODS
ECOSYSTEM SERVICES MAPS

ABSTRACT. – In this study, an operational tool for environmental accounting is proposed to assess natural capital value and to obtain a budget encompassing ecosystem services, putting into practice the notion of "ecosystem services cascade". The accounting system is based on a previous framework (EAMPA project) developed for MPAs. The tool implements some additional features bringing significant improvement of the framework in order to achieve sustainability. At this purpose two parallel accounts, ecological and economic, are developed and then compared aiming at achieving a net benefit from both domains. The economic approach considers, together to financial revenues and costs, all the direct and indirect benefits from MPA's ecosystem services fruition. The ecological approach is formulated so that results are obtained under a strong sustainability perspective and direct impacts on MPA natural capital, associated with ecosystem services fruition by MPA's customers, are taken into account and included into the budget.

INTRODUCTION

Haines-Young & Potschin proposed in 2011 the "ecosystem services cascade", a framework that highlights the feedback from the socio-economic system on ecosystems. This feedback is due to impacts generated not only by ecosystem services (ES) fruition but also by management strategies (Fig. 1). The cascade can be interpreted as the pathway from ecosystem structure and processes to human well-being, a framework where the ES are the link between ecosystems and economics. From biophysical components, that make up the natural capital (NC), all the functions potentially useful for mankind are originated. Ecosystem functions represent the potential to generate ES from NC stock and they exist independently from humans' behaviour (TEEB 2010). When humans find some utilities in a function, this function enters the ES domain. Benefits to humans are originated from ES fruition.

Based on these theoretical foundations, in 2013 the Italian Ministry of the Environment and Protection of Land and Sea launched the Environmental Accounting in Marine Protected Areas (EAMPA) project. EAMPA is a 4-years research programme aimed at implementing an environmental accounting system across Italian Marine Protected Areas (MPAs).

The main goal of EAMPA was the calculation of a budget taking into account the ecological and economic value of the MPAs, with particular reference to ES generated in each protected area (Franzese et al. 2015) and the aggregated net benefit returned to the economy.

The program aimed at the achievement of a standardized assessment of NC as well as environmental costs and benefits in all Italian protected areas by means of two parallel pathways and six operational phases (Fig. 2, Table I). The detailed methodology and steps of the project are described in Franzese *et al*. (2015) and Vassallo *et al*. (2017).

Following EAMPA, in the context of the EU Interreg project *Integrated management of ecological networks through parks and marine areas* (GIREPAM), an upgraded version of the framework has been realized and it is here illustrated. The updated framework aims: 1) to obtain two different budgets (with the corresponding net benefit), the economic and the ecological accounts; 2) to highlights the interactions between the ecological and the human domains, according to the ES cascade theory.

The ES cascade clearly shows how human economies are constrained by the availability of natural stocks.

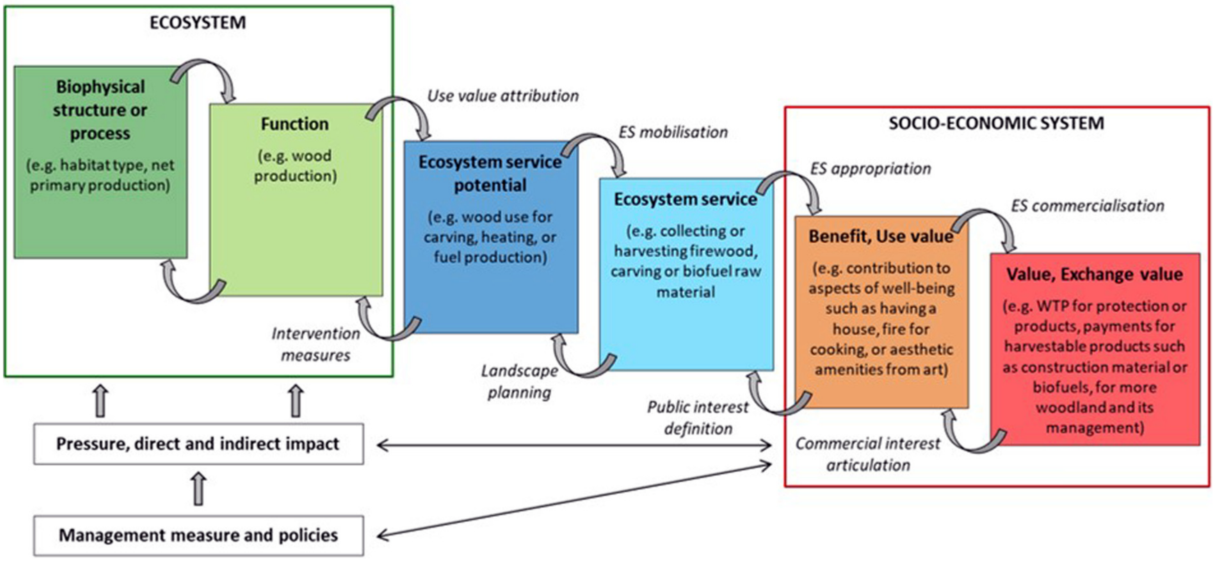

Fig. 1. – A schematic representation of the ecosystem services cascade (Spangenberg *et al*. 2014).

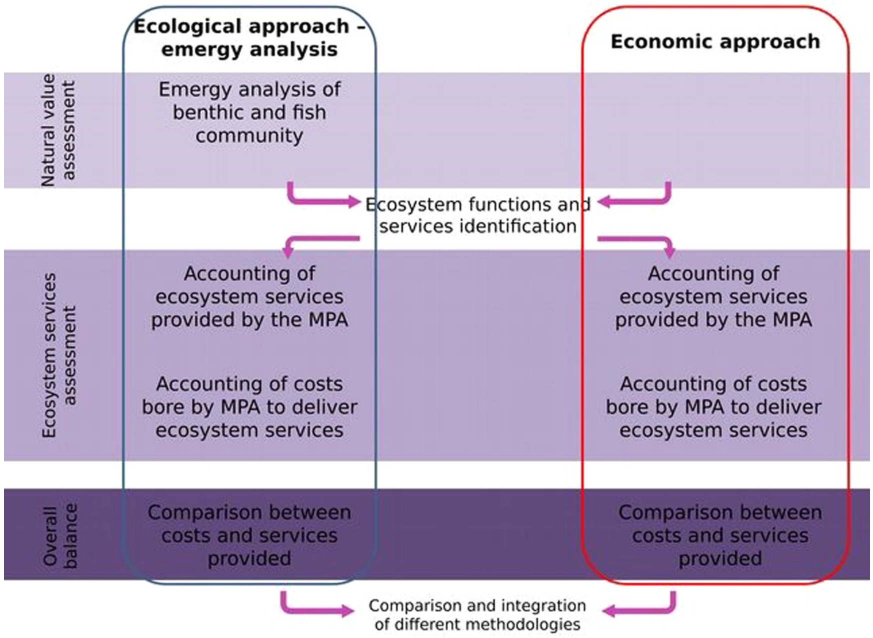

Fig. 2. – Flowchart of the EAMPA project: environmental and economic research pathways.

Table I. – Main steps of the EAMPA project and calculation methods employed for the fulfilment of the different project phase.

Activity description	Ecological pathway calculation method	Economic pathway calculation method
Data gathering: analysis of existing data and new data collection		
Assessment of the ecological value of the MPAs by means of emergy analysis	Emergy analysis (Odum 1996, Vassallo *et al.* 2017, Paoli *et al.* 2018)	
Identification of ecosystem functions and services	Haines-Young & Potschin 2011, CICES	
Assessment of environmental and economic costs and environmental impacts	Emergy analysis (Odum 1996)	Carbon footprint with social cost of carbon (Visintin *et al.* 2016)
Assessment of environmental and economic benefits		Willingness to pay, financial statement analysis (Visintin *et al.* 2016)
Overall costs-benefits balance	Franzese *et al.* 2015	
Implementation of an operational GIS platform		

Indeed, ES flows that keep our economies working originate from NC (Sukhdev *et al.* 2010). Costanza and Daly (1992) introduced the concept of NC, associated with human capital and manufactured capital. NC is the economic metaphor for the limited stocks of physical and biological resources and it includes land, air, water, sea and ecosystems themselves. Human capital comprises all individuals' capacities for work, while manufactured capital encompasses material goods generated through economic activity and technological change (UNU-IHDP & UNEP 2012). Under the perspective of strong sustainability, NC is irreplaceable with manufactured capital (de Groot *et al.* 2002, 2012) since the current level of ES supply can be ensured only if NC is maintained constant.

It is important to distinguish financial and environmental accounting. Financial accounting is designed to convey information to external shareholders and financial authorities by means of standardized procedures that generate comparable data. The main goal of financial accounting is to assess the economic performance of a company or institution in accordance with national laws and international accounting standards (Jasch 2003). Environmental accounting, instead, is based on material flow budgets. These budgets are realized through the quantification of material and energy flows within a defined system boundary and expressed in physical units. Biophysical evaluation methods, able to quantify physical features and developed to be integrated with the preference-based assessments of natural resources (Jørgensen 2010, Müller & Burkhard 2012, Odum 1996, Wackernagel *et al.* 1999), are particularly suitable for environmental accounting. Biophysical methods usually use a cost of production approach or the so-called *donor-side* perspective. To understand this perspective nature can be represented as an input-state-output system (Pulselli *et al.* 2011). A *user-side* approach focuses on outputs and on the identification of users that exploit them; a *donor-side* one focuses on inputs. The ES theory is a typical *user-side* approach (Costanza *et al.* 1997, TEEB 2010) based on an anthropocentric viewpoint (de Groot *et al.* 2002), while biophysical methods are founded on the assessment of taken resources and are thus classified as *donor-side* approaches.

To gain a real sustainability, integrating both economic and ecological approaches, it is fundamental to connect the two sides of the coin (donor/user) in order to set up efficient management strategies. Making this connection a paradigm shift is needed, from weak to strong sustainability theory. The weak sustainability theory presupposes the full substitutability of NC with the manufactured capital and aims to maintain their sum constant over time, compensating for the decrease of one with the increase of the other. According to this theory, an economy can be considered sustainable even if it impoverishes the NC on which is based upon. Moreover, if the weak sustainability concept is embraced, there is no contradiction between sustainability and continuous economic growth, since the NC can be replaced by a same amount of manufactured capital (Gowdy & O'Hara 1997) blinding the loss of intrinsic value of the NC that so occurred. On the contrary, according to strong sustainability theory, natural and manufactured capital is not mutually replaceable, so each component must be kept constant (Chiesura & de Groot 2003). The unsubstitutability lays on several reasoning among which the existence of NC "critical" components contributing to welfare in a unique way (Chiesura & de Groot 2003). Furthermore, according to the laws of thermodynamics, the transformation of NC into artificial is an irreversible process. A decrease in NC is, therefore, a sign of non-sustainability (Vitousek *et al.* 1997).

As a consequence, to embrace the strong sustainability theory, two parallel budgets should be realized aiming at preserving the NC intact (Chiesura & de Groot 2003, Vitousek *et al.* 1997). Moreover, a net benefit in both of them must be obtained to manage the ecological and the economic components in a sustainable way. These two budgets can be named ecological and economic: the ecological approach measures the biophysical effort made by nature to create the exploited resources (*e.g.*, sun, wind, rain, materials, fuels, manpower) and it gives information about the environmental sustainability, while the economic one assesses the financial flows derived from this exploitation. The main goal of this research is to provide synthetic indicators of ecological and economic sustainability dealing with the ecological issue in a strong sustainability perspective and to describe the operational results of the framework application to the Portofino Marine Protected Area (NW Italy).

MATERIALS AND METHODS

Portofino MPA: The Portofino MPA was established in 1999 in the Northwestern part of Italy. It is 363 ha wide and it is widely recognized as a high natural value area, worldwide known for its emerged and submerged landscapes as well as for the rich biodiversity hosted with the remarkable presence of several endemic and endangered species. The MPA of Portofino is included in the European Natura 2000 Network as Site of Community Importance (SCI IT1332674: Fondali monte di Portofino). Since 2005 the Portofino MPA is a SPAMI (Specially Protected Area of Mediterranean Interest) according to the decision of the RAC/SPA Office (UNEP 2005).

Within the MPA many activities such as diving, fishing and recreational boating are carried out and regulated with different protection levels, from more severe in zone A to less severe in zone C. Despite the protection regime, activities, mainly tourism oriented, are very common and the pressure on local environment is very high: for instance, recreational boating reaches even around 200 units per days (Venturini *et al.* 2016) and diving activities count over 40,000 annual dives (Betti *et al.* 2019).

Natural capital assessment: NC value has been assessed as described in Vassallo *et al*. (2017) and Paoli *et al*. (2018) through emergy analysis. To create and maintain natural good and services, the environment must perform a work that requires an energy or material sources and a number of transformations. Emergy is the total amount of energy used directly or indirectly to generate a product. Since the fundamental energy that powers the biosphere is solar energy, the work done by the environment through all the transformations to obtain a product can be calculated as the total amount of equivalent solar energy. In such a way, emergy is able to attribute a value to environmental goods and services in terms of production cost necessary to obtain them (Odum 1996). Emergy analysis pertains to the so-called biophysical methods for NC evaluation. These methods allow to ascribe a value to a good or service on the basis of its intrinsic characteristics, regardless of market laws. Biophysical methods are then particularly suitable to be used in association with economic methods to obtain a full assessment (de Groot *et al*. 2010).

Table II. – UEVs employed for the MPA's emergy calculation, 15.20E+24 sej emergy baseline was used (Brown and Ulgiati 2010).

ITEM	UEV (sej/unit)	Reference
C	1.02E+08	Campbell *et al.* 2014
N	7.40E+09	Odum 1996
P	2.86E+10	Odum 1996
Sun	1.00E+00	Odum 1996
Rain	2.93E+04	Odum 1996
Wind	2.41E+03	Odum 1996
Currents	3.80E+04	Odum 1996
Geothermal heat	2.00E+04	Brown & Ulgiati 2010
Tides	7.20E+04	Brown & Ulgiati 2010
Runoff	6.61E+04	Odum 1996

NC is a stock of resources that nature stored in space and time and with a certain effort.

To evaluate MPA's NC, an inventory of all biocenosis, their surfaces and their biomass was realized. At this purpose previous studies about benthos and demersal fishes have been used (Guidetti *et al*. 2011). All items required to generate the biomass stocked in each biocenosis and in the entire MPA were assessed and then converted in emergy units. The required inputs are those allowing the photosynthetic process: through photosynthesis biomass is originated and stored in space and time. Considered items are then carbon, phosphorous, nitrogen, sun, wind, rain, tides, currents, runoff, all expressed in biophysical units (sej) using conversion factors (UEVs) in Table II. When emergy is calculated for each biocenosis, the sum of their values gives the MPA overall NC. In this work 15.20E+24 sej emergy baseline (Brown & Ulgiati 2010) was used for emergy calculation. The final unit of measure for NC evaluation is emergy-euro (em€), namely the emergy biophysical unit (sej) translated in money equivalent by means of appropriate conversion factors (Vassallo *et al*. 2017). The conversion of biophysical NC value in "virtual" money value or currency equivalent can be done by using the indicator named Emergy to Money Ratio (EMR) (Lou & Ulgiati 2013). This indicator is calculated as the ratio between the total emergy supporting a nation and its gross domestic product in the same year (Brown & Ulgiati 2004). EMR represents the average amount of emergy needed to generate one unit of money in the national economy (Odum 1996). The monetary value of NC for each habitat is then calculated by dividing the emergy value by the EMR. The monetary value of NC for the whole MPA is calculated as the sum of the monetary values of all the habitats (Vassallo *et al*. 2017). Even if the NC conversion in monetary units is not compulsory, most of all in a strong sustainability approach, nonetheless this makes results easily conveyable from scientists to managers and also from managers to general public or key stakeholders (*e.g*., tourists or fishermen). Detailed results are presented in Paoli *et al*. (2018).

Table III. – List of selected and evaluated services framed in the context of CICES scheme.

Section	Division	Group	Class	Simple descriptor	Specific service evaluated
Provisioning (biotic)	Biomass	Wild animals (terrestrial and aquatic) for nutrition, materials or energy	Wild animals (terrestrial and aquatic) used for nutritional purpose	Food from wild animals	Wildlife exploitation for food purposes through professional artisanal fishing
Regulation & maintenance	Regulation of physical, chemical, biological conditions	Atmospheric composition and conditions	Regulation of chemical composition of atmosphere and oceans	Regulating our global climate	Climate regulation through Carbon storage by autotrophs
Cultural	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	Physical and experiential interactions with natural environment	Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through passive or observational interactions	Watching plants and animals where they live; using nature to destress	Tourist use and economic impacts from: bathing tourism; pleasure boating; recreational diving; sport and recreational fishing

Table IV. – Items considered for emergy environmental costs of considered ES.

	ES					
	Bathing	Diving	Recreational boating	Sport and recreational fishing	Professional and artisanal fishing	MPA institutional activity
Fuel for users' journey	X	X	X	X		
Fuel for users' navigation		X	X	X	X	
Fuel for MPA vehicles						X
Electricity by activity	X	X				X
Natural gas by activity	X	X				X
Drinking water by activities	X	X				X
Means of transport			X	X	X	X
Consumer goods						X
Expenditures	X	X	X	X	X	
Human labor	X	X	X		X	X

ES assessment and budget implementation: The ES taken into account and evaluated were selected among CICES scheme (Haines-Young & Potschin 2011) (Table III) and in particular are: 1) wildlife exploitation for food purposes through professional artisanal fishing; 2) climatic regulation; 3) tourist use (*i.e.*, bathing tourism; pleasure boating; recreational diving; sport and recreational fishing); 4) economic impacts. Even if the list of ES provided by marine ecosystems is much greater (Liquete *et al.* 2013), this ES selection has been identified within the EAMPA project by MPA managers as a core set of services directly affected by the protection regime of the MPAs. This selection is also reported within the official National Account for the NC of the Italian ministry in the section dedicated to the MPAs (Comitato Capitale Naturale 2018).

Budget implementation was realized on an annual basis and according to Table IV from Marangon *et al.* (2008) and Visintin *et al.* (2014).

For each ES environmental annual costs and benefits are calculated through data collection and treatment from:

– questionnaires and interview campaigns for data gathering about users presences, habits and expenses, and users and economic operators resources' consumption;

– improvement of authorization system for ES fruition by users and economic operators in order to obtain data about their MPA attendance;

– inventory of resources consumed, detailed revenue and expenditure of the MPA itself;

– set up a specific data management system and a website for the rationalization of previous described data (biological data, questionnaires, authorizations) and project results.

In addition to costs and benefits related to ES, also those related to MPA institutional activities (*e.g.*, administrative and scientific activity) have been accounted.

Environmental costs and benefits are flows, respectively imposed to and generated from NC, as a consequence of ES fruition. Environmental costs are calculated here with a biophysical, ecological approach and then assessing the annual quantity of removed or damaged NC. This is an ecological donor side perspective since NC is the core of the cascade and the base from which ES arise. Environmental benefits are evaluated with both the economic, user side perspective, and the ecological, donor side perspective. When economic side is used, direct and indirect financial gains are estimated. When ecological side is embraced, the net ecological production of key components is assessed in biophysical units. Biophysical units are later translated in monetary equivalents as described for NC.

Economic benefits and costs are financial flows received and spent by the MPA.

Environmental costs: Environmental costs originate from the use of natural and man-made resources and the related impacts on natural environment due to the activities carried out by users during a year. They are therefore attributable to each ES. Environmental costs are divided into *direct environmental costs*, whose effects occur within the borders of the MPA (direct impacts), and *indirect environmental costs*, whose effects take place outside the MPA, sometimes even at very large distances (indirect impacts). Both costs categories are assessed with ecological donor side perspective using emergy analysis. The calculation of direct costs was not foreseen by the EAMPA framework and has been added as new budget module in the context of GIREPAM project.

Donor side direct environmental costs

Direct costs were assessed in the context of GIREPAM project for boaters, divers and fishermen (both recreational and professional artisanal). For boaters and divers, the cost is represented by the impacts made on the sensitive biocenosis (*i.e.*, *Posidonia oceanica* (Linnaeus) Delile and coralligenous) in terms of annual removal of NC. Specifically, boaters exert an impact due to the anchoring action on *P. oceanica* meadows. The mechanical damage due to the anchorage can be very significant especially on seagrass meadows, so much so that its survival is at risk. The exerted damage affects the entire habitat whose organ-

Table V. – Calculation formulas for environmental costs items.

Item	Data required	Data source
Fuel for users' journey	Average km travelled per user per presence	User questionnaires or authorizations
	Average consumption per km	Bibliographic or statistical sources
	Users attendance per year	Authorizations or monitoring
Fuel for users' navigation	Average expenditure per user presence for activities within MPA	Users questionnaires or authorizations
	Fuel price	Bibliographic or statistical sources
	Users attendance per year	Authorizations or monitoring
Fuel for MPA vehicles	Yearly consumption	Interviews to MPA staff
Electricity by activity	Annual consumption of operators and of the MPA institution	Interviews with commercial operators and MPA staff
Natural gas by activity	Annual consumption of operators and of the MPA institution	Interviews with commercial operators and MPA staff
Drinking water by activities	Annual consumption of operators and of the MPA institution	Interviews with commercial operators and MPA staff
Means of transport	Vehicle weight / life time	User questionnaires or authorizations
	Days of use in MPA for user presence	User questionnaires or authorizations
	Users attendance per year	Interviews with commercial operators and MPA staff
Consumer goods	Goods consumed in a year for carrying out the institutional activities of the MPA	Interviews to MPA staff
Expenditures	Average expenditure per user presence	User questionnaires or authorizations Commercial operators interview Bibliographic or statistical sources
	User attendance or total annual expenses for operators	Authorizations or monitoring and operator interviews
Human labor	Number of annual working hours dedicated to the ecosystem service	Operator interviews and authorizations Bibliographic or statistical sources

isms are impacted causing, in some cases, even changes in the trophic structure of the habitat (Francour *et al*. 1999, Backhurst & Cole 2000, Milazzo *et al*. 2002, 2004, Lloret *et al*. 2008). Divers instead impact through the physical contact with sea-bottom. Even if diving is traditionally considered an activity generating benefits without inflicting damage on the marine environment, its increase in the last decades has shown direct effects. In particular, the benthic calcareous organisms are affected due to the presence of species with high fragility and low growth rate (Milazzo *et al*. 2002, Ballesteros 2006, Lloret *et al*. 2006, Di Franco *et al*. 2009, Luna *et al*. 2009, Hammerton 2014, Betti *et al*. 2019). These negative effects are both assessed based on the presence of users yearly attending the MPA. For recreational and professional artisanal fishing, the impact is represented by the annual fish catches. Once the amount of biocenosis surface removed or damaged by boaters and divers was calculated, the value per unit of surface calculated by Paoli *et al*. (2018) has been applied to this area. The value associated to the withdrawn of fishes have been instead estimated as NC removal following Vassallo *et al*. (2017) and Paoli *et al*. (2018).

Donor side indirect environmental costs

Indirect environmental costs, on the other hand, concern the exploitation of the resources (*e.g*., fuels, materials) necessary for ES fruition within MPA (bathing, boating, diving, fishing).

Table VI. – UEVs used for calculation of emergy associated to ES fruition.

Item	UEV		Reference
Diesel	1.81E+05	sej/J	Brown *et al.* 2011
Electricity	6.53E+04	sej/J	Brown & Ulgiati 2002
Water	7.61E+05	sej/J	Buenfil 2001
Methane	1.78E+05	sej/J	Brown *et al.* 2011
Wood	3.03E+04	sej/J	Buonocore *et al.* 2014
Fiberglass	3.77E+10	sej/g	Puca *et al.* 2017
Rubber	5.79E+09	sej/g	Puca *et al.* 2017
Aluminum	2.04E+10	sej/g	Buranakarn 1998
Steel	2.63E+13	sej/kg	Puca *et al.* 2017
Manpower	9.51E+12	sej/h	Pereira *et al*. 2013
Money	9.60E+11	sej/€	Pereira *et al.* 2013

Table V lists the items included in the calculation of the environmental costs associated to consider ES. For each item, the data necessary for the calculation of the quantity consumed are reported in Table IV.

Indirect environmental costs have been accounted as:

– impact on global warming by calculating the carbon footprint;

– consumption of resources through emergy analysis assessment.

The quantities of resources consumed and expressed in

Table VII. – Conversion factors for the application of the methodologies emergy analysis and carbon footprint.

Methodology	Conversion factor	Unit pf measure	Reference
Carbon footprint	36.92	€ 2015/tCO_2	Pereira *et al*. 2013
Emergy analysis	9.60E+11	sej/em€	EPA 2016

their specific unit of measurement (*e.g*., grams, joules, kilowatt hours) are then transformed into the weight of CO_2 equivalents emitted (for calculation of carbon footprint) and into equivalent solar energy (sej, for the calculation emergy analysis).

The carbon footprint provides information related to the impact on the environment and humans as a result of greenhouse gas emissions. Emissions are quantified in tons of equivalent carbon dioxide produced by the use of energy and materials for carrying out anthropogenic activities. For the estimation of these emissions, the database published by the United Kingdom Government's Department for Business, Energy & Industrial Strategy was used (Hill *et al*. 2013). This database provides the conversion factors to transform the quantity of material or energy of each resource used into the corresponding equivalent CO_2. These conversion factors come from the Fourth Assessment Report of IPCC (Intergovernmental Panel on Climate Change; IPCC 2007) and refer to a 100-year Global Warming Potential (GWP 100). The conversion factors produced by IPCC take into account the greenhouse gas emissions generated during the entire life cycle of an item.

Emergy analysis, expresses resources required for ES fruition in the single unit of measurement of sej. At this purpose UEVs listed in Table VI were employed.

For both measures the sum of all the elements consumed provides the value of the total impact and the year was chosen as the temporal functional unit.

The values in emergy and carbon footprint units can be transformed into equivalent monetary units through the use of the conversion factors shown in Table VII (Pereira *et al*. 2013, EPA 2016). This conversion allows the two measures to be included in "cost-benefit" analyses. As a consequence, they represent tools to carry out an assessment of the damage generated and to implement mitigation measures.

Environmental benefits: Environmental benefits were accounted with both an economic and an ecological approach. In particular, when the economic approach is embraced, the environmental benefits are assessed as real or virtual yearly monetary benefit to humans associated with ES fruition. These benefits are called user side environmental benefits since they generate advantages only for humans, and not for nature, but they directly arise from the enjoyment of nature. On the contrary, when the ecological perspective is taken into account, the environmental benefits can be assessed as the monetary value associated to the biophysical production of the considered biocenosis and are then called donor side environmental benefits since they represent, first of all, a profit for nature.

User side environmental benefits

The environmental benefits associated with the following ES have been considered: 1) wildlife exploitation for food purposes; 2) climatic regulation; 3) tourist use; 4) economic impacts.

Wildlife exploitation for food purposes is the catches of biological resources due to fishing. The catches amounts are converted into monetary values at market prices.

Climate regulation is associated with the greenhouse gas cycles regulation performed by ecosystems. The sea, in particular, plays a fundamental role thanks to its ability to accumulate CO_2 that would otherwise be released into the atmosphere, increasing the greenhouse effect.

Tourist use refers more precisely to the physical and experiential use of plants, animals, marine and terrestrial landscapes and, therefore, to the environmental benefits which divers, sports fishermen, boaters and bathers appropriate. It is quantified through the number of users and its monetary value can be estimated through the contingent valuation method (CVM), and in particular by estimating the Willingness to Pay (WTP, Hawkins 2003). This represents the maximum amount that a user is willing to pay for a specific good or service, in this case for the preservation of the MPA, over the amount already paid to carry out the specific activity. CVM use can be controversial if applied in non-use value and it has been criticized for some weaknesses and biases that include, for instance, the failure of respondents to incorporate their personal budgets in valuation decisions, embedding effect, and overestimation of values (Diamond & Hausman 1994, Hausman 2012). Nonetheless, it is considered an effective method for estimating ES and it is a widely used for estimating non-marketed values given its wide applicability, flexibility and strong operability (Brander & Koetse 2011, Mutandwa *et al*. 2019, Bostan *et al*. 2020, Chu *et al*. 2020, Malinauskaite *et al*. 2020).

Economic impacts derive from the physical and experiential use of plants, animals and marine and terrestrial landscapes. In particular, it relates to direct, indirect and induced economic revenues associated with the activities of divers, sports fishermen, boaters and bathers exercised by tourists spending on the economic system. The direct effect is the impact of the expenses incurred by the user on the local economy, which would not have materialized in the absence of the aforementioned ES (*e.g*., food, accommodation). The indirect effect is the impact on supply companies that respond to the greater local demand due to the direct effect (*e.g*., food industry, maintenance). The induced effect is the impact deriving from the change in the level of income available to residents due to the greater demand for work.

Donor side environmental benefits

Donor side benefits, generated by the habitats or habitat components subjected to direct pressures and costs and described in the paragraph about donor side direct environmental costs, have been assessed. These benefits have been assessed only for the components subjected to direct cost in order to investigate if the impact exerted by humans is sustainable or not in a strong sustainability perspective. If costs are greater than benefits the NC is eroded as a consequence of ES fruition.

Table VIII. – Framework for budget calculation.

A	BENEFITS PER YEAR	B	COSTS PER YEAR
	ENVIRONMENTAL BENEFITS		ENVIRONMENTAL COSTS
a1	*ENVIRONMENTAL BENEFIT – economic user side*	b1	*INDIRECT ENVIRONMENTAL COSTS – ecological donor side*
	Wildlife for food		Pleasure boating
	Control of erosive phenomena		Recreational diving
	Nursery		Sport and recreational fishing
	Climate regulation		Professional artisanal fishing
	Tourist use		Bathing
	Economic impacts		MPA Institutional activity
	Scientific activity		
	Educational activity		
a2	*ENVIRONMENTAL BENEFITS – ecological donor side*	b2	*DIRECT ENVIRONMENTAL COSTS – ecological donor side*
	Coralligenous secondary production		Pleasure boating
	Fish secondary production		Recreational diving
			Sport and recreational fishing
			Professional artisanal fishing
a3	*ECONOMIC BENEFITS*	b3	*ECONOMIC COSTS*
	Current revenues		Current expenditures
	Capital revenues		Capital expenditures
	Reallocation of funds		Reallocation of funds
	TOTAL BENEFITS		TOTAL COSTS
	AGGREGATED NET BENEFIT (A – B)		
	NET USER SIDE ECONOMIC BENEFIT (a1 + a3 – b3)		
	NET DONOR SIDE ECOLOGICAL BENEFIT (a2 – b1 – b2)		

These components are: 1) coralligenous habitat (damaged by divers); 2) *P. oceanica* habitat (damaged by anchoring); 3) fish stocks (subjected to sport and recreational fishing as well as to artisanal professional fishing).

The benefits are then assessed as secondary production generated, taking into account the production/biomass ratio and the mortality rates of composing organisms according to the following equation:

$$\textit{Net secondary production} = \sum_{i=1}^{n} B_i \cdot \left(\frac{P_i}{B_i} - M_i\right)$$

where *Bi* is the biomass, *Pi*/*Bi* is the production/biomass ratio and *Mi* is the mortality rate of the considered organism *i*.

Since *P. oceanica* meadows in Liguria show a general condition of regression, the meadow was considered not able to compensate the damage (Montefalcone *et al*. 2007).

Economic benefits and costs: The economic benefits are the financial revenues of the MPA deriving, for instance, from national financing and self-financing.

The economic costs are the expenses associated with the maintenance of the MPA, including, for instance, the ordinary maintenance of buildings and structures, the scientific projects, the purchase of goods and equipment.

Budget accounting: All results obtained through the application of the described approach, namely cost and benefits associated to each service, allow obtaining all items to be included in the framework presented in Table VIII. From the budget three main results are obtained and reported as follows together with calculation formulas referring to Table VIII:

1) Aggregated net benefit: total benefits – total costs = A – B

2) Net economic benefit = user side environmental benefits economic side + economic benefits – economic costs = a1 + a3 – b3

3) Net ecological benefit = donor side environmental benefits – environmental costs = a2 – b1 – b2

Aggregated net benefit is a synthetic index of ecological and economic performances of the MPA, it is a weak sustainability indicator. Net economic benefit is a financial benefit taking into account also revenues directly related to ES fruition. Net ecological benefit is a strong sustainability indicator since it takes into account the benefits associated to protection regime intended as NC increase as well as costs imposed to the environment as NC decrease.

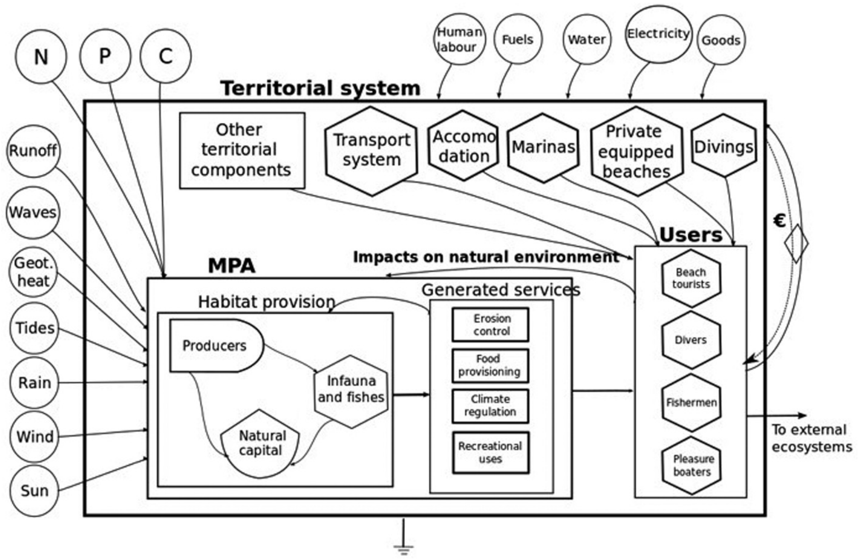

Fig. 3. – Emergy diagram of MPA and the surrounding territorial system.

RESULTS

Three main results have been obtained from the application of the framework: 1) the diagram of MPA functioning; 2) the value of NC in Portofino MPA; 3) the MPA budgets.

MPA functioning diagram

The diagram in Fig. 3 shows the analyzed system represented as a box. Inputs are depicted as circles around the main box while system components are represented within box boundaries as producers (bullets), consumers (hexagons), units with mixed or unclear behavior (little boxes) according to Odum's symobology (Odum 1967).

MPA is part of a wider territorial economic system to which is connected by means of users and their activities. Analogously MPA is connected to external ecosystems receiving and exporting materials and energy or playing important roles such as nursery or reserve area for fishes (Jennings 2009).

NC value in Portofino MPA

The NC value of the MPA and all the biocenosis included within its boundaries has been calculated in biophysical emergy units and later transformed in monetary equivalent (Table IX, Fig. 4). Biocenosis whose values are greater than 6 €/m^2, occupy the 19 % of MPA surface, but compose the 51 % of value. More in detail, habitats whose values are within the top range (9-18 €/m^2, namely coralligenous and caves) represent hot spots and are located in the MPA zones where the protection level is more severe. They occupy the 5 % of MPA surface representing the 20 % of NC value. Habitats in the 6-9 €/m^2 range (*P. oceanica* on soft bottom and on rocks) occupy the 14 % of surface mainly in the C shallow zone contributing to the overall NC value for the 31 %.

Table IX. – NC values for Portofino MPA.

	NC		Surface
	Sej	em€	m^2
Photophilous algae	1.46E+18	1.52E+06	2.65E+05
Sciaphilous circalittoral algae	1.04E+16	1.09E+04	2.65E+03
Sciaphilous infralittoral algae	7.85E+17	8.18E+05	1.62E+05
Coralligenous	1.89E+18	1.96E+06	1.80E+05
Coastal detritic	7.98E+17	8.31E+05	5.68E+05
Muddy detritic	9.25E+17	9.63E+05	1.16E+06
Muds	1.05E+17	1.09E+05	3.11E+05
Caves	3.38E+16	3.52E+04	5.15E+03
P. oceanica dead matte	2.59E+17	2.70E+05	1.61E+05
P. oceanica and dead matte	3.53E+17	3.68E+05	1.02E+05
P. oceanica	2.22E+18	2.31E+06	3.64E+05
P. oceanica on rocks	8.69E+17	9.05E+05	1.34E+05
Sands	7.56E+16	7.88E+04	1.79E+05
Stones and pebbles	2.26E+16	2.36E+04	3.24E+04
Total	**9.80E+18**	**1.02E+07**	**3.63E+06**

The 66 % of the MPA surface hosts low value habitats (< 2 €/m^2) that represent the 22 % of the Portofino MPA value. The overall value of Portofino MPA is 9.80E+18 sej equal to over 10 million of Euros.

Budgets results

The budget of the MPA takes into account five main components (Table VIII): 1) economic user side environmental benefits (a1): financial revenues obtained from the fruition of MPA ES; 2) ecological donor side environ-

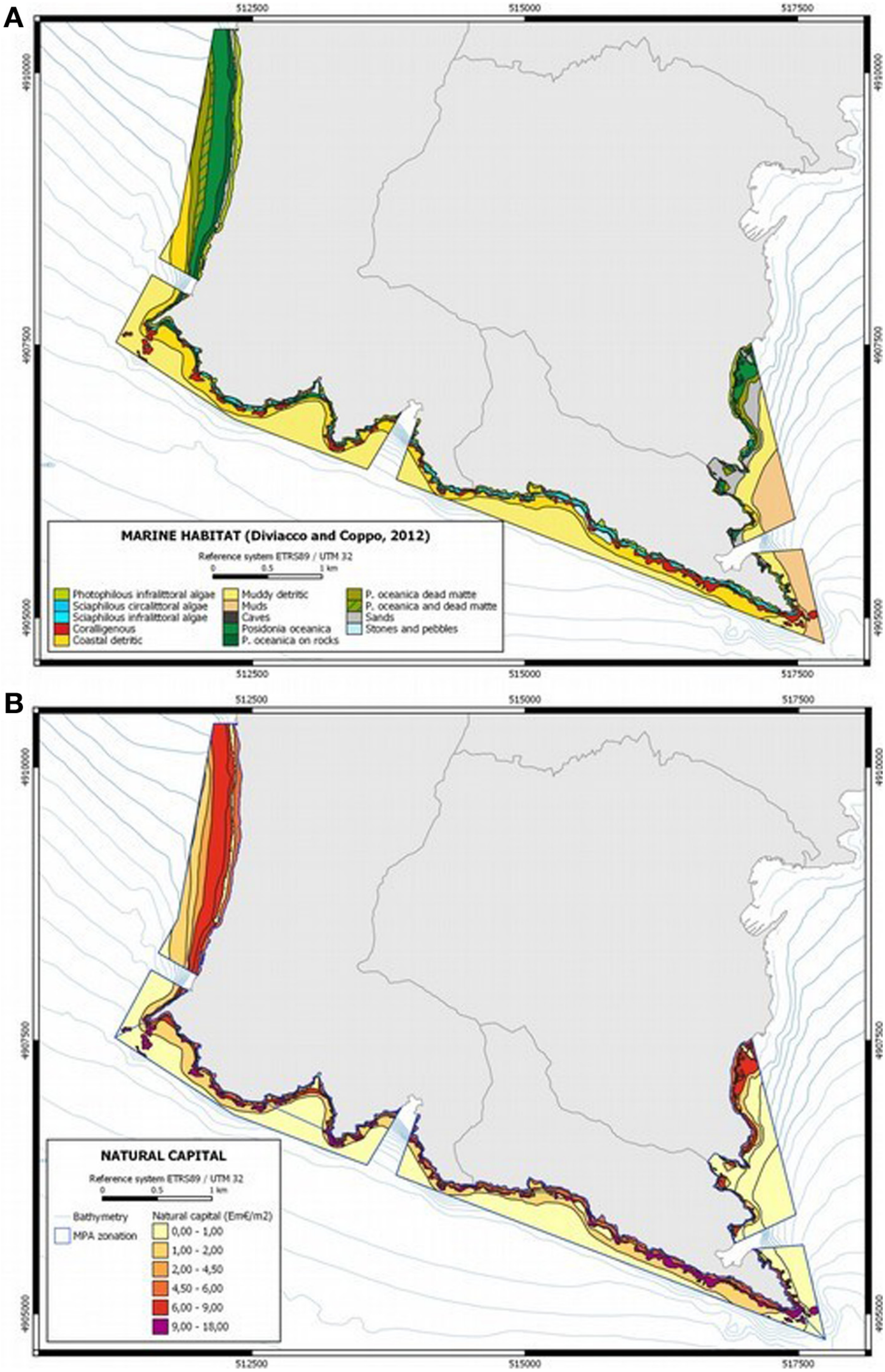

Fig. 4. – Maps of (**A**) habitats and (**B**) natural capital in Portofino MPA

Table X. – Modified budget for Portofino MPA, scientific and educational activity are not considered for the net benefit.

A	*BENEFITS PER YEAR*	€y⁻¹	B	*COSTS PER YEAR*	€y⁻¹
	ENVIRONMENTAL BENEFITS	27,639,387		ENVIRONMENTAL COSTS	13,265,532
a1	*ENVIRONMENTAL BENEFITS – economic user side*	*24,856,843*	b1	*INDIRECT ENVIRONMENTAL COSTS – ecological donor side*	*13,129,430*
	Wildlife for food	37,174		Pleasure boating	5,126,476
	Control of erosive phenomena	n.d.		Recreational diving	4,680,290
	Nursery	n.d.		Sport and recreational fishing	119,108
	Climate regulation	7,348		Professional artisanal fishing	79,976
	Tourist use	1,756,294		Bathing	3,032,989
	Economic impacts	23,056,027		MPA Institutional activity	90,591
a2	*ENVIRONMENTAL BENEFITS – ecological donor side*	*2,782,544*	b2	*DIRECT ENVIRONMENTAL COSTS – ecological donor side*	*39,337*
	Coralligenous sec. production	1,349,945		Pleasure boating	2,033
	Fish sec. production	1,432,599		Recreational diving	19,085
				Sport and recreational fishing	18,219
				Professional artisanal fishing	96,765
a3	ECONOMIC BENEFITS	843,156	b3	ECONOMIC COSTS	838,738
	Routine revenues	617,539		Routine expenditures	653,875
	Capital revenues	124,725		Capital expenditures	83,971
	Reallocation of funds	100,892		Reallocation of funds	100,892
	TOTAL BENEFITS	28,482,543		TOTAL COSTS	14,007,505
	AGGREGATED NET BENEFIT (A – B)	14,378,273			
	NET USER SIDE ECONOMIC BENEFIT (a1 + a3 – b3)	24,861,261			
	NET DONOR SIDE ECOLOGICAL BENEFIT (a2 – b1 – b2)	–10,482,988			

mental benefits (a2): gains in generated production for the environment; 3) economic benefits (a3): financial inputs from national and local administrations and from MPA activities (*e.g.*, licenses, sales, merchandising); 4) donor side ecological indirect costs (b1): environment impacts associated to users activities and MPA management calculated with carbon footprint and emergy; 5) donor side ecological direct costs (b2): damages to MPA habitats generated by users exploiting ES; 5) economic costs (b3): financial expenditures.

Portofino MPA returns to economy an aggregated net benefit (a1 + a2 + a3 – b1 – b2 – b3) of over 14 million of Euros per year, generating 78,469 €/ha/y of environmental benefits and 39,611 €/ha/y of net benefit. Benefits per year are 2 times greater than costs and are mainly due to environmental benefits (97 %) with a predominance of economic user side environmental benefits (87 %). The greatest benefit items are economic impacts (81 % of benefits) and tourist use (6 %). Analogously, environmental costs compose the 94 % of total costs. Donor side indirect costs represent almost the totality of environmental costs (93 %), with pleasure boating (36 %) and diving (33 %) being the main contributions. Donor side direct costs represent the 1 % of costs with professional artisanal fishing being the greatest item. The economic net benefit (a1 + a3 – b3) is positive and equal to almost 25 million of Euros per year, proving MPA economic sustainability while the ecological net benefit (a2 – b1 – b2) is negative (deficit of almost 10 million of Euros per year) (Table X).

DISCUSSION

This study is a first effort to synthesize biophysical and ecological information with economic measures within the context of ES theory and to provide a practical tool able to put into practice this integration as well as the ES cascade theory (Haines-Young & Potschin 2011). This effort is necessary if the scale and the intensity of growth of many economies are considered. In fact, these economies are completely dependent on natural resources exerting an ever-increasing pressure on ecosystems. This condition becomes critical since: 1) resources are finite and the excessive withdrawal leads to ecosystems degradation, also affecting ability to provide ES themselves; 2) all demands cannot always be fulfilled simultaneously generating trade-offs across ES, among beneficiaries and time periods. Concerns about the degradation of ES and the consequences on human well-being are more and more reflected in environmental policy (Bateman *et al.* 2013, Mace 2013). Over the past two decades, researches related to ES increased notably, also thanks to the development of several international initiatives that brought the ES theory to the attention of both scientists and policymakers (Nicholson *et al.* 2009, Seppelt *et al.* 2011). The Millennium Ecosystem Assessment, MEA (MEA 2005), the Convention on Biological Diversity Aichi Targets (CBD, UNEP 2010), The Economics of Ecosystems and Biodiversity, TEEB (Sukhdev *et al.* 2010) and The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, IPBES (Perrings *et al.* 2011), are examples of the initiatives developed in the last years. Against this background, the integration of the ES theory into real-world management decisions rose to prominence (Daily *et al.* 2009, de Groot *et al.* 2010, Goldstein *et al.* 2012, Maes *et al.* 2013, Martinez-Harms *et al.* 2015). As a consequence, the use of tools borrowed from financial analysis such as, for instance, cost benefit analysis, can be supportive, *e.g.*, as effective tool for choosing among alternative options (Pearce *et al.* 2006, Daily *et al.* 2009). In this context, these methods must be integrated in the ES cascade theory (Costanza *et al.* 1997, Turner *et al.* 2003, Norgaard 2010). The proposed approach suits these goals and it helps overcoming the gap between ecology and economy. The application to Portofino MPA allowed the calculation of NC value and a budget of MPA where ecological and economic magnitudes are assessed in the same unit of measure. In the budget, the costs imposed to the environment, as well as the benefits generated by ES (accounted not only as market prices but also as indirect benefits to users and territory), are included. In the specific case, the aggregated net benefit is positive since benefits per year (item A in Table X) are significantly greater than costs per year (Table X). This makes the MPA sustainable in a weak sustainability perspective.

Nonetheless, this result should be carefully interpreted. A vision taking into account only the aggregated net benefit could be ineffective: considering the budget result without splitting ecological and economic side can be short-sighted in assessing the environmental and economic consequences associated to a potentially unsustainable use of the ES. If some services are highly valued by market, an unsustainable use of NC might not appear in the aggregated calculation of net benefit. This is because the effects of ES fruition on NC status can be hidden by economic revenues: it happens when economic and ecological sides are uncoupled and when economy is not able to record negative externalities associated to NC depletion. This can lead to NC depletion and, consequently, in the long run, to the impossibility of using ES at the current level. In such a condition only weak sustainability can be achieved. To pursue strong sustainability NC must kept intact instead and this happens only if the ecological net benefit is zero or better in surplus.

As a consequence, in a strong sustainability approach two parallel budgets are required (Chiesura & de Groot 2003, Vitousek *et al.* 1997), an ecological one and an economic one. Considering ecological budget, NC is then a strong sustainability indicator if monitored through time: it must not diminish or even better it must increase.

In Portofino MPA, moreover, ES exploitation returns to the economy more than what the economy spends. In particular, if the sum of economic and ecological benefits (only economic side) is divided by economic costs, it can be seen that the exploitation of NC returns to economy 30 times the invested monetary resources. NC exploitation is then a very profitable activity.

The greatest part of the economic net benefit is due to the user-side component of environmental benefits and, in particular, to the economic impacts. Economic impacts include direct, indirect and induced economic revenues associated with the activities of MPA users: they also incorporate the part of income associated with sub-suppliers and that can be even generated in faraway lands. As a consequence, it can be said that NC exploitation exports wealth. Nonetheless, being the ecological budget negative, it cannot be assured that this wealth will be maintained in the long run. It could be appropriate to use part of this profit to restore the damaged NC.

Analyzing the environmental side of the budget, if only direct costs are compared with environmental benefits-ecological side, the result is positive. These items both are directly related to the MPA since the direct costs are those generated by users to MPA biocenosis while environmental benefits-ecological side are accounted as the value of net production generated by the same biocenosis. The MPA use of NC comprised within its border is then sustainable. But when the indirect costs are considered, the budget drop drastically down. Indirect costs are those associated to the impacts of all activities made by users and operators to get access to the ES located within the MPA (*e.g.*, fuels and material consumption to reach the MPA). Analogously to economic impacts, these costs can be generated in territories located far from the MPA borders.

Hence, the results show that the costs and benefits with the largest budget share generate effects external to the MPA borders that can hardly be handled by MPA managers.

It is then probably necessary to deal with the issue of sustainability considering a broader context able to take into account all consequences directly and indirectly generated. Even more so considering the possibility that some positive impacts, due to the establishment of the MPA conservation regime (e.g. nursery or protection from erosion effects) or some negative ones (e.g. the impact generated by lost fishing gears within and outside MPA borders) are not included in the budget.

REFERENCES

Ballesteros E 2006. Mediterranean coralligenous assemblages: a synthesis of present knowledge. *Oceanogr Mar Biol* 44: 123-195.

Backhurst MK, Cole RG 2000. Biological impacts of boating at Kawau Island, north-eastern New Zealand. *J Environ Manage 60*(3): 239-251.

Bateman IJ, Harwood AR, Mace GM, Watson RT, Abson DJ, Andrews B, Binner A, Crowe A, Day BH, Dugdale S, Fezzi C, Foden J, Hadley D, Haines-Young R, Hulme M, Kontoleon A, Lovett AA, Munday P, Pascual U, Paterson J, Perino G, Sen A, Siriwardena G, van Soest D, Termansen M 2013. Bringing ecosystem services into economic decision-making: land use in the United Kingdom. *Science* 341: 45-50.

Betti F, Bavestrello G, Bo M, Coppari M, Enrichetti F, Fravega L, Cappanera V, Venturini S, Cattaneo-Vietti R 2019. On the effects of recreational SCUBA diving on fragile benthic species: the Portofino MPA (NW Mediterranean Sea) case study. *Ocean Coast Manage* 182: 104926.

Bostan Y, Ardakani AF, Sani MF, Sadeghinia M 2020. A comparison of stated preferences methods for the valuation of natural resources: the case of contingent valuation and choice experiment. *Int J Environ Sci Technol* 17: 4031-4046.

Brander LM, Koetse MJ 2011. The value of urban open space: Meta-analyses of contingent valuation and hedonic pricing results. *J Environ Manage* 92(10): 2763-2773.

Brown MT, Ulgiati S 2002. Emergy evaluations and environmental loading of electricity production systems. *J Clean Prod* 10: 321-334.

Brown MT, Ulgiati S 2004. Energy quality emergy, and transformity: H.T. Odum's contributions to quantifying and understanding systems. *Ecol Model* 178: 201-213.

Brown MT, Ulgiati S 2010. Updated evaluation of exergy and emergy driving the geobiosphere: a review and refinement of the emergy baseline. *Ecol Model* 221: 2501-2508.

Brown MT, Protano G, Ulgiati S 2011. Assessing geobiosphere work of generating global reserves of coal, crude oil, and natural gas. *Ecol Model* 222: 879-887.

Buenfil AA 2001. Emergy evaluation of water. Doctoral dissertation, University of Florida.

Buonocore E, Häyhä T, Paletto A, Franzese PP 2014. Assessing environmental costs and impacts of forestry activities: a multi-method approach to environmental accounting. *Ecol Model 271:* 10-20.

Buranakarn V 1998. Evaluation of recycling and reuse of building materials using the emergy analysis method. PhD dissertation. Department of Architecture, University of Florida, Gainesville, FL.

Campbell DE, Lu H, Lin BL 2014. Emergy evaluations of the global biogeochemical cycles of six biologically active elements and two compounds. *Ecol Model* 271: 32-51.

CBD, UNEP 2010. Strategic plan for biodiversity 2011-2020 and the Aichi targets. *In* Report of the Tenth Meeting of the Conference of the Parties to the Convention on Biological Diversity.

Chiesura A, de Groot R 2003. Critical natural capital: a socio cultural perspective. *Ecol Econ* 44(2-3): 219-231.

Comitato Capitale Naturale 2018. Secondo Rapporto sullo Stato del Capitale Naturale in Italia. Roma.

Chu X, Zhan J, Wang C, Hameeda S, Wang X 2020. Households' willingness to accept improved ecosystem services and influencing factors: application of contingent valuation method in Bashang Plateau, Hebei Province, China. *J Environ Manage* 255: 109925.

Costanza R, Daly HE 1992. Natural capital and sustainable development. *Conserv Biol* 6(1): 37-46.

Costanza R, d'Arge R, O'Neill RV, Paruelo J, Raskin RG, Sutton P, van den Belt M 1997. The value of the world's ecosystem services and natural capital. *Nature* 387: 253-259.

Daily GC, Polasky S, Goldstein J, Kareiva PM, Mooney HA, Pejchar L, Ricketts TH, Salzman J, Shallenberger R 2009. Ecosystem services in decision making: time to deliver. *Front Ecol Environ* 7(1): 21-28.

de Groot RS, Wilson MA, Boumans RM 2002. A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecol Econ* 41(3): 393-408.

de Groot R, Fisher B, Christie M, Aronson J, Braat L, Gowdy J, Haines-Young R, Maltby E, Neuville A, Polasky S, Portela R, Ring I 2010. Integrating the ecological and economic dimensions in biodiversity and ecosystem service valuation. *In* Kurmar P Ed, The Economics of Ecosystems and Biodiversity (TEEB): Ecological and Economic Foundations. Earthscan, Routledge: 456 p.

de Groot R, Brander L, van der Ploeg S, Costanza R, Bernard F, Braat L, Christie M, Crossman N, Ghermandi A, Hein L, Hussain S, Kumar P, McVittie A, Portela R, Rodriguez LC, ten Brink P, van Beukering P 2012. Global estimates of the value of ecosystems and their services in monetary units. *Ecosyst Serv* 1: 50-61.

Di Franco A, Milazzo M, Baiata P, Tomasello A, Chemello R 2009. Scuba diver behaviour and its effects on the biota of a Mediterranean marine protected area. *Environ Conserv* 36(1): 32-40.

Diamond PA, Hausman JA 1994. Contingent valuation: is some number better than no number? *J Econ Persp* 8(4): 45-64.

EPA (United States Environmental Protection Agency) 2016. Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis, August 2016.

Francour P, Ganteaume A, Poulain M 1999. Effects of boat anchoring in *Posidonia oceanica* seagrass beds in the Port-Cros National Park (north-western Mediterranean Sea). *Aquat Conserv* 9(4): 391-400.

Franzese PP, Buonocore E, Paoli C, Massa F, Stefano D, Fanciulli G, Miccio A, Mollica E, Navone A, Russo GF, Povero P, Vassallo P 2015. Environmental accounting in marine protected areas: the EAMPA project. *J Environ Accounting Manage* 3(4): 324-332.

Goldstein JH, Caldarone G, Duarte TK, Ennaanay D, Hannahs N, Mendoza G, Polasky S, Wolny S, Daily GC 2012. Integrating ecosystem-service tradeoffs into land-use decisions. *Proc Natl Acad Sci USA* 109: 7565-7570.

Guidetti P, Cattaneo-Vietti R, Tunesi L, La Mesa G, Di Lorenzo M, Molinari A, Bussotti S 2011. Pre-valutazione dell'Effetto Riserva presso i cinque parchi marini della Liguria (Annualità 2010).

Gowdy J, O'Hara S 1997. Weak sustainability and viable technologies. *Ecol Econ* 22(3): 239-247.

Hammerton Z 2014. SCUBA-diver impacts and management strategies for subtropical marine protected areas. PhD thesis.

Haines-Young R, Potschin M 2011. Common international classification of ecosystem services (CICES): 2011 Update. Nottingham: Report to the European Environmental Agency.

Hausman J 2012. Contingent valuation: from dubious to hopeless. *J Econ Persp* 26(4): 43-56.

Hawkins K 2003. Economic valuation of ecosystem services. Univ Minnesota, 23.

Hill N, Venfield H, Dun C, James K 2013. Government GHG conversion factors for company reporting: methodology paper for emission factors. DEFRA and DECC.

Jasch C 2003. The use of Environmental Management Accounting (EMA) for identifying environmental costs. *J Clean Prod* 11(6): 667-676.

Jørgensen SE 2010. Ecosystem services, sustainability and thermodynamic indicators. *Ecol Complex* 7(3): 311-313

Jennings S 2009. The role of marine protected areas in environmental management. *ICES J Mar Sci* 66(1): 16-21.

IPCC (Intergovernmental Panel on Climate Change) 2007. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Core Writing Team, Pachauri RK, Reisinger A Eds. IPCC, Geneva, Switzerland: 104 p.

Lloret J, Marin A, Marin-Guirao L, Carreño MF 2006. An alternative approach for managing scuba diving in small marine protected areas. *Aquat Conserv* 16: 579-591.

Lloret J, Zaragoza N, Caballero D, Riera V 2008. Impacts of recreational boating on the marine environment of Cap de Creus (Mediterranean Sea). *Ocean Coast Manage* 51(11): 749-54.

Liquete C, Piroddi C, Drakou E G, Gurney L, Katsanevakis S, Charef A, Egoh B 2013. Current status and future prospects for the assessment of marine and coastal ecosystem services: a systematic review. *PLoS ONE* 8(7).

Lou B, Ulgiati S 2013. Identifying the environmental support and constraints to the Chinese economic growth – an application of the Emergy Accounting method. *Energy Policy* 55: 217-233.

Luna B, Pérez CV, Sánchez-Lizaso JL 2009. Benthic impacts of recreational divers in a Mediterranean Marine Protected Area. *ICES J Mar Sci* 66(3): 517-523.

Mace G 2013. Global change: ecology must evolve. *Nature* 503: 191-192.

Maes J, Teller A, Erhard M, Liquete C, Braat L, Berry P, Egoh B, Puydarrieux P, Fiorina C, Santos F, Paracchini ML, Keune H, Wittmer H, Hauck J, Fiala I, Verburg PH, Condé S, Schägner JP, San Miguel J, Estreguil C, Ostermann O, Barredo JI, Pereira HM, Stott A, Laporte V, Meiner A, Olah B, Royo Gelabert E, Spyropoulou R, Petersen JE, Maguire C, Zal N, Achilleos E, Rubin A, Ledoux L, Brown C, Raes C, Jacobs S, Vandewalle M, Connor D, Bidoglio G 2013. Mapping and Assessment of Ecosystems and their Services. An analytical framework for ecosystem assessments under action 5 of the EU biodiversity strategy to 2020. Publications office of the European Union, Luxembourg.

Malinauskaite L, Cook D, Davíðsdóttir B, Ögmundardóttir H, Roman J 2020. Willingness to pay for expansion of the whale sanctuary in Faxaflói Bay, Iceland: a contingent valuation study. *Ocean Coastal Manage* 183: 105026.

Marangon F, Spoto M, Visintin F 2008. An environmental accounting model for a natural reserve. *Environ Manage Accounting Cleaner Prod* 24: 267-282.

Martinez-Harms MJ, Bryan BA, Balvanera P, Law EA, Rhodes JR, Possingham HP, Wilson KA 2015. Making decisions for managing ecosystem services. *Biol Conserv* 184: 229-238.

MEA (Millennium Ecosystem Assessment) 2005. Ecosystems and Human Well-Being. Washington, DC, Island Press: 137 p.

Milazzo M, Chemello R, Badalamenti F, Camarda R, Riggio S 2002. The impact of human recreational activities in marine protected areas: what lessons should be learnt in the Mediterranean Sea? *Mar Ecol* 23(1): 280-290.

Milazzo M, Badalamenti F, Ceccherelli G, Chemello R 2004. Boat anchoring on *Posidonia oceanica* beds in a marine protected area (Italy, western Mediterranean): effect of anchor types in different anchoring stages. *J Exp Mar Biol Ecol* 299: 51-62.

Montefalcone M, Morri C, Peirano A, Albertelli G, Bianchi CN 2007. Substitution and phase shift within the *Posidonia oceanica* seagrass meadows of NW Mediterranean. *Estuar Coast Shelf Sci* 75(1-2): 63-71.

Müller F, Burkhard B 2012. The indicator side of ecosystem services. *Ecosyst Serv* 1(1): 26-30.

Mutandwa E, Grala RK, Petrolia DR 2019. Estimates of willingness to accept compensation to manage pine stands for ecosystem services. *Forest Policy Econ* 102: 75-85.

Nicholson E, Mace GM, Armsworth PR, Atkinson G, Buckle S, Clements T, Ewers RM, Fa JE, Gardner TA, Gibbons J, Grenyer R, Metcalfe R, Mourato S, Muûls M, Osborn D, Reuman DC, Watson C, Milner-Gulland EJ 2009. Priority research areas for ecosystem services in a changing world. *J Appl Ecol* 46: 1139-1144.

Norgaard RB 2010. Ecosystem services: from eye-opening metaphor to complexity blinder. *Ecol Econ* 69(6): 1219-1227.

Odum HT 1967. Energetics of food production. *In* The World Food Problem, Report of the President's Science Advisory Committee, Panel on World Food Supply, Vol 3. The Whitehouse: 55-94.

Odum HT 1996. Environmental accounting: emergy and environmental decision making. Wiley: 370 p.

Paoli C, Povero P, Burgos E, Dapueto G, Fanciulli G, Massa F, Scarpellini P, Vassallo P 2018. Natural capital and environmental flows assessment in marine protected areas: the case study of Liguria region (NW Mediterranean Sea). *Ecol Model* 368: 121-135.

Pearce D, Atkinson G, Mourato S 2006. Cost-benefit analysis and the environment: recent developments. OECD, Paris.

Pereira L, Zucaro A, Ortega E, Ulgiati S 2013. Wealth, trade and the environment: carrying capacity, economic performance and wellbeing in Brazil and Italy. *J Environ Accounting Manage* 1(2): 159-188.

Puca A, Carrano M, Liu G, Musella D, Ripa M, Viglia S, Ulgiati S 2017. Energy and eMergy assessment of the production and operation of a personal computer. *Resour Conserv Recycl* 116: 124-136.

Perrings C, Duraiappah A, Larigauderie A, Mooney H 2011. The biodiversity and ecosystem services science-policy interface. *Science* 331: 1139-1140.

Pulselli FM, Coscieme L, Bastianoni S 2011. Ecosystem services as a counterpart of emergy flows to ecosystems. *Ecol Model* 222(16): 2924-2928.

Seppelt R, Dormann CF, Eppink FV, Lautenbach S, Schmidt S 2011. A quantitative review of ecosystem service studies: approaches, shortcomings and the road ahead. *J Appl Ecol* 48: 630-636.

Spangenberg JH, von Haaren C, Settele J 2014. The ecosystem service cascade: further developing the metaphor. Integrating societal processes to accommodate social processes and planning, and the case of bioenergy. *Ecol Econ* 104: 22-32.

Sukhdev P, Wittmer H, Schröter-Schlaack C, Nesshöver C, Bishop J, Brink PT, Gundimeda H, Kumar P, Simmons B 2010. The economics of ecosystems and biodiversity: mainstreaming the economics of nature: a synthesis of the approach, conclusions and recommendations of TEEB (No. 333.95 E19). UNEP, Ginebra (Suiza).

TEEB 2010. The Economics of Ecosystem Services and Biodiversity. Earthscan, London. Turner RK, Paavola J, Cooper P, Farber S, Jessamy V, Georgiou S 2003. Valuing nature: lessons learned and future research directions. *Ecol Econ* 46: 493-510.

Turner RK Ed 1993. Sustainable Environmental Economics and Management. Principles and Practice. Belhaven Press, London.

UNEP 2005. Report of the 14th Ordinary Meeting of the Contracting Parties to the Convention for the Protection of the Marine Environment and Coastal Region of the Mediterranean and its Protocols. UNEP (DEP)/MED IG. 16/13.

UNU-IHDP, UNEP 2012. Inclusive Wealth Report 2012. Measuring Progress Toward Sustainability. Summary for Decision-Makers. New Delhi, UNU-IHDP.

Vassallo P, Paoli C, Buonocore E, Franzese PP, Russo GF, Povero P 2017. Assessing the value of natural capital in marine protected areas: a biophysical and trophodynamic environmental accounting model. *Ecol Model* 355: 12-17.

Venturini S, Massa F, Castellano M, Costa S, Lavarello I, Olivari E, Povero P 2016. Recreational boating in Ligurian Marine Protected Areas (Italy): a quantitative evaluation for a sustainable management. *Environ Manage* 57(1): 163-175.

Visintin F, Tomasinsig E, Spoto M, Ciriaco S, Samec D. 2014. Applying Environmental Accounting for assessing the value for money of Miramare Marine Protected Area. Conference: Italian Association of Environmental and Resource Economists, 7th Annual Conference, Udine, Italy.

Visintin F, Marangon F, Spoto M 2016. Assessing the value for money of protected areas. *Riv Stud Sostenibilità* 1: 49-69.

Vitousek P, Mooney H, Lubchenco J, Melillo J 1997. Human domination of earth's ecosystems. *Science* 277(5325): 494-499.

Wackernagel M, Onisto L, Bello P, Linares AC, Falfán ISL, Garcıa JM, Suarez-Guerrero AI, Suarez-Guerrero MG 1999. National natural capital accounting with the ecological footprint concept. *Ecol Econ* 29(3): 375-390.