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Environmental Accounting of Marine Protected Area "*IsoleCiclopi*" by means of Emergy analysis

Ph.D thesis

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Alla memioria Emanuele Mòllica,
uomo di grande spessore umano, culturale e intellettivo,
che ha dedicato la sua vita alla conoscenza e tutela del mare.

A mio padre,
seguendo il suo esempio di onestà e dedizione al lavoro
ho trovato la motivazione per mettermi sempre in gioco
e raggiungere ogni giorno nuovi obiettivi.

A mia madre,
donna forte e paziente che, con amore discreto,
ha saputo sostenere, incoraggiare e seguire ogni mio passo.

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Preface

The purpose of this work is to illustrate the procedural and methodological approaches, with field-testing of materials and methods, necessary to carry out an environmental accounting studyEmergy-based in a marine protected area. The study was conducted in the marine protected area "*IsoleCiclopi*" following a multi-year pathway, in line with the document "*Environmental accounting in Italian Marine Protected Areas*" (EAMPA), developed by several research groups and coordinated by *Federparchi* (Italian federations of Parks and Nature Reserves).In particular, the aim of EMPA project is the assessment of the ecological and economic value forthe Italian marine reserves, elaborated in order to answer ministerial applications.Indeed, in 2014, the Italian Ministry of the Environment and Protection of Land and Sea financed the four-year project "Environmental accounting for Italian marine protected areas" aimed at implementing an environmental accounting system for the Italian marine protected areas (MPAs). The main purpose of this project is to detect and evaluate both biophysical and economic aspects of the reserves in order to assess the Natural Capital stocks and the Ecosystem Services generated by MPAs. The PhD research is based on a bibliographic analysis of international and national literature, oriented both in the study of the relationship between the economy and the environment, and in theevaluation of environmental policies with a focus on marine protected areas.From this, emerged the absence of a scientific methodology of evaluation, able to provide in a way immediate and complete summary information on the context of marine reserve about the economic sphere, social and environmental aspects.It is important to point out that, at the time of the bibliographic research activity (2015), research proposals for environmental accounting analysis in MPAs had not yet been published, there were only general guideline. These works have been published since 2017 and, where necessary, they have been integrated, in this PhD research, to the methodologies already adopted.The results of the research are intended to partially fill this gap by offering an innovative methodology and new points of reflection in the field of environmental evaluation and of policies while having some limitations set out inthe paper.

Chapter 1

Introduction

1.1 The basis of the research

Since the United Nations World Conference on Environment and Development in Rio de Janeiro (1992), the need to integrate environmental, economic and social issues into the decision-making process and into the legislative, regulatory and planning framework, as well as into the market and national accounting systems has been highlighted. From it derives the Strategic Plan for Biodiversity 2011-2020, declared by the United Nations General Assembly in December 2010, with the forecast of 5 strategic objectives to face the safeguard of the loss of biodiversity and of the connected Ecosystem Services (ES). The 189 member countries are required to prepare a multi-year report on the state of biodiversity and the monitoring of the state of progress with respect to the targets. In the same year, Italy defined its National Biodiversity Strategy 2011-2020, which refers to the commitments made and shared at global and EU level. The strategy includes the development of a system of "Environmental Accounting" in protected areas that allows a collection and analysis of data integrated and coordinated between different parks, to detect not only the economic potential. The inclusion of environmental aspects in traditional economic accounts has the task of introducing corrective measures. In this perspective, for example, the loss of biodiversity, the consumption of natural capital and the restoration of impoverished resources can be considered and accounted for, in order to integrate the environmental dimension in the social and economic dimension of development policies. In 2014, the Italian Ministry of the Environment and Protection of Land and Sea financed the four-year project "Environmental accounting for Italian marine protected areas" aimed at implementing an environmental accounting system for the Italian marine protected areas (MPAs). The main objective of this system was the calculation of the ecological and economic value of the Marine Protected Areas with reference to the Natural Capital stocks and the Ecosystem Services generated in each protection area. In addition, the environmental and economic costs, arising from the anthropic impact, must be assessed and a net balance of benefits calculated.In the last years, the use of environmental accounting for the assessment and monitoring of ecosystems has seen an ever-increasing interest at international and national level. This is due to the need to improve environmental policies towards the protection of natural resources that provide goods and services for the well-being of society.In 2016, since increasing interest on ecosystem assessment and sustainable development and on the basis of "*Collegato green*" ("Environmental provisions to promote green economy measures and contain excessive use of natural resources", linked to the 2014 Stability Law, approved by the Chamber and amended by the Senate), in Italy was established the "Committee on Natural Capital". Its task was to prepare and send an annual report on the state of the country's Natural Capital to the President of the Council and the Minister for the Economy and Finance, in order to ensure the achievement of social, economic and environmental objectives consistent with the annual financial and budgetary planning. The report must be accompanied by environmental information and data expressed in physical and monetary units, as well as ex ante and ex post evaluations of the effects of public policies on natural capital and ecosystem services.The year 2017 marked an important turning point in the complex question of sustainability in Italy. Within the framework "Agenda 2030 ONU" on Sustainable Development and the National Strategy for Sustainable Development (SNSvS), the above Committee on Natural Capital has presented the First Report on the State of Natural Capital in Italy. It allowed highlighting, for the first time, the most important features and value of Natural Capital of the country, from the complex institutional system to the fundamental role played by with respect to the collective socio-economic system of Italy. This value is expressed in benefits that we enjoy every day and that come from the set of ecosystem services that nature provides us, but that often we do not perceive and do not evaluate at their proper value. The objective that the Committee for Natural Capital pursues is also to make visible to citizens and policy makers the value of these benefits. In 2018, with the Second Report, important progress has been made in terms of enriching the factors of analysis thanks to an ever-increasing synergy between experts in the field, national and international research centers, and the public administration. This Report further improves the biophysical evaluation of terrestrial ecosystems at eco-regional and regional level,updates the state of conservation of some of them. Moreover, the focus on the biophysical value of Natural Capital stocks in marine ecosystems highlights the first results of the experimental above mentioned projectof environmental accounting system for Italian Marine Protected Areasstarted in 2014. Finally, the Committee on Natural Capital proposes new recommendations, that will serve as an agenda for future reports, which are intended to make a significant contribution to achieving the global objectives set out in Agenda 2030 for sustainable growth, which Italy must continue to pursue for present and future generations.In this framework, this doctoral project is configured as a methodological research with field-testing of materials and methods useful to conduct a comprehensive accounting survey in line with ministerial guidelines.

1.2 Environmental accounting in Italian Marine Protected Area

Coastal and marine ecosystems are among the most productive environments in the world and their Natural Capital stocks provide a set of Ecosystem Services essential to human life (Costanza et al., 1997). Marine protected areas were created with the aim of achieving conservation of marine habitats and key role species. Moreover, the protection measures adopted, would led to a sustainable use of marine resources.The term Natural Capital identify the stock of a system capable of providing the natural resources at the base of production of goods and services, from which all human activities originate. It is necessary to measure the amount of natural resources but also to understand which uses affect them leading to high environmental costs. Usually, no market value was assigned to natural capital by classical environmental analysis. Its value is attributed by the economyonly to the final benefit (the only thing perceived by humans), while the effort of nature in the productive process is neglected.Environmental accounting represents a model of analysis that assess natural capital, based on the investment made by nature, in terms of resources committed. In this way, it is possible to evaluate the real effort of nature in maintaining a certain good or service. Ecosystem services are the components of the natural capital which man exploits directly and that allow him to get a benefit. They can only be supported by the presence of that basic environmental heritage mentioned above.To understand the functioning of a natural system it is essentialto know not only the value of this capital, but also evaluate the processes, the functions and the knowledge of the most exploited services.This is because the possibility to preserve and increase environmental heritage depends on the type and from the degree of exploitation. An accurate evaluation of the services can correctly address administrators and operators, highlighting the main administration opportunities for managers. Therefore, the purpose environmental accounting is to quantify both the physical and monetary value of natural systems and to monitor their variations in order to maintain it at least intact.Environmental accounting in marine protected areas is an experimental project, started in 2014 and aimed at implementing an environmental accounting system for Italian MPAs. Among the different methodologies for assessing resources in quantitative terms, emergy accounting (Odum, 1996) has been selected.The application of this methodology allowsto express all the resources necessary to maintain a system in a single ecological unit of measurement and then to translate the total amount into monetary units. In this way, the value of one or more ecosystems is calculated as resources that have been (or are) necessary to store the biomass contained in it and maintain its functioning and goods and services are evaluated according to the work done by the biosphere for their production. The methodology has to be applied to the benthic habitats of MPAs, thus arriving at an estimate of the capital and the flows of resources that maintain it, as well as an assessment of the ability of the MPAs to generate these resources and be, therefore, more or less independent from external systems.It isalso necessary to transport the general definitions to a local context, considering the supply and demand that territory can offer, contextualizing them toimprove and implement "*ad hoc*" policies of management. The importance of this project lies in achieving methods and tools useful to assess environmental features in order to estimate and monitor the natural heritage in a reserve. This survey also aims to return a complete profile of the system investigated, including social and economic characteristics, to highlight interaction between humans and nature for management purpose. The

methodological approach of environmental accounting in MPAs can be divided into several operational phases and requires the collection and analysis of data for each MPA, including bathymetric and bionomic mapping, the characterization and extension of the macro-ecosystems present and the quantitative evaluation of the biomass of macro-benthonic organisms and sedentary fish fauna.
The different phases of the analysis (from the document "Environmental Accounting in Marine Protected Area" *Federparchi*, 2014) are described as follows:

<u>Phase 0. Photograph of data availability relating to the naturalistic accounting of the MPAs.</u>

1. Inventory of the data necessary for the realizationof the model and already available to the MPAs, and evaluation of the comparability between different samplings and/or different sites.
2. In case of missing data, formulation of a shared and standardized protocols for the collection of information functional to the implementation of the model and comparable between different sites.Creation of a database connected to SIT (System Territorial information) containing biomass associated with each taxon.

<u>Phase 1. Accounting of the ecological and economic value of the Natural Capital of the MPAs.</u>

1. Identification of benthic communities in the area (e.g. through the consultation of cartography) and the associated fauna (e.g. by means of consultation of data from visual census campaigns).
2. Attribution of an ecological and economic value through the modelling of each biocenosis and the application of the systemic methods (Emergy Analysis) (For a more detailed description see Chapter 3).

<u>Phase 2. Identification of the main functions and Ecosystem Services.</u>

Once assessed the ecological value of the environmental heritage,it will be necessary toidentify the functions and ecosystem services. Their identification is essential in order to find the relationships between ecosystem and anthropic system and to quantify their resource flows. To do this, it will be consulted and carefully analyzed the entire bibliography of reference, paying particular attention to the marine environment (e.g. Liquete et al., 2013; De Groot et al., 2002; MA, 2005; Ronnback et al,2007). The mapping of ecosystem services will be conduct also according to the guidelines indicated by the MAES working group (Mapping and Assessment on Ecosystems and their Services) to support the implementation of the Action 5 of the European Biodiversity Strategy (European Union, 2013, 2014). Functions and services will also be identified based on in-depth knowledge of the ecosystems analyzed through the phases or by identifying all the previous characters from an ecological point of view. This is to achieve a classification of functions and services specifically designed for each MPA.

<u>Phase 3. Accounting of the environmental and economic costs.</u>

Ecocentric approach

1. Identification of uses and their impacts exercised in the area or of the activities carried out from users e.g. seaside tourism and walking, boating, sport and professional fishing, diving.
2. Assessment of direct environmental costs in terms of use of natural and anthropic resources and environmental degradation, whose repercussions are recorded within the MPA.
3. Evaluation of indirect environmental costs (in terms of resource use and degradation of natural environment), the effects of which are recordered outside the MPA.

Anthropocentric approach

1. Environmental costs contribute to the formation of the environmental flow statement.Therefore, they will be traced back to some main types, such as, for example: the anthropogenic presence, consumption of resources,fuel consumption for the determination of emissions, electricity and raw material consumption.
2. Monetization takes place through steps that result in the transformation of consumption into tones of CO_2 equivalents and their subsequent conversion into

in monetary units, through the adoption of economic and monetary conversion factor that attributes a social cost to each unit emissions (social cost of carbon).

3. Economic costs: accounting data, financial statements of the marine protected area.

<u>Phase 4. Accounting of the environmental and economic benefits.</u>

Ecocentric approach

From an ecocentric point of view, the benefits of a MPA originate from the maintenance of the ecological heritage and the functions it performs. The natural system, in fact, constantly provides services that derive from the environment, and that are generated regardless of the utility, the direct benefit or advantage of humans.

Anthropocentric approach

The evaluation of ecosystem services, as well as what happened with the mapping, will be conduct in accordance with the guidelines laid down by the working group of the MAES (Mapping and Assessment on Ecosystems and their Services) to support the implementation of the Action 5.

1. Environmental and economic benefits: The monetary value of ecosystem services is quantified at this stage:

a. Identification of biophysical indicators and socio-economic factors appropriate for measuringecosystem services.

b. Monetization of indicators calculated in the previous phase. Definition of ecosystem services is preparatory to the formulation of the correct indicators.

2. The environmental benefits, as well as the costs of environmental and economic factors, contribute to the formation of the flow statement.

3. Profits: accounting data, financial statements of the area

<u>Phase 5.Environmental flows and implementation of the cost-benefit balance.</u>

The flow statement is acost-benefit analysis based (Fig. 1) which add-ons the economic account (costs and profits) of the managing organization with the accounting of environmental resources (benefits and environmental, social and economic costs) of the area.

Environmental accounting		
Natural stock account	Natural flow account	
- Quality assessment (by genus or species) - Quantity assessment (density)	- Costs / expenses: -- PA expenses -- Environmental costs	- Benefits / revenues: -- PA revenues -- Environmental benefits
	PA net benefits produced/consumed	

Figure 1. Cost-benefit analysis approach in environmental accounting.

Regarding resources accounting, the environmental costs and benefits can be compared to understandthe effectiveness of management policies for the maintenance and growth of the ecological heritage.

The sum of costs and benefits makes it possible to carry out a budget of the MPA, i.e. thewealth produced or consumed. The relationship betweennet benefits produced by the area and thepublic finance makes it possible to estimate thereturn on investment made by the institution public in the marine area (Marangon et al., 2008). Cost and benefit assessments are used in the construction of the balance sheet of flows according to the evaluation described in phases 3 and 4.The results of the eco-centric andanthropocentric procedures conducted in all phasesof the project will be comparedto get more information about the complete and detailed information on the value of the MPA and the perception of this value byusers. The two approaches will also allowto better understand the consequences of management actions within the MPAs about conservation or promotion activities.

<u>Phase 6.Computerization data management and development of the accounting system.</u>

The collected data can be managed byusing information systems, already available for the different MPAs or "*ad hoc*" developed. The use of structures, interoperable and potentiallyexpandable, will allow a simpler and morerational dynamic management of accountingenvironmental procedure, in order to make itfunctional toadministrationpurpose. Moreover, an easier data and information collection and exchangebetween operators, institutions and users of different MPAs should improve the communication web. In addition,the new information systems will allow to fit in with the recent networks ofEuropean and international environmental information systems,and collecting, managing,making the data according to the new international standards (INSPIRE, OGC, etc.).

1.3 PhD research proposal structure

A summary of the activities carried out during the doctorate, in order to facilitate understanding of the research work, is presented below.

At first, the definition of the theoretical framework of the research has been conducted. The focus was oriented both in the study of the relationship between the economy and the environment, and in the evaluation of environmental policies with attention on marine protected areas. In this phase, the evolution of the historical and cultural background, underlying the study of ecosystems, has been reconstructed,paying particular attention to the paradigm shift between the conception of the neoclassical economic system model and the environment model. In addition, the rise of System Ecology and its application in the study of ecosystems wastaken into account, in order to have a more conscious approach to Emergy. Based on these concepts, the second part of the PhD research has developedand adapted to the setting the environmental accounting model emergy-based in accordance with the guidelines of the Ministry. At the same time, field-surveys were conducted to get an overview of the main features present in the study area from ecological to socio-economic point of view. The knowledge of the whole system is fundamental to achieve conservation objectives with a view to sustainable development. The last phase of the thesis concerns the application of the model of evaluation elaborated in the study area and the discussion of results gained from the data analysis, also defining strengths and weaknesses of the accounting system proposed. Finally, the last objectivewasto point out the knowledge of marine reserve performance as essential instrument for management purpose: a more accurate awareness of the issues involved would allow the public decision-makers to develop conservation and protection strategies as consistent as possible with the realities in these areas.

Chapter 2

Introduction to Emergy

2.1 From qualitative to quantitative approach in environmental analysis

Environment can provide support for men and the society. Support means to have all natural resources useful for men's health, culture and economy. Consequently, our well-being is strictly linked to the relationship with environment and its components. The great economic development is leading to a decreasing of natural capital (defined as the world's stocks of natural assets which include geology, soil, air, water and all living things) with a consequent loss of raw material, loss of biodiversity and loss of other stored-energy sources.Really, it is from this natural capital that humans derive a wide range of services, often called ecosystem services, which make human life possible. There is a conflict between what is important for the actual/further economic development and the will to protect environment. In the past,industrialized society based the growth model on the maximum economic profit using natural resources over the natural renewal rate. Fromthis perceptionsustainable development became more and more important.There are many definition of sustainable development, probably the best one is the one given by World Commission on Environment and Development: *development that meets the needs of the present without compromising the ability of future generations to meet their own needs*. The aim of sustainable development is to maintain a stable relationship between human activities and the natural world, guiding economic growth together with the protection of environmental quality: humanity must take no more from nature than nature can replenish.Nowadays, renewable resources are used by humans at a rate that, in most cases, is higher than their replacement rate. It implies that the renewable resources are decreasing. In addition,non-renewable resources are used by humans at a rate that is higher than the rate at which alternatives to the non-renewable resources are found. The decreasingrenewable and non-renewable resources demonstrate that the earth is not in a sustainable development (Jørgensen 2012). Two different systems have to be investigated to study sustainable development from a scientific point of view, the economical-productive system and the ecological one.The use of the most common environmental analysis methods, that take into account a qualitative approach, can generate a wrong estimation of natural capital because without a market price it could result underestimated. On the contrary, environmental problems require a quantitative approach that is able to consider both ecological and economical values.

2.2 The arose of ecological economics

Ecology and economics have been pursued as separate disciplines through most of the 20th century.By the end of the 19th century, the trend to increasing specialization and professionalization in science was well under way, and economics as a profession became more and more popular (Coats 1993). What has come to be called the "reductionist" paradigm was beginning to hold sway. This paradigm assumes that the world is separable into relatively isolated units that can be studied and understood on their own, and then reassembled to give a picture of the whole. As the complexity of science increased, this was a very useful idea, since it allowed dividing the problem into smaller, more manageable pieces that could be attacked intensively.This rapidly led to a reduction in communication across disciplines and a tendency for the disciplines to develop their peculiar unique languages, cultures, and ways of looking at the world. In economics, this led to a growing isolation from the natural resource (or land) component of the classical triad of land. Ecology itself there was something a split between the population ecologists (e.g., Robert MacArthur) who concentrated on individual populations of organisms, and ecologists(e.g., E. P. and H. T. Odum) who focused on whole ecosystems. Through all of this, ecologistshave maintained communication across most of the natural sciences (Costanza et al. 1997).In 1971 two authors,Howard T. Odum's (ecologist) and Nicholas Georgescu-Roegen's (economist) published two books that seem to have made a major contribution to setting the stage for ecological economics.The books,"Environment, Power, and Society" and "The Entropy Law and the Economic Process",were very different in style but both of them were about energy, entropy, power, systems and society.Georgescu-Roegen argued that all economic processes entail the use of energy and that the second law of thermodynamics, the entropy law, clearly indicates that the available energy in a closed system can only decline. Like others before him, he also noted the parallel between the degradation of the availability of energy and the degradation of the order of materials. Biodiversity degradation can also be thought of as a parallel problem. New technologies do not "create" new resources; they simply allow us to degrade energy, material order, and biological richness more rapidly (Costanza et al. 1997).Howard T. Odum has been concerned with material cycles and energy flow in ecosystemsand he produced one of the first energy flow descriptions of a complete ecosystem in his famous study of Silver Springs, Florida (H.T. Odum 1957). He also contributed heavily to his brother Eugene P. Odum's influential textbook, *Fundamentals of Ecology,* first published in 1953 (E. P. Odum 1953). Lotkainfluenced H. T. Odum in his thinking, and he was concerned with many of the same problems as Georgescu-Roegen. His approach went beyond economics and thermodynamics to include systems in general, from simple physical and chemical systems to biological and ecological systems to economic and social systems. The work of E. P Odum and H. T. Odumhas inspired a whole generation of ecologists to study ecology as a systemscience and to link it with economics and other disciplines.In 1980 a group of scholars realized that improvements in environmental policy and management and protecting the well-being of future generations were dependent both on ecological and economic issues. It was immediately clear that these subjects had to be considered as one and evaluated together. This was the birth of Ecological economics. Numerousexperiments with joint meetings between economists and ecologistswere held, particularly in Sweden and the United States, to explorethe possibilities of working together (Jansson 1984; Costanzaand Daly 1987). Economists and ecologists joined to encourage the major international agencies to develop accounting systems that included the environment (Ahmad et al. 1989). Buoyed by such initialefforts, the International Society for Ecological Economics (ISEE) was formed during a workshop of ecologists and economists held in Barcelona in late 1987, and the journal, *Ecological Economics*, was initiated in 1989. Ecological economics is not a single new paradigm based in shared assumptions and theory. It represents a commitment among economists, ecologists, and others, both as academics and as practitioners, to learn from each other, to explore new patterns of thinking together, and to facilitate the derivation and implementation of new economic and environmental policies (Costanza et al. 1997).

2.3 Systems ecology

Another important contribution to the new approach to environmental analysis is the systemsecology, a branch of ecosystem ecology. System ecology aims to clarify the structure and the function of ecosystems using applied mathematics, mathematical simulation models and computer programs. It can be also defined as the application of system theory to the study of ecology because it studies the interaction between biotic and abiotic components through system modelling. As a system science, it is based upon the principle called *synthesis*, which is focused primarily on the interaction between system componentsand the patterns that emerge out from interactions instead ofthe properties of the components themselves. It arose in 1960, after computers became available and system analysis were successfully applied in military and industrial settings. The origin of the term “systems ecology” and the breadth of this new field are found in E. P. Odum’s “The New Ecology” (Odum, 1964). Odum sees computers and the mathematical systemapproach as powerful means to advance theory of ecosystem self-organization and establish principles of ecosystem management (Dale, 1970). Systems ecology is applied widely in environmental management and in particular in the ecological subdisciplines: ecological modelling, ecological engineering and assessment of ecosystem health or integrity by ecological indicators (Jørgensen, 2012). To the point, System Ecology is able to explain changes in ecosystems through changes in energy and material flows. This working definition of Systems ecology let us introduce the concept of Emergy accounting. Indeed, Emergy accounting is able to evaluate energy and material flows of different qualities to overcome diversity of metric used for quantifying processes and activities (Tilley and Swank, 2003).

2.4 A new approach in environmental evaluation

The development of emergy and its theoretical base cannot be separated from development of the concept of energy quality (Brown and Ulgiati, 2004). Since 1970, the concept of energy quality was evolving: from a qualitative description of the different forms to quantitative methods of expressing the different energies for comparative purpose. It was clear that all forms of energy have different ability to do work and some corrections were necessary to compare and evaluate them correctly. For example, a Joule of sunlight is not the same as a Joule of fossil fuel or a Joule of food, unless it is being used to power a steam engine (Brown and Ulgiati, 2004).Energy has been defined as the ability to do work and it is measured in units of heat or molecular motion that are quantified in calories or Joules.The use of heat measures of energy that can only recognize one aspect of energy, its ability to raise the temperature of things, cannot adequately quantify the work potential of energies used in more complex processes of the biosphere (Brown and Ulgiati, 1999). In biosphere system, energies should be converted to units able to take into account for multiple levels of system processes, ranging from the smallest scale to the largest scales of the system, and useful to evaluate processes different from that of heat engine technology.Odum was reflecting on these differences when he understood the errors of energy technologies that promised unlimited energy from society from sun or from oil shale. In both cases, the costs associated to the concentration of energy were greater than the net yield.H. T. Odum began to investigate the quantification of energy quality, the net yield of energy sources to understand how the biosphere worked through the different levels.In fact, Ecosystems circulate materials, transform energy, support populations, join components in network interactions, organize hierarchies and spatial centers, evolve and replicate information, and maintain structure in pulsing oscillations (Ulgiati and Brown, 2009). Odum introduced the concept of emergy in order to account for the quality of incoming energy andresources, i.e. for the environmental services supporting a process as well as for their convergence through a chain of energy and matter transformations in both space and time.

2.5 Emergy, Transformity and Hierarchical organization of Systems

In 1996 Odum published the book "Environmental Accounting", which explicitly laid out the accounting rules for EMERGY analysis, and in the introduction he started…"*A science-based evaluation system is now available to represent both the environmental values and the economics value with a common measure. EMERGY spelled with an "m", measures both the work of nature and that of humans in generating products and services. By selecting choices that maximize EMERGY production and use, policies and judgements can favour those environmental alternatives that maximize real wealth, the whole economy, the public benefit*" (Odum, 1996).

All environmental processes, systems and societies present interconnections characterized by a complex net of interchange involving energy, materials and information. The possibility to understand the relationships between energy flows and matter transformation may be fundamental to identify and to describe the complex inter-relationships between society and biosphere. In fact, the maintenance of society is due to the use of energy (in term of energy fluxes and storage) produced by the biosphere. Human society draws energy directly from the environment, from short-term storage (form 10-1000 year turnover times) like wood, soils, and ground water, and from long-term storages of fossil fuels and minerals (Brown and Ulgiati, 1999). Neoclassical economic theory does not attempt to quantify the value of all the environmental goods (biomass, food, etc.) and service (evapotranspiration, waste assimilation, etc.) of ecosystems that represent the benefits that humans derive from ecosystem functions (Berrios et al., 2017). Therefore, natural goods and service without commercial importance often end up being ignored in public and private decisions, compromising the sustainability of ecosystems from a global point of view (Odum and Odum, 2000). Emergy accounting (Odum, 1996) is a technique of quantitative analysis that offers theoretical and applicative basis to make a biophysical accounting of natural and anthropic ecosystems. This procedure returns the value of environmental resources as a function of the work of the biosphere to produce them (donor-side approach); it provides an evaluation of environmental value of a resource and the real welfare of a system.

Emergy is a system concept, and cannot be fully understood or utilized outside of systems (Brown et al., 2000). Emergy is context driven and has been described as the memory of energy used in the past to make something (Scienceman, 1987). In other words, can be considered the energy required doingthe work of productionand represents an expression of all the energy used in a process. By definition Emergy is the amount of energy of one form (usually solar) that is required, directly or indirectly, to provide a given flow or storage of energy or matter. The unit of emergy is the Emergy Joule or emjoule.When we take into account the biosphere, the energy used as common unit is usually sunlight. Solar Emergy is the available solar energy used up directly and indirectly to make a service or product (Odum, 1996). The unit of Solar Emergy is Solar Emergy Joule or emjoule (abbreviated sej).Being able to convert all form of energy into equivalents of one form, let us exceed one of the most relevant problem inthe study of energy fluxes: different energy sources are not comparable because they are not equivalent in their ability to do work.Emergy then, is a measure of the global processes required to produce something expressed in units of the same energy form (Brown et al., 2000).To derive the Solar Emergy of something, it is necessary to calculate the energy of each kind required to produce it; then resources and energy have to be express in the amount of Solar Emergy that went into their production. The ratio between the Emergy of a product and its energy returns a transformation coefficient called TRANSFORMITY. By definition Solar Transformity is the solar Emergy required to make one joule of a service or product. Its units are solar emjoul per joule (sej/j) (Odum, 1996). The coefficient is useful to transform a given energy into Emergy, by multiplying the energy by the transformity. Sometime, the unit related to particular products must be more specific and easier to quantify and so it can be expressed in:

- Sej/g (Emergy per unit mass);
- Sej/€ (Emergy per unit money), defined as the Emergy supporting the generation of one unit of economic product;
- Sej/yr or sej/hr (Emergy per unit labor), defined as the amount of Emergy supporting one unit of labor directly supplied to a process).

The more energy transformation there are contributing to a product, the higher is the transformity because at each transformation, available energy is used up to produce a smaller amount of energy of another form (Odum, 1996). Therefore, when the production of goods have required the most work to make, they have low energy and the value of the transformity is elevated.

As a result, transformity value play an important rule into the evaluation of the efficiency of a process: the lower is the value of transformity, the higher is the ability to make a rational and effective use of the resources.Another size used is Empower, defined as the flow of Emergy per unit time,it measure isemjoule per unit time. Evaluating Emergy of a system means identify all sources of energy involved in the productive processes of the system considered and follow their transformations. ,(Brown et al., 2000). A series of successive energy transformations can generate an energy hierarchy.The structure of the system is hierarchal organized as a web (Fig. 2) in which energies are concentrated, through a series of energy transformations, in the final product. Transformation web can be aggregated in into transformation chains (Fig. 2), where energy flows decrease with each transformation step and transformity increases (Brown et al., 2000).The final product has less energy but a higher quality than the initial one.

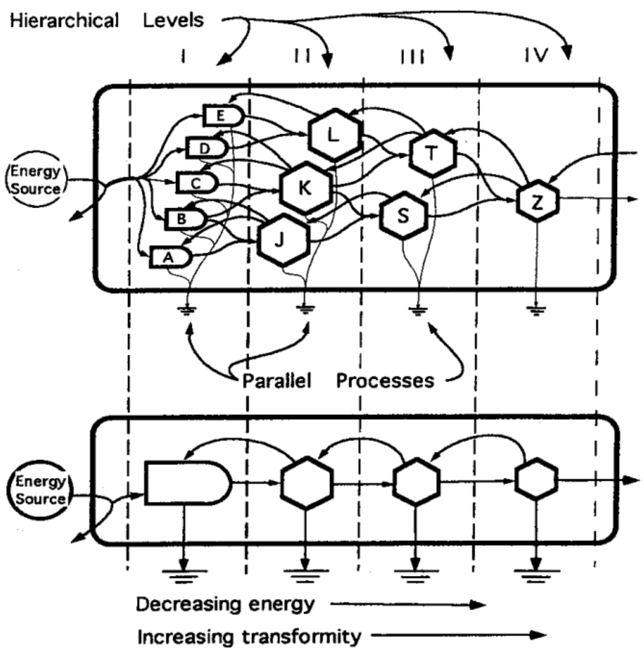


Figure 2. Systems hierarchical organization and transformation chains (From Brown et al. 2000)

In other words, the diagram of the process of figure above shows an energy transformation hierarchy starting with large flow of low-quality energy that are transformed into smaller volumes of higher quality energies.The use of a system approach in environmental analysis, let us better understand the principles that govern natural and human systems and to predict their performances under different conditions.

2.6 Geobiosphere emergy baseline (GEB)

The emergy method accounts for all inputrequirements of systems and processes by expanding temporal system boundaries to include all energy, material and information sources consumed previously in support of processes that supply contemporary inputs (Brown and Ulgiati, 2004). Energy and matter are extracted from the geobiosphere that gives the environmental support to productive process of goods and services. The geobiosphere contribution can be evaluated by estimating the whole emergy driving the geobiosphere and apportion to it. There are three primary exergy (available energy) sources of different origins (solar radiation, geothermal heat and gravitational energy) that interact to drive processes between geobiosphere and can be expressed with the same unit by equivalency factors. Each of this sources are expressed in solar equivalent exergy from which, all other forms of energy can be computed, so that they may be expressed as emergy in units of solar emjoules (Brown et al., 2016). Equivalent in this context means equal in quality or value, or corresponds in value to another. The result is the amount of direct available energy supporting the biosphere, expressed in terms of solar equivalent exergy, named “geobiosphere baseline” (GEB), in a temporary domain of one year. This baseline is an important contribution to emergy evaluations because is the basis to calculate unit emergy value (UEVs) of storage and flows in the geobiosphere. Over time, the new GEBs were developed since the availability of updated information about earth’s energy budget. In 1971, at the beginning of emergy development, Odum considered solar energy as the basis for all other forms of energy, estimating 1000 joules of sunlight to produce 1 joule of organic matter and about 42E+6 joules of solar energy to produce 1$ of human service. After further amendments, in 1996 Odum, with the publications of Environmental Accounting, proposed the baseline of 9.44E+24 sej y^{-1}. The first emergy folio (Odum and Odum, 2000) used a new value called “global empower base” of 15.83E+24 sej y^{-1}. Since 2000, researches have proposed several baselines as alternatives to values put forward by Odum, ranging from 9.44E+24 sej y^{-1} to 15.83E+24 sej y^{-1} and based on different methods of computation, different assumption regarding system organization and inclusion or exclusion of emergy sources driving biosphere processes. The presence of different and alternative baselines raised the problem of standardization to make comparison among studies and generated some confusion within the scientific community. The results obtained with one baseline can be easily updated to another baseline by using a scaling factor: to convert data obtained with analyses performed under an earlier baseline to this new baseline, the data should be multiplied by the ratio of the new baseline to the older one. However, a research effort was undertaken to obtain a unified baseline. During 8th biennial emergy conference in January 2014, a group of scientist re-examined the latest three approaches used in GEB evaluation. Finally, Brown et al. (2016) updated the baseline value to 1.20E+25 sej yr^{-1}. Past analysis, with reference to old baselines, can be easily compared to new studies by using a scaling factor as already explained.

2.7Application of Emergy principles to ecosystems: a graphic model to evaluate energy flows

The systems are defined as group of parts that are connected and work together. Ecosystems are systems that present living and non-living components. To survive an ecosystem needs a continuing supply of materials and in its processes energy is always required. Some living organisms take energy from the sun and create a flow of energy and materials through a food web. Organisms that are capable to make their own food from chemicals, using the energy of the sun, are called PRODUCERS. Organic products of living organisms are biomass. Other organisms consume products made by producers and are known as CONSUMERS.

There are different type of consumers related to what they eat:

- Herbivores → plant eaters
- Carnivores → meat eaters
- Decomposers → digesters or dead organic matter

The chemical waste product, coming from consumer's digestion, are called NUTRIENTS and can be taken by producers to form organic matter again: we said they are recycled. H. T. Odum in his books uses symbols as a simple graphic representation of system components (Fig. 3). The use of this system language can help in the understanding of how systems operate.

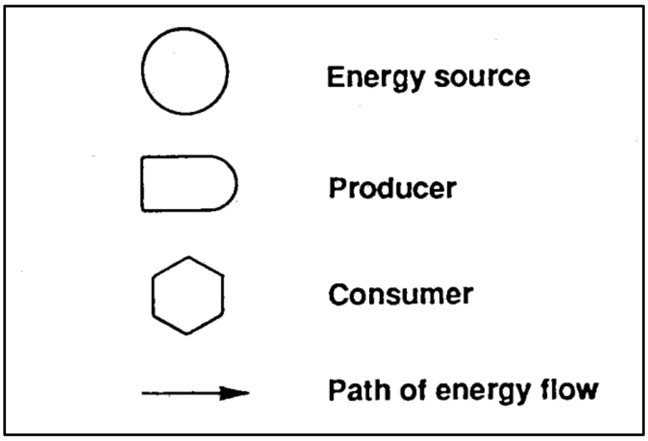


Figura 3. Symbol used for parts of an ecosystem

Figure 4 shows an example of a simplify ecosystem food chain using the language described. Sun is presented as the energy sources, plants are represented by the symbol of producers and animals indicated as consumers. Arrows point out materials and energy flows.

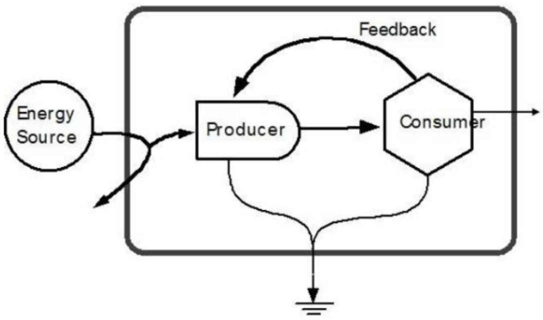


Figure 4. A food web model in system language.

Environmental components require a system overview. The diagram is a simple model showing the relationship between the different components of the ecosystem and the flow of energy and materials from one unit to another. It helps us to get the whole picture of the system. For this, Energy System diagrams are a necessary step in the emergy analysis of ecosystems. They are called "energy" because every element has some energy. To easily understand and investigate energy exchanges within a food web it is convenient to transform the web into a single food chain. Figure 5 shows a food chain with numbers on the flow lines representing the rates of flows of energy per year.

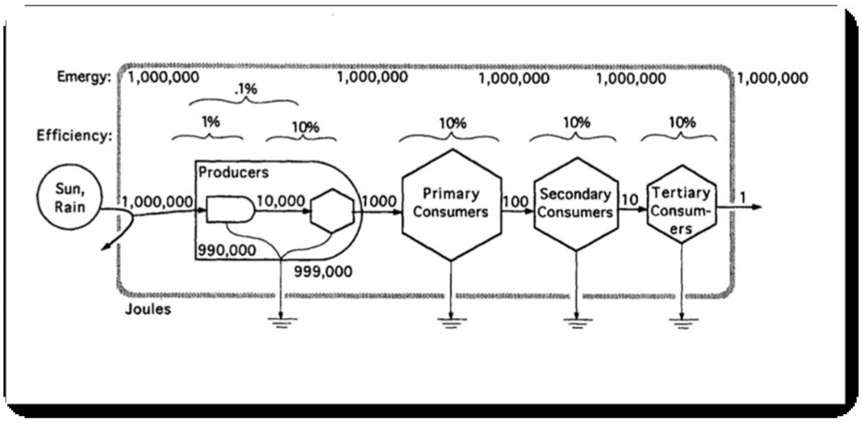


Figure 5. System diagram of a quantitative food chain (from Brown, 2003).

The source of energy is the sunlight, part of it is direct and the other part is the sun energy that falling on the ocean to give rain. About 1% of the 1.000.000 joules of sunlight that support the system in one year are transformed by producers into plant biomass (about 10.000 joules of new trees and plants are produced per year). The efficiency use of sunlight is calculated by the ratio 10.000/1.000.000 = 1/100 or 1%. At each successive level, about 10% of the energy available is converted to new biomass. In conclusion, 1.000.000 joules of sun and rain are required to produce 1 joule of tertiary consumers. The food chain is characterized by different steps, each representing the food categories consumed by organisms that are called trophic levels. In the food web, producers are in the left end of the chain while consumers are in the right end. Generally, consumers took more energy than producers, so they can be considered organisms that required higher quality of energy. Many joules of energy are taken at the left of the chain to produce few joules at the right: the energy quality is lowest at the left and rises at each level of the food chain. Interactions between different elements are represented in system diagrams by interaction symbols. In addition, quantity have their symbols: the storage tank symbol (Fig. 6).

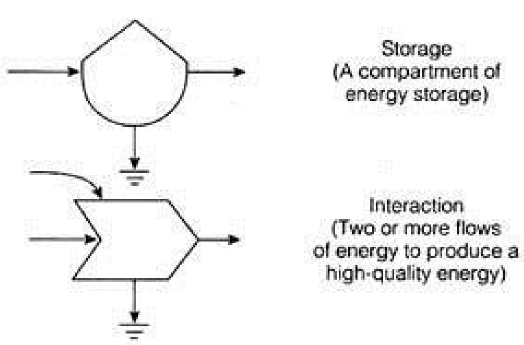


Figure 6. Interaction and storage symbolsFigure 7. Heat sink symbol

During interaction processes, some energy can be dispersed from a storage of concentrated energy (the form available to do work). All storage and processes are accompanied by energy dispersal that cannot be used again and it is indicated with the heat sink symbol (Fig. 7).In the system diagram, symbols are enclosed by a box that marks the boundary of the ecosystem (Figs. 4, 5). Sources and heat sink are outside the box because the source (sun) is provided from an external font and energy dispersed cannot be reused. Moreover, figure 5 shows the sunlight source with one branch coming out again because part of solar radiation flows without being used. The outside sources (circle) influence the ecosystem. Sun drives photosynthesis, wind tide and river inflow release their emergy used for water movements (kinetic energy). The tide and the river also bring into the ecosystem nutrients, carbon dioxide, organic matter and other components. On the right side of the diagrams there are the inputs coming from human services and economy: fishing activities, boats, fuels and so on. All items farther to the right are defined as higher quality because they require more resources to maintain. Consequently, there is a gradient of energy through the energy diagrams: the amount of energy decrease to left end to right end of the diagram while its quality rise. A simple system (as shown in figure 4) usually contains at least one source, a producer, a consumer, a heat sink and the connecting pathways. In the diagram the energy of sources are transformed by processes to give items called products. Production is the process by which two or more ingredients are combined to form a new product (Odum, 1988). When a consumption process accompanies production process, two different kind of production have to be considered:

- GROSS PRODUCTION that represents the rate at which new productare made;
- NET PRODUCTION (product minus the accompanying consumption process) is the production observed when production and consumption processes are occurring at the same time.

The productive process go faster when materials or energy required are available in large quantities. If they are no or less available, they are called limiting factors. Some systems are more able to survive than others, the MAXIMUM POWER PRINCIPLE explains the reason.

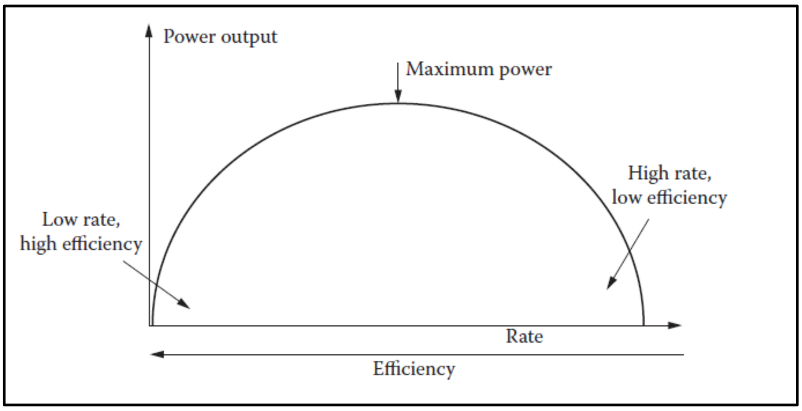


Figure 8. The maximum power principle claims that the development of an ecosystem is a trade-off (a compromise) between the rate and the efficiency, i.e., the maximum power output per unit of time (from Jørgensen, 2012).

Lotka (1956) formulated it and H.T. Odum used this principle to explain some characteristics of ecosystems. The principle states that the most successful ecosystems are those in which energy-capturing devices are most efficient in directing available energy into channel useful to their preservation and maintenance. In other words, system prevail if they manage to maximize the flow of useful energy (for their maintenance and growth). Lotka's principle of Maximum Power revisited in terms of emergy of systems is known as Maximum Empower Principle. At all scales, systems prevail through system organization at first developing the most useful work, with inflowing emergy sources by reinforcing productive processes and overcoming limitation and secondly by increasing the efficiency of useful work. The term "useful work" means the use of the inflowing emergy in reinforcement actions that ensure and, if possible, increase it. Energy dissipation without the increasing of inflowing emergy is not a reinforce and, consequently, a system cannot compete with other systems that use inflowing emergy in self-reinforcing ways. Maximum Empower Principle is an important basis for emergy accounting.

Chapter 3

Emergy evaluation procedure

Emergy analysis is an environmental accounting method used to comprehensively measure the sustainability of human and natural systems. This analytical procedure is able to evaluate system's relationship with its human and natural surroundings by using similar units, considering all contributions to the formation of a particular good or service. Emergy analysis generally translates each form of matter or energy in a system into its equivalent solar energy or solar emergy by way of a unit emergy value (UEV) that reflects the quality value of matter and energy (Brown and Ulgiati, 2004). Both UEVs and other conversion factors provide the means of evaluating all the fluxes supporting the system in a common unit of measure called the solar emjoule(sej) (Vassallo et al., 2009). Specifically, it can be used to account for estimating the work required to deliver ecosystem services, environmental flows of energy and storage of energy in the form of natural capital (Tilley, 2006).

According to Hau and Bakshi (2004) the emergy analysis offers a number advantages, as it:

- Provides a way to bridge economic and ecological systems.
- Provides an objective means by which to quantify and value non-market inputs into a system.
- Shares the rigor of thermodynamics and is scientifically sound.
- Provides a common unit that allows for a comparison of all resources.
- Provides a more holistic alternative to many existing methods of decision-making.

For such reasons, emergy analysis overcomes the shortcomings of traditional economic statistical methods and the energy analysis method. It has gradually become an important method to evaluate the sustainability of systems. The general methodology used to conduct an emergy analysis consists of defining the system boundary and using energy systems diagrams to depict the system's features, inputs and outputs to be analyzed. The next step involves creating an emergy table summarizing the emergy values of the system's stocks and flows. The stocks and flows are converted from units of energy or mass to equivalent units of emergy by using transformity coefficients. The system's sustainability can then be investigated using a number of emergy indicators.

3.1 System diagram

The evaluation starts with energy Systems diagramming (Fig.9) to obtain an overview of the system because, to understand a problem, it is necessary to understand both the mechanism and the way the problem is controlled by the larger surrounding system.

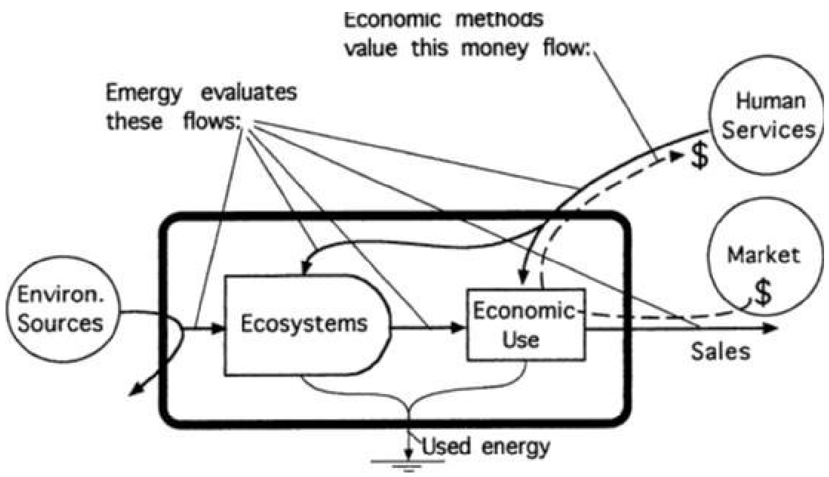


Figure 9. Energy systems diagram of a general system with ecosystem and the economy (From Odum, H.T. and E.P. Odum, 2000).

The diagram underline the components and the processes of the system considered the contributing factors and the alternatives for management. The pathways of the diagram determine the line items in the following emergy evaluation table.

According to Odum (1996) several steps are essential in diagramming:

- Identification of the boundary of the system.
- Analyze and list the most important external sources (an effect is suspected to be 5% or more of the total system functioning).
- Analyze and list the most important components within the system boundary.
- Analyze and list the processes within the system boundary as flows, relationships, interactions, production, consumption and transactions of money.
- Draw the diagram.

In order to standardize the diagram there are some rules to follow in drawing. The system is represented as a rectangular frame; external sources are arranged around the rectangle while internal components are inside it. Both sources and components are characterized by symbols (Fig. 10) with specific energetic and mathematical meanings. Even pathways are connected by symbols. It is important to include all known connections between system components in the draft diagram to insure completeness of the evaluation. Items and flows are arranged in order of transformityfrom left (lower transformity value) to right (higher transformity value).

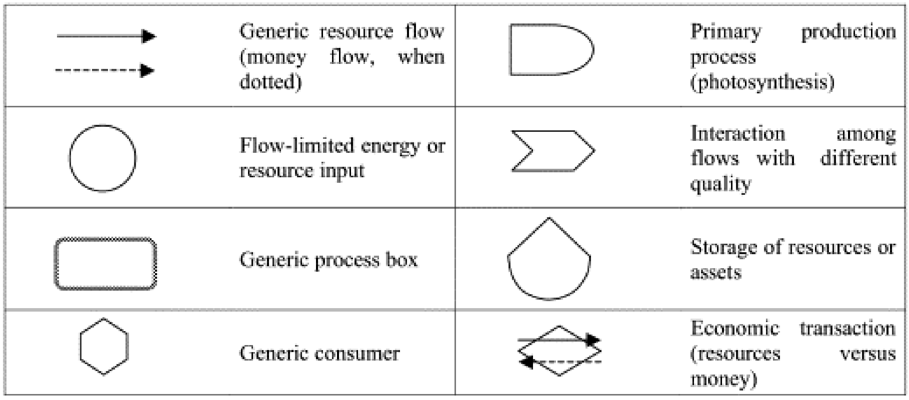


Figure10.Odum's systems language symbols (from Ascione et al. 2009)

At each process in the system most of the available energy is degraded, dispersed and transformed in a smaller amount of energy of another type to the right. In addition, it is possible to color the draw to make it easier to focus.

In this case, the following color scheme is suggested:

COMPONENTS	**COLOR**
Sunlight, heat dispersal	Yellow
Producers	Green
Water, nutrients, material resources	Blue
Consumers, cities, high transformity units	Red
Money	Purple

Sometimes the diagram is complex because there are more components and pathways. For this reason, the first detailed diagram can be simplify by aggregation that combines all sources and components in a model with less pathways and symbols. In addition, the time scale for the diagram is important. If it is established that time scale for the matter of interest is one year, then items with a turnover time shorter than one year are aggregated and storage tanks are not included for them. A diagram like this is a useful tool for defining data needs, it shows clearly the main inputs to evaluate.

3.2. Emergy evaluation table

After a system diagram is drawn, all relevant items identified (flows of matter and energy) have to be categorized and added to a computational table or emergy table. The table is created in order to group flows with the same characteristics and to allow their conversion from conventional units (for example mass, energy euros or other currency) into emergy units (sej). In the emergy tables, raw data on the mass of flows and storage reserves are converted to energy and then to emergy units and Emeuros to aid in comparisons and public policy inferences. This is possible thanks to conversion factors called transformities. The emergy of each input is its energy multiplied by its transformity. Apart from the sun, that has a transformity of one by definition, it is necessary to calculate the transformitiesof the various resources. Today in the literature it is possible to find transformities of the main natural flows in the biosphere. Many are periodically revised by emergy scientists in special publications called folios.

Emergy flows to the system are divided into the maincategories as given in the following:

- **Local Renewable Resources (R)** represent the resources replenished on a regular baseas a result of the use of planetary emergy inflows (solar radiation, geothermal heat). In general all renewable resources (rain, runoff, tide, wind…) are included in the emergy tables, but not all of them are calculated in emergy evaluation. This is due to the possibility that some resources could be co-product and so they cannot be counted twice to avoid double counting of the same flow.

- **Local Non-Renewable Resources (N)** are raw materials that have been built over a long time by environmental processes, with use rates exceeding replacement rates. For example the fuel, metal and mineral extraction are non-renewable resources.
- **Purchased Resources (F)** and service coming from outside system.
- **Yield (Y)** are the output of the system.

Solar emergy is calculated for each inflow, product or item of special interest. Tables provide a template for the calculation of the emergy values for energy sources and flows.The common format used to set up emergy tables is illustrated above. Each emergy evaluation table has almost six columns as shown in table1:

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
Note	**Item**	**Data**	**Solar Emergy/Unit**	**Solar Emergy**	**Em€**
		J, g, €	sej/J, sej/g, sej/€	sej, sej/y	Em€/y

Table 1. Tabular format for an emergy evaluation

- Column 1: Note. The line number for the item evaluated is listed. Each line number corresponds to a footnote in a table where raw data sources are cited and calculations shown.
- Column 2: Item. The name of the item is listed.
- Column 3: Data. For each line item the raw data is given in joules, grams, euros or some other appropriate unit.
- Column 4: Solar Emergy per Unit. For many items the solar emergy per unit (transformitywhere the unit is energy) has already been calculated in previous studies. If it has not, the solar emjoulesper unit can be calculated using one of the methods listed in Odum (1996).
- Column 5: Emergy. The solar emergy is given here. It is the product of columns three and four. It can be an emergy flow (sej y-1) or emergy storage (sej).

- Column 6: EmEuros. This number is obtained by dividing the emergy in column 5 by the emergy/euro ratio for the economy in the selected year.

The total emergy of the output is the sum of the emergy inputs, and the tranformity of the output is its emergy divided by its energy value (see emergy algebra below 3.6).

3.3 Emergy signature

Emergy signature of a system show the magnitude of environmental and economic inflows and outflows of a system on a synoptic plot that is useful in characterizing and classifying systems. The emergy signature is a bar graph of energy flows, with the magnitude and direction of the flow (in or out of the system) in sej per year shown on the ordinate and the type of energy flow identified on the abscissa. Emergy signature shows the relative contributions of the various energy inputs in terms of equivalent ability to do work. If functionally distinct areas have different emergy signatures and similar areas exhibit similarities in their emergy signature, the emergy signature may be useful in classifying different environmental systems based on differencesin their inputs.

3.4 Emergy indicators

Once the system has been quantified in emergy units, it can then be analyzed by using a number of
emergy indicators.
Several of these most common indices are listed and defined as follows:

- **Local Renewable Sources (R):** the flow of free renewable resources that are locally available.
- **Non-Renewable Resources (N):**the flow of non-renewable resources that are locally available.
- **Imports Non-Renewable Resources (F):** the flow of emergy imported in the form of goods and services from outside.
- **Total emergy use (U=R+N+F):** a measure of the global emergy support the system.

- **Percent Renewable (%Ren):** the percent of the total energy driving a process that is derived from renewable sources **(R/(R+F+N)**. It represents the Renewable fraction of emergy use, an indicator of the actual carrying capacity. In the long run only processes with high %Ren are sustainable.
- **Nonrenewable to renewable ratio (NRR)**: is the ratio of non-renewable
- **Emergy density (U/area):** the ratio of the total emergy use and the area of the system.It measures spatial concentration of emergy. If the system needs high rates of emergy,compared to its surface the index value is elevate. High values indicate elevated range of anthropic pressure and environmental stress. The index can be considered also a measure of system's *carrying capacity* that represents the maximum load of a system.

- **Emergy-to-money ratio (Em/€):** describes purchasing power, in emergy units, of one unit of currency spent within the local economy. It is computed by dividing the total emergy use (R+N+F) by GDP (Gross Domestic Production).

- **Emergy Yield ratio (EYR=U/F):** is the emergy supporting the Yield (U=R+N+F) divided by the emergy of all the feedbacks from the economy including fuels and services.Calculates the amount of renewable energy utilized per investment of non-renewable energy. It is an indicator of the yield compared to inputs other than local and gives a measure of the ability of the process to exploit local resources. Low value of EYR indicate that a small amount of renewable energy is used per investment of amount of non-renewable energy.

- **Environmental Loading ratio (ELR=(F+N)/R):** is calculated as the sum of the emergy of non-renewable goods and services supplied by the economy and local free non-renewable sources, divided by the free renewable emergy drawn from the environment. ELR ratio is related to the fraction of renewable resources, it is an indicator of the pressure of the process on the local ecosystem and can be considered a measure of the ecosystem stress due to production activity.

- **Emergy Sustainability Index (ESI=EYR/ELR):** is a ratio that globally indicates if a process provides a suitable contribution to the user with a low environmental pressure. The index is a function of yield, renewability, and load on the environment. According to Brown and Ulgiati (1997), an SI<1 indicates a consumer process while an SI>1 is indicative of products that have net contributions to society. Values of SI between 1 and 10 are indicative of developing economies.

- **Emergy investment ratio (EIR=F/R+N):** is a ratio of emergy fed back from outside a system to the indigenous emergy inputs (both renewable and non-renewable). It gives an evaluation if the process is a good user of the emergy that is invested, in comparison with alternatives. It is not an independent index, but it is linked to the above EYR.

3.5 Monetary and economic evaluations

The buying power of money within an economy may be calculated by dividing emergy use by the money circulation to obtain the emergy/money ratio. If the total emergy used in a year by a state or the Gross Economic Product, expressed in local money units, divides a nation an emergy-money index results (Odum, 1996). The ratio of emergy to money (EMR) can be considered as the fraction of total emergy required to circulate one unit (expressed as local money unit) of Gross World Product, taking into account the assumption that economy and biosphere are an integrated system. EMR is able to converts emergy flows in equivalent monetary flows.The ratio of emergy to money is a useful indexbecause it connects aggregate economic activity tothe emergy flows that support it. In other words the emergy/money ratiotells us the purchasing power of a monetary unit in terms ofthe real wealth (emergy) that it can buy.Dividing the emergy of aproduct or service by the emergy to money ratio for its system gives the monetary value, in emergy terms, of the item. The emergy monetary value of a product or service represents theportion of the total purchasing power in the systemthat is due to a particular product or service from theeconomy or from nature. The emergy to money ratiohas another useful property. Because money are onlypaid to people for their services, the emergy to money ratio for a system can be used as an estimate of theaverage value of human services in that system. Thus, multiplying a money unit value of a product or service by the emergy to money ratio gives, onaverage, the emergy equivalent of human serviceembodied in that item.

3.6 Emergy algebra

Emergy accounting procedure needs some rules that describe how to assign correctly emergy to the flows of energy, matter information within systems. These general rules or accounting procedures have been called by Odum (1996) Emergy Algebra.

Rules can be summarized into four statements: the first four describe how to assign emergy to outputs including splits and co-products, the last deals with double counting a special issue in static Emergy

Algebra to insure that feedbacks, recycle and co-products are treated correctly to avoid double counting.

In short, the main rules of emergy algebra are

1. All source of emergy to a process is assigned to the process's output(s). The emergy of the output is equal to the sum of the inputs multiplied by their (unit Emergy Value) UEVs. The first emergy rule indicates that it is necessary to know the emergy of the inputs in order to calculate the emergy of the output.
2. Co-products from a processes have the total emergy assigned to each pathway;
3. When a pathway splits the emergy is assigned to each branch of the split based on its percent of the total available energy flow 8 or mass) on the pathway before the split;
4. Emergy cannot be counted twice within a system: emergy in feedbacks should not be double counted and co-products, when reunited, should not be added to equal a sum greater than the source emergy from which they were derived.

As a consequence, when a process results in the output of two different products (for example co-products) the input emergy is assigned to both outputs, since each cannot be made without the other and all emergy is required to make each. This create much confusion since it appears that more emergy is output from a process than is input, and it is thus a violation of the Conservation Law of Thermodynamics. However, under no circumstances should the emergy outputs from a process be added together. It would be a violation of rule four, a double counting of emergy (Jørgensen, 2001).

The following list shows common terms used in emergy field:

Emergy: all the available energy that is used in the work of making a product, expressed using a common energy unit.

Emjoule: the unit of emergy, which has the dimensions of the energy previously used.

Energy hierarchy: the convergence and transformation of energy of many small units into smaller amounts of higher-level types of energy with greater ability to intersect with and control smaller units.

Emdollar value: to calculate emdollars, you must first determine the national or regional ratio of emergy to money by dividing the total emergy output by the gross domestic product of the country or region. Once this emergy ratio (sej/$) is determined, you can then multiply it by the emergy value of a product or service to obtain a dollar value, or the emdollar value of the service or product being examined.

Net emergy: the emergy yield from a resource after all the emergy used to process it has been subtracted.

Emergy yield ratio: the ratio of the emergy yield to the emergy required for processing.

Solar transformity: solar emergy per unit of energy, expressed in solar emjoules per joule (sej/J).

Transformity: A measure of the scale of energy convergence. In other words, the emergy of one type required to make a unit of energy of another type. For example, since three coal emjoules (sej) of coal and one cej of services are required to generate one joule (J) of electricity, the coal transformity of electricity is four coal emjoules per joule (4 sej/J).

Maximum power principle: An explanation for the design observed in self-organizing systems (energy transformations, hierarchical patterns, feedback controls, amplifier actions and so on). Designs prevail because they draw in more available energy and use it with more efficiency than alternatives.

(Sources: Odum, 1996; Odum et al., 2000)

Chapter 4

The Marine Protected Areas

A Marine Protected Area (MPA) sets aside to protect marine ecosystems and consists of marine spaces where human activities are more strictly regulated than the surrounding waters to keep them in their natural state. The most common definition of marine protected area is the IUCN (International Union for Conservation of Nature) one: "*A clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values*".

Globally, MPAs cover 3.4% of the world's oceans, and over 10% of coastal waters (Fig. 11).

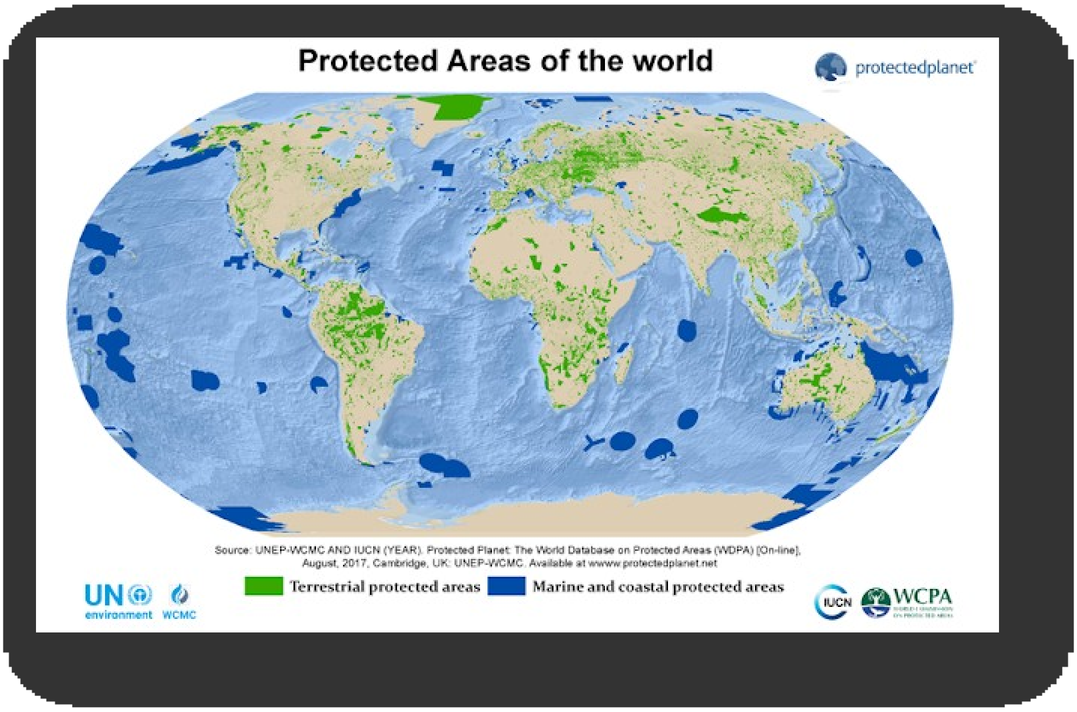


Figure 11. Terrestrial and Marine Protected Areas of the world (from www.iucn.org)

MPAs presence is important for the management of economic resources andto achieve long-term conservation of nature, considering associated ecosystem services and cultural values. MPAs have legal and administrative boundaries delineating zones with permitted and non-permitted uses. Different protection zones are useful to regulate human activities by segregating them spatially, to give special protections for natural or historic marine resources of special interest and to propose an eco-sustainable socio-economic development of that area. This happens through the activation of new economic resources linked to the services offered: i.e. quality tourism and the rediscovery of traditions and products. To pursuit these objectives and define ecological boundaries,a depth knowledge of the area in which MPA sets is essential. It is also important to have the support of the common people and institutions and to use established techniques for surveillance and monitoring of compliance. MPAs are just one of many marine resource management tools; they alone cannot address problems such as pollution, climate change, or overfishing. For this, complementary administration strategies are needed to improve their effectiveness in management measures.

The following scheme summarize a wide range of conservation objectives, with reference with two different categories, that the established of marine protected areas can include:

Ecological objectives:	**Human objectives:**
Ensure the long-term viability and maintaining the genetic diversity of marine species and ecosystems	Provide for the continued welfare of people by the creation of marine protected areas;
Protect depleted, threatened, rare or endangered species and populations	Preserve, protect, and manage historical and cultural sites and natural aesthetic values of marine and estuarine areas, for present and future generations
Preserve habitats considered critical for the survival and/or lifecycles of species, including economically important species	Facilitate the interpretation of marine and estuarine ecosystems for the purposes of conservation, education and tourism
Prevent outside activities affecting the marine protected areas	Accommodate with appropriate management systems a broad spectrum of human activities compatible with the primary goal in marine and estuarine settings

Sometime people think that marine protected areas are those reserves where extraction of any resources is prohibited; this is not the only type of MPA. In fact, many of them may include areas marine in which partial protection is afforded (seasonal closures, catch limits, etc.) and where a variety of uses are allowed. For example, there are many different kinds of MPAs in U.S. waters including national parks, wildlife refuges, monuments and marine sanctuaries, fisher closures, critical habitat, habitat areas of particular concern, state parks, conservation areas, estuarine reserves and preserves, and numerous others. While a few sites exist as no-take marine reserves, the vast majority of MPAs, both in terms of numbers and area, are open for fishing, diving, boating, and other recreational and commercial uses.The strictness of the regulations largely depend upon the objectives of the MPA.Most management systems for MPAs will use a variety of management approaches to achieve the MPA objectives.Among the wide range of management techniques, that MPA administrators can use,it is possible categorized them into ways of prohibiting and limiting activity (Kenchington and Kelleher 1995):

- Prohibition: Absolute prohibition of access to a prescribed area is the simplest form of regulation. It is a form of control that establishes a clear yes/no basis – if a person is found in the area, he has violated the regulation. Prohibition of certain activities within a prescribed area is another prohibitive technique. For example, if fishing is prohibited in a specific area and a person is caught fishing there, he is in violation.
- Limitations: Both terrestrial and marine protected areas around the world often allow some level of human activity, especially if it involves recreation, nature appreciation, education, or research. The management challenge is to design and enforce measures that limit allowed human activities to levels that do not cause harmful or unacceptable impacts. Limitations are also more challenging than prohibitions – they are more complex for area users to understand and may be more difficult for managers to enforce. However, limiting rather than prohibiting activities in an area is usually more acceptable to area users and may be more easily implemented. Limitation by spatial control involves regulating activities specifically to a part or parts of the MPA that can be summarized as follows:

- Zonal management: Spatial control of activities.
- Temporal control: Management changes over time, such as a closed fishing season. For example, this may be used to protect spawning areas for fish or breeding habitats for seabirds.
- Equipment restriction: Regulation of the use of equipment or technology that is efficient for its purpose in the short term but damaging to resources in the long term (e.g., trawl restrictions).
- Quotas: Setting limits on the allowable harvest with the goal of leaving enough of the resource to replenish itself. Quotas are most commonly applied towards fishing.
- Licenses or permits: Issuing permission, through official documentation, for a person or people to engage in specific activities in the MPA. Licenses and/or permits can be issued based on skill, resource allocation, or other characteristics.

The location, number and surface area of MPAs depends on the management goals of the area. There are three basic plans: a small single area (used to protect a unique habitat or a site-specific life cycle event), a large single area (used to protect species nursery grounds or representative habitat), or a network of areas (used to protect habitats needed for the diversity of life stages common among marine species). Authorities and management strategies differ substantially from nation to nation.

4.1 The Italian network of Marine Protected Areas

The Italian Ministry of the Environment and Protection of Land and Sea is responsible for controlling and defending this resource through a system of marine protected areas (MPAs), which are part of a more complex framework of protection at national level and also includes parks and land reserves.
Italy has the largest network of MPAs in Europe and it is planned to establish 54 a total of Marine protected areas. There are 27 marine protected areas as well as 2 submerged parks that protect a total of about 228 thousand hectares of sea and about 700 kilometers of coastline (Fig. 12).

Figure 12. Italian Marine Protected area network (from www.minambiente.it); blue triangles indicate the twosubmerged parks.

The MPAs are established according to the laws n. 979 of 1982 and n. 394 of 1991 with a Decree of the Minister of the Environment containing the name and the delimitation of each area, the objectives and the discipline of protection to which the protection is aimed. Each area is divided into three types of zones with different degrees of protection. They consist of marine environments given by the waters, the seabeds and the stretches of coastline in front of them, which are of considerable interest for their natural, geomorphological, physical, biochemical characteristics with particular regard to marine and coastal flora and fauna and for the scientific, ecological, cultural, educational and economic importance they have. In this regard, it is important to emphasize how these areas serve to promote the dissemination and knowledge of ecology, environmental education, study and scientific research. There are also the Sanctuary of marine mammals, also known as the Sanctuary of Cetaceans and 2 submerged parks: Baia, in the Gulf of Pozzuoli, andGaiola, in the Gulf of Naples,formed a marine environment with significant historical, archaeological, environmental and cultural value.

4.1.1 Zonation

Marine protected areas are generally divided into different types of zones called A, B and C. The intention is to ensure maximum protection for the areas of greatest environmental value, which fall within the integral reserve areas (zone A), strictly applying the constraints established by law. Zones B and C are intended to ensure a gradual protection by implementing, through the Institutional Decrees, exceptions to these constraints in order to combine the conservation of environmental values with the use and sustainable use of the marine environment. The three types of zones are delimited by geographical coordinates and reported in the map attached to the Institutional Decree published in the Official Gazette.

The strategies adopted in the three type of zone, according with the different degree of protection are:

- Zone A (in the cartography highlighted with the red color), of integral reserve, forbidden to all the activities that can cause damage or disturbance to the marine environment. Zone A is the "core zone" of the reserve. In this area, identified in small areas, are generally allowed only the activities of scientific research and service activities.
- Zone B (in the cartography highlighted with the color yellow), of general reserve, where are allowed, often regulated and authorized by the management body, a series of activities that, while allowing a sustainable use and use of the environment affect with the least possible impact. Zones B are not usually very large.
- Zone C (in the cartography highlighted with the color blue), partial reserve, which represents the buffer strip between the areas of greatest naturalistic value and the sectors outside the marine protected area. In this zone, activitiesof fruition and sustainable use of the sea of modest environmental impact are allowed and regulated by the management body, in addition to what is already allowed in other areas. The largest extension of the marine protected area generally falls in zone C.

4.1.2 Procedure for the establishment of a Marine Protected Area

In order to establish a marine protected area, a stretch of sea must first be identified by law as a "marine retrieval area". Once the preliminary procedure has been started for the marine retrieval area, it is considered a "marine protected area to be established soon". Within the list of the areas of retrieval established by the laws, for the effective establishment of a marine protected area it is necessary first of all to have an updated framework of knowledge about the natural environment of interest, in addition to the necessary data on the socio-economic activities that take place in the area. The Ministry of the Environment and Protection of Land and Sea for the acquisition of such knowledge and data can also avail itself of scientific institutes, laboratories and research bodies. The studies are generally divided into two phases: in the first phase, the existing literature on the area is examined; in the second phase, the necessary in-depth studies for a concrete and exhaustive cognitive framework are carried out. Subsequently, the Experts of the Technical Secretariat for Marine Protected Areas (art.2, co.14 of L. n. 426 of 1998) can start the institutional investigation. In order to outline a proposal for the future marine protected area that respects its natural and socio-economic characteristics, the Experts of the Technical Secretariat enrich the survey provided by the studies with targeted inspections and comparisons with local authorities and communities. The definition of the perimeter of the area (the external borders), the zonation within it (the different zones A, B and C), and the protection carried out through the different degrees of constraints in the three zones, are part of the draft decree drawn up at the end of the investigation. On the draft decree, the Region and the local authorities involved in the institution of the marine protected area are consulted, in order to obtain a concrete and harmonious local consensus. Finally, as established by Legislative Decree no. 112/98 art.77, it is necessary to obtain the opinion of the Unified Conference on this DM scheme. At this point, the Minister of the Environment, in agreement with the Minister of the Treasury, proceeds to the actual establishment of the marine protected area, also authorizing the financing to meet the first expenses related to the institution (L. n. 394/91 art.18 and L. n. 93/01 art.8). Unless otherwise specified, the

Ministerial Decree shall enter into force on the day following its publication in the Official Gazette.

4.1.3 Reserve commission

The reserve commission assists the delegated body in the management of the reserve, formulating proposals and suggestions for everything concerning the operation of the reserve itself. In particular, the commission gives its opinion to the proposal for the regulation implementing the decree establishing the reserve and organizing it, including the provisions relating to management costs, drawn up by the delegated body.

It is established by the Managing Body and is composed as follows:

- A president, designated by the Minister of the Environment;
- The commander of the Harbor Master's Office, or his delegate;
- Two representatives of the coastal municipalities designated by the same municipalities;
- One representative of the regions concerned;
- one representative of the economic-productive categories concerned designated by the Chamber of Commerce for each of the provinces in whose boundaries the reserve has been established;
- Two experts appointed by the Minister of the Environment in relation to the particular purposes for which the reserve was established;
- A representative of the most representative environmental associations chosen by the Minister of the Environment;
- A representative of the Education Authority;
- A representative of the Administration for Cultural and Environmental Heritage;
- A representative of the Ministry of the Environment.

4.1.4 Regulation

The Marine Protected Area regulation definitively defines and regulates prohibitions and possible derogations according to the degree of protection required for the protection of valuable ecosystems.

Proposed by the Managing Authority, after hearing the opinion of the Reserve Commission, it is approved by decree of the Minister of the Environment. Before the formulation of the regulation, a managing body has the faculty to apply temporary disciplines for some of the activities that take place within the marine protected area, of course within the framework of what is established by the founding decree.

4.1.5 Constraints

Law 394/91 article 19 identifies the activities prohibited in marine protected areas, i.e. those that may compromise the protection of the characteristics of the environment that is the object of the protection and the institutional purposes of the area. The Institutional Decrees of the marine protected areas, considering the nature and the social-economic activities of the places, can however provide some exceptions (derogations) to the prohibitions established by Law 394/91 as well as detailing in a more exhaustive way the constraints. In this regard, reference should be made to each individual Institutional Decree or any subsequent amending decree and, where present, to the regulation, for each of the 16 marine protected areas.

In general, Law 394/91 prohibits in marine protected areas:

A) The capture, collection and damage of animal and plant species and the removal of minerals and archaeological finds;

(B) Alteration of the geophysical environment and of the chemical and hydro biological characteristics of the water;

C) Carrying out advertising activities;

D) The introduction of weapons, explosives and any other destructive and capture means;

(E) Motorized navigation;

(F) Any form of landfill of solid or liquid waste.

4.1.6 Future Marine Areas

The marine protected areas to be established in the near future are the retrieval areas for which the preliminary procedure is in progress. This procedure is foreseen for the areas included in the list of the 48 retrieval areas indicated by laws 979/82 art.31 and 394/91 art.36. The figure 13 shows the 17 marine protected areas that will soon be established, whatever the state of progress of the planned administrative procedure.

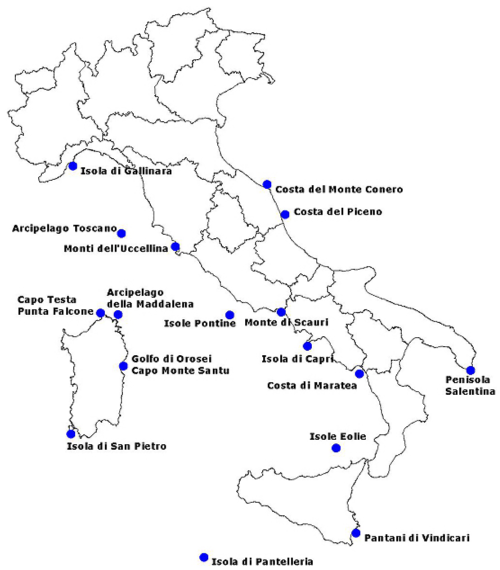


Figure 13. Future Marine Areas

4.2 The network of Marine Protected Areas in Sicily

Sicily holds the richest network of Marine Protected Areas in Italy, counting 6 marinereserves all around the island (Fig. 14), while 8 more MPAs are bound to be established.

- ✓ Ustica (1986)
- ✓ Isole Egadi (1991)
- ✓ Capo Gallo – Isola delle Femmine (2002)
- ✓ IsolePelagie (2002)
- ✓ Plemmirio (2005)
- ✓ IsoleCiclopi (1989)

Figure 14. The network of Marine Protected Areas in Sicily (from www.minambiente.it)

On 18 February 2011, the Regional Department of Environment of Sicily updated by decree the perimeter of 6 marine Sites of Community Importance (SCI), bringing them to coincide with the perimeter of corresponding Marine Protected Areas.On 12° July 2016, the same Regional Department delegated the management of those 6 SCI to MPA management bodies. This was an unprecedented choice, which enforced both the MPA management and the SCI effectiveness.The presence of reliable management bodies, with good experience in marine conservation and sustainable coastal management, such as Italian MPAs, allows us to produce Conservation Measures and Management Plan of marine SCI very fast and with a concrete vision.The research project proposed in this work has been conducted in the Marine Protected Area "*IsoleCiclopi*" located in the eastern coast of Sicily, extending north of Catania (Ionian Sea). For the peculiarity of its location and the close relationship with the socio-economic context of the area, it is necessary to provide a more detailed description of the setting and the organization of the MPA.

Chapter 5

Marine Protected Area "*IsoleCiclopi*"

5.1 The "*Riviera dei Ciclopi*"

The coastline between *Acireale* and *Catania* (eastern coast of Sicily) is drawn by water and fire. In some stretches, the cliff is the result of primordial underwater eruptions, in others of the cooling of lava flows that have come here in ancient times along the slopes of the great volcano: *Etna*. A popular legend identifies these places as the scenery to the love between *Galatea*, a marine nymph, and a shepherd boy named *Aci*. Unfortunately, the girl had also aroused the interest of Cyclops*Polifemo*, the opponent of *Ulisse*, who upset by hatred and jealousy killed the shepherd boy. *Zeus*, taking pity on *Galatea*, transformed his lover into a river (the current *Akis*) that flowing towards the sea allowed the two lovers to meet. It is also said that the body of *Aci*, dismembered into nine parts, fell where then were founded the municipality of *AciBonaccorsi*, *Aci Castello*, *Aci Catena*, *Aci Platani*, *Acireale*, *Aci S. Filippo*, *Aci S. Antonio*, *Aci S. Lucia* and *AciTrezza*. The coast is also called "*Riviera dei Ciclopi*". The panorama consists of a succession and alternation of large inlets, coves and beaches between the rocks. The famous *Faraglioni*, located right in front of the port of *Aci Trezza*, which looks like natural sculptures, the result of ancient underwater eruptions and of the work of the waves and winds, enriches the scenery. MPA "*Isole Ciclopi*" extends from the municipality of *Punta Aguzza* to *Capo Mulini*, covering an area of 323 hectares within the territory belonging to the municipality of *Aci Castello*. The municipality of *AciCastello*is divided into four hamlets: *Aci Castello*, *Aci Trezza*, *Cannizzaro* and *Ficarazzi*. The coastline on which the reserve stands belongs to the municipalities of *Aci Castello* and *Aci Trezza*, especially the MPA's core (A zone) is located in front of the harbor of *Aci Trezza*, far few kilometers from the coast.

5.1.1 *Aci Castello*

Aci Castello, located 10 km from *Catania*, is an ancient seaside village that over the years, while maintaining its ancient origins, has become a seaside destination for many tourists. An earthquake in the second half of 1100 destroyed the village and the inhabitants were forced to repair in nearby locations, which in turn developed as autonomous centers and today are recognizable by the prefix *Aci* (*Aci Trezza*, *Acireale* etc…). The most characteristic element of this center is the Norman castle (Fig. 15) built by the Byzantines in the seventh century, on a ridge of lava, to defend the population from raids and called "*Castrum Jacis*". The castle gives its name to the country and the composition of the rock on which the building stands is extremely rare. It originated from a marine basaltic volcanic eruption over 500,000 years ago, the lava stone is covered with a glassy crust (generated by the high temperatures of magma) and divided into prisms inside. This particular shape and structure is due to the presence of sand and clay in the original seabed and the sudden cooling of the magma, caused by contact with cold seawater.

Figure 15. The Norman castle

5.1.2 *Aci Trezza*

A few kilometers northbound from *Aci Castello*, there is the municipality of *AciTrezza* fishing center of ancient and remarkable tradition. At the beginning of the seventeenth century it was an uninhabited area where some merchants of *Acireale* kept tanks of water for the maceration of flax and hemp, intended for the production of ropes. At the end of the 17th century the town was founded and towards the beginning of the 19th century it succeeded in transforming its economy from a place for the production of ropes to a town of fishermen. The village, which today has about 5,000 inhabitants, overlooks the Ionian Sea in front of the small archipelago of the "*Isole Ciclopi*". The panorama is dominated by the "*Faraglioni dei Ciclopi*" (Fig. 16), rocks of lava that emerge from the water. According to tradition, *Ulisse* met the Cyclops *Polifemo* in the 9th chant of the Odyssey, blinding him. The stacks would represent, in fact, the huge boulders thrown by the Cyclops, in the grip of anger and pain, against the ships of the Greeks fleeing. Of the four islets worthy of note is the "*Isola Lachea*" (Fig. 18) home to a biological station of the University of *Catania*. *Aci Trezza*, confirming its attitude as land of fishermen, was the home of "*I Malavoglia*" a novel written by Giovanni Verga and the setting of the famous film "*La terra trema*" based on this book and directed by *Luchino Visconti*.

Figure 16. *Isola Lachea* and *Faraglioni dei Ciclopi*seen from above.

5.2 Marine Protected Area “*Isole Ciclopi*”

The Marine Protected Area, established in 1989, extends from *Punta Aguzza* to *Capo Mulini* covering an area of 323 hectares within the territory belonging to the municipality of *Aci Castello*(Fig. 17). It takes its name from a small archipelago composed of the islands of *Lachea*, *Faraglione Grande*, *Faraglione di Mezzo* and *Uccelli* and 3 other large rocks arranged in an arch in front of which stands the village of *AciTrezza*. The management of the MPA is entrusted to the consortium "*Isole dei Ciclopi*", formed by *Cutgana* (University Center for the protection and management of natural environments and agro-ecosystems), the University of *Catania* and the City of *Aci Castello*.

Figure 17. Marine Protected Area "IsoleCiclopi" (from www.parchipertutti.it)

5.2.1 Origins

The formation of the products, that today form the *Isola Lachea* and the *Faraglioni dei Ciclopi*, dates back to about 500,000 years ago. In that period, the eastern edge of the wide gulf sloping towards the basin of the Ionian Sea, which then occupied the southern part of the area where now extends *Etna*, was affected by intense eruptive activity in an underwater environment. Subsequently, the entire area was raised, which led to the emergence of *Pleistocene* clays, currently raised up to 300 meters above sea level in the area upstream of *Aci Castello-Aci Trezza*. In this way, the feeding centers were moved from the eruptive manifestations that became sub aerial and covered with their products most of the previous submarine flows, giving rise to the gradual construction of the *Etna* volcanic massif, as we see it today. The seabed of the *Isola Lachea* descend towards a platform that reaches a depth of about 30-35 meters; the sandy seabed is found in the short stretch of sea that separates the islands from the mainland, with a maximum depth of 12 meters in the middle. The *Isole Ciclopi* represent the remains of a single original subvolcanic mass consisting mainly of columnar-fissured rocks (www.isoleciclopi.it).

Isola Lachea

Figure 18. Isola Lachea

The elliptically shaped *Isola Lachea* (Fig. 18) covers an area of about 1.5 hectares and reaches a maximum height of 35 meters. In the northern area, a split that seems to divide it in two and that extends into the submerged portion of the island furrows it, creating a narrow and deep canyon. Its summit parts have a whitish coloring caused by the process of transformation and hardening of the clays in contact with the incandescent lava. On the island, there are two small buildings, one at the bottom and the other at the top. The first houses a scientific laboratory, while the second is home to a nature museum. The first traces of the presence of man date back to prehistoric times and are supported by the discovery of archaeological finds, traces of houses, shelters and a precious axe in diorite dating back to the Stone Age. Along the staircase that starts from the northern entrance of the island there are two large circular holes "*bothros*" about a meter deep and inside one of them were found fragments of late Roman objects. The island also has a cave, called the Hermit's Cave, which in the past was inhabited by a monk in search of silence and solitude.

Faraglioni

There are three stacks: the largest is called the “*Faraglione di Santa Maria*” or the “*Faraglione Grande*”, the “*Faraglione di Mezzo*” and the “*Faraglione degli Uccelli*” (Fig. 16). The *Faraglione di S.Maria* is the largest, reaches a height of 40 meters and is the only one to have been affected by human intervention. The remaining two are smaller and differ from the rest of the landscape in the absence of the clays that originally covered them and that the force of the sea has slowly eroded. The landscape is completed by the presence of minor rocks that flank the stacks and characterized by family names given by fishermen.

5.2.2 Zonation

The MPA is divided into three zones with different degrees of protection (Fig. 19):

- The **integral reserve zone "A"** includes the sea area surrounding *IsolaLachea* and *Faraglione Grande*, delimited by five yellow stationary buoys.

<u>In the zone are allowed:</u>

a) rescue, surveillance and service activities;

b) scientific research activities duly authorized by the Managing Body;

c) bathing, exclusively in the stretch of sea, along the western side of *IsolaLachea*, which extends from the access road to the island to the channel of *Longa* with an extension of 30 meters from the cliff and in the stretch of sea that surrounds *Punta Cornera*. The *Punta Cornera* extends from the extreme north of IsolaLachea to the first inlet of the eastern side, with an extension of 30 meters from the cliff (Fig. 18);

d) access by rowing boats only to reach the bathing areas.

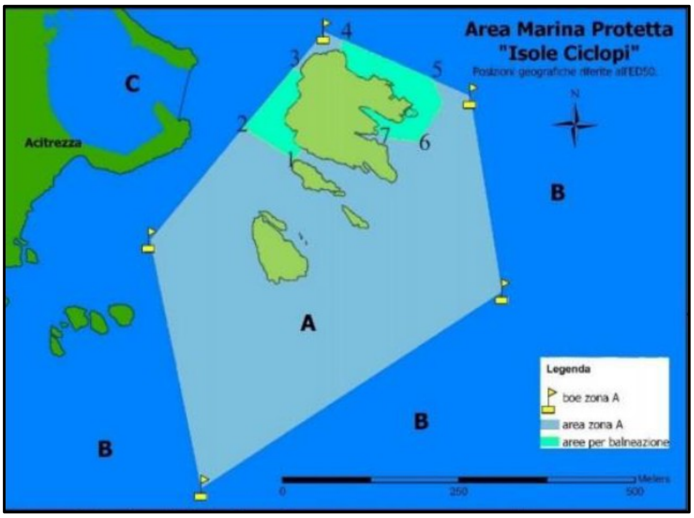


Figure 19. Zonation of MPA "*IsoleCiclopi*". Bathing sites in A zone of MPA (green fluorescent colored) (from www.isoleciclopi.it).

- **Zone "B" of general reserve**, includes the stretch of sea surrounding zone A.

<u>In the zone are allowed:</u>

a) all activities allowed in zone A;

b) bathing;

c) sailing and rowing;

d) motor navigation to boats, with the exception of jet skis or jet skis and similar means, and to boats at a speed not exceeding five knots;

e) motor navigation for collective transport and guided tours, authorized by the Managing Authority and in any case at a speed not exceeding five knots;

f) mooring in areas identified and authorized by the Managing Authority by means of special buoy fields, positioned in accordance with the need to protect the seabed;

g) the exercise of small-scale artisanal fishing, subject to authorization from the Managing Authority, reserved for fishing companies operating both individually and in cooperative form, with registered office in the communications included in the Marine Protected Area, on the date of entry into force of the Institutional Decree of the Marine Nature Reserve of 7 December 1989, and for members of these cooperatives included on the same date in the register of each cooperative;

h) fishing tourism activities, subject to authorization from the Managing Authority, reserved for fishing companies that carry out their activities both individually and in cooperative form, having their registered office in the municipalities included in the Marine Protected Area on the date of entry into force of the Institutional Decree of the Marine Reserve of 7 December 1989, and for members of these cooperatives included, on the same date, in the register of each cooperative;
i) sport fishing, with pole-and-line fishing, authorized by the Managing Authority and reserved for residents of the Marine Protected Area;
j) the underwater guided tours, carried out according to the needs of protection of the seabed, organized by the diving centers authorized by the Managing Authority and having their registered office in the municipalities included in the Marine Protected Area at the date of entry into force of the decree of 24/11/04;
k) SCUBAdiving carried out according to the needs of protection of the seabed and authorized by the Managing Authority.

- **Zone "C" of partial reserve** includes the residual stretch of sea within the perimeter of the Protected Marine Area and the harbor of *Aci Trezza*.

In general, all three areas are subject to the limitations laid down by law, in particular by art. 19, paragraph 6 of Law 394 of 6 December 1991, which prohibits any activity that may alter the characteristics of the environment and compromise the institutional purposes of the protected area. Therefore, as indicated by art. 7 of the Institutional Decree of 2004, in the whole Protected Marine Area -saving the relevant derogations of which we will say below- is not allowed:
a) any activity that may constitute a danger or disturbance of plant and animal species, including bathing, sailing, anchoring, mooring, the use of jet skis or jet skis and similar means, the practice of water skiing and similar water sports, underwater fishing, the introduction of alien species and active restocking;

b) any activity of catching, collecting and damaging specimens of animal and plant species, including hunting and fishing;
c) any activity of removal, even partial, and damage to archaeological finds and geological formations;
d) any alteration, by any means, direct or indirect, of the geophysical environment and of the biochemical characteristics of water, including the release of any toxic or polluting substance, the dumping of solid or liquid waste, aquaculture, the release of discharges that do not comply with the most restrictive requirements provided for by current legislation;
e) the introduction of weapons, explosives and any destructive or catching means, as well as toxic or polluting substances;
f) the use of open fires.

<u>In the zone are allowed:</u>
a) all activities permitted in zones A and B;
b) motorized navigation on vessels, with the exception of jet skis or jet skis and similar means, and to boats at speeds not exceeding ten knots;
c) motor navigation of the units used for collective transport and guided tours, authorized by the Managing Authority and in any case at a speed not exceeding ten knots;
d) anchoring in areas specifically identified by the Managing Authority, compatibly with the need to protect the seabed;
e) sport fishing, with pole-and-line and reed, subject to authorization by the Managing Authority for non-residents of the Protected Marine Area.

5.2.3Regulation

Access

In zone A of integral reserve is allowed the access and the transit to swim or of boats, to reach the zones destined for the bathing and the point of landing to the *Isola Lachea*.
In zones B and C, access by vessels is allowed to both:

- ✓ rowing units

- ✓ boats and boats at reduced speed

Inside the MPA it is forbidden to use water scooters or similar.

Stopping and anchoring

The stationing of naval units at sea, according to the way in which it is carried out, is classified as:

-anchorage: all the operations carried out to ensure that the vessels are kept on the seabed only by lowering the anchor or similar gear;

-stop: the permanence, in a position, of a naval unit without giving bottom to anchors of any shape or type;

-mooring: the stationing of the boat through the use of buoys specially prepared (subject to authorization of the Harbor Master's Office).

Inside the MPA there are different regulations for parking, mooring and anchoring depending on the different reserve areas:

- Zone A of integral reserve: the anchorage and mooring of boats are prohibited, parking is allowed only to units authorized to transport visitors on the *IsolaLachea*, for the only time necessary for the operations of embarkation and disembarkation of passengers, without the use of anchors, buoys or any other device, maintaining the position with the use of oars.
- General reserve zone B: anchoring is prohibited to protect the seabed. However, it is allowed to moor the boats at the buoy fields specially prepared by the managing body.
- Zone C of partial reserve: the anchorage, within the limits provided by the ordinances of the Harbor Master's Office is allowed in all zone C, except in the stretch of sea between the pier of the harbor of *AciCastello* and the small stacks.

It is also permitted to moor the boats at the buoy fields specially prepared by the managing body. Mooring in the diving sites in zone C is reserved for residents and diving centers. The latter have absolute priority of mooring, even in the case of previous stopovers of residents.

SCUBA diving without breathing apparatus

The observation of the seabed with mask and fins (snorkeling), if practiced individually or by residents, is allowed in areas not prohibited to bathing. For guided tours, a special authorization issued by the managing body is required.

Underwater activities with self-contained breathing apparatus

To dive in the MPA it is necessary to have a sports diver's license (recognized at least at the national level). Those who do not hold a diver's license can dive only if accompanied by a diving school in compliance with the regional and national regulations governing diving education and in possession of an authorization issued by the managing body. Scuba diving, if carried out in pairs, is allowed in zones B and C, in the manner and within the time limits indicated in national laws and in the ordinances issued by the competent authority governing the diving activity, only with permission issued by the managing body. In the case of groups or guided tours, it is necessary to use specially authorized structures.

Sport fishing

Underwater fishing is prohibited throughout the MPA Residents with a specific authorization are allowed to fish in zones B and C, only by hand or with a rod, from the ground or by boat or boat (including trolling), with a maximum of three hooks. Cephalopods may be fished with no more than two lines for each fisherman (each one armed with a special lure).

Chapter 6

Emergy accountingof Marine Protected Area "*IsoleCiclopi*"

Environmental accounting of MPA "*IsoleCiclopi*" can be organized into different analysis patterns represented in figure 20.

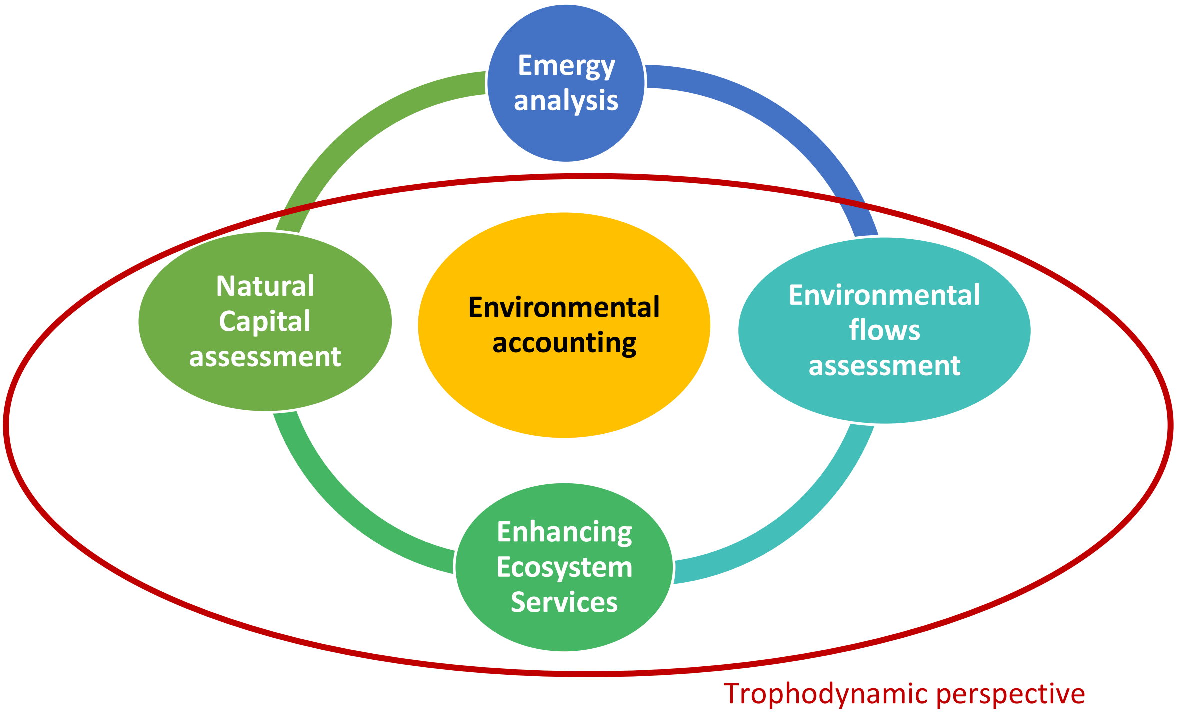


Fig. 20 Evaluation procedures involved in MPA "*Isole Ciclopi*" environmental accounting.

Emergy analysis:procedure to determine the values of energy flows, storages of material and information within an ecosystem based on the normalization of all types of available energy used in the production of ecosystem and socioeconomic goods or services to emergy. Emergy offers a quantitative, objective method for measuring the contribution of ecosystem goods and services to the economy (Berrios et al.,2017).

Trophodynamic perspective: evaluation of a dynamic framework for the primary productivity of each system. Such a trophodynamic perspective would provide the biomass data to assess i) environmental flows, ii) ecosystem services, and finally iii) Natural Capital (a more detailed procedure and results for the benthos are described in chapter 7).

Natural Capital assessment: Natural Capital describe the stock of all natural resources that exist on environment. It provides humansa wide range of free goods and services, often called ecosystem services, which make human life possible. There are serious risks associated with Natural Capital decline. Assessing natural capital value is fundamental, in order to manage these risks and enable a better future for all (a more detailed procedure and results are described in chapter 7).

Environmental flows assessment: Environmental flows are useful to estimate the annual environmental flows supporting natural capital (a more detailed procedure and results are described in chapter 7).

Enhancing ecosystem services: Ecosystem Services represent the varied contributions the environment provides to manand society. From the perspective of policy decision makers, it is a supporting instrument for planning the use of a natural system (a more detailed procedure and results are described in chapter 8).
In this chapter emergy analysis procedure and resultsare illustrated.

6.1 Emergy analysis

6.1.1 Materials and methods

Environmental evaluation of the inflows, outflows and storages of energy, materials, and information, throughout emergy analysis, has been carried out in Marine Protected Area "*IsoleCiclopi*", following the procedure outlined by Odum (1996).The first step followed, to perform the emergy evaluation, was the identification of boundaries (spatial and temporal) of the study area. The spatial boundary of the MPA, considered in the study, corresponds to the administrative boundary of the marine reserve. The time boundaries assumed to estimate environmental flows of matter and energy was one year. For modelling information the three most season covering the seasonal variability in the annual average have been used: for exampleautumn, spring and summer.Then system diagrams were drawn to obtain an overview of the system and focusing on: natural renewable inputs, imported non-renewable inputs (also economic inputs) and generated goods and services (outputs). Raw data were collected, elaborated, converted in emergy units (sej) and included in emergy table, directly from the diagrams. The table accounts the annual flows that support the system, such as materials, energy, and information.Emergy table is also created in order to group flows with the same characteristics and to allow their conversion from conventional units (for example mass, energy euros or other currency) into emergy units (sej).

In current study table, emergy flows are divided into different categories:

- NATURAL INPUTS Local Renewable Resources (R)
- ECONOMIC INPUTS Imports Non-Renewable Resources (F)

In this study, import non-renewable resources (**F**) are calculated for the whole MPA and then were clustered in four categories:

- IMPORTS NON-RENEWABLE RESOURCES for fishing sector ($\mathbf{F_f}$)
- IMPORTS NON-RENEWABLE RESOURCES for whole tourism ($\mathbf{F_T}$)
- IMPORTS NON-RENEWABLE RESOURCES for tourists ($\mathbf{F_t}$)
- IMPORTS NON-RENEWABLE RESOURCES for divers ($\mathbf{F_d}$)

As can be noted in the previous list, tourism (**F_T**) has been divided into two categories:

1. Tourists (**F_t**) that represents all users of MPA services as guided excursions, seabed observation with the glass-bottom boat and snorkeling.
2. Divers (**F_d**) that represents only the users of local diving center services.

This parting is important to highlight possible differences, in the same area, between a tourism closely related to the activities of the MPA and one dependent on other entities.

The common format used to set up emergy table is illustrated above. In this work, emergy evaluation table has nine columns as shown in table 2:

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9
Note	**Item**	**Units** **(g, J, €)**	**Amount** **(Unit/year)**	**Reference**	**Emergy /Unit** **(sej/unit)**	**Solar Emergy** **(sej/yr)**	**Emergy** **%**	**Emeuros** **(Em€)**

Table 2. Tabular format used for the emergy evaluation in MPA "*IsoleCiclopi*".

- Column 1: Note. The line number for the item evaluated is listed. Each line number corresponds to a footnote in a table. The footnotes referenced on table, including raw data sources and calculations,in this paper maybe found in the appendices (appendices B, C and D).
- Column 2: Item. The name of the item is listed.
- Column 3: Units. For each line item is given the unit of measure adopted.
- Column 4: For each line item the raw data is given in appropriated unit.
- Column 5: For each line item a list of references for transformity values, used in this study, is provided. Complete references can be found in appendix D.
- Column 6: Solar Emergy per Unit (transformity). For all items the solar emergy per unit has already been calculated in previous studies.
- Column 7: Emergy. The solar emergy is given here. It is the product of columns three and four. It can be an emergy flow (sej y^{-1}) or emergy storage (sej).

- Column 8: Emergy %.Percent of the total energy driving a process that is derived from renewable sources is given.
- Column 9: EmEuros. This number is obtained by dividing the emergy in column 7 by the emergy/euro ratio for the economy of Italy in the selected year.

Transformities for local renewable resources (R) (sunlight,rain, wind, geothermal heat, tide, run off and nutrients) and Imports non-renewable resources (F)have already been calculated in previous studies and were taken from literature.Transformity ratios used in this report are documented in appendix D.Tables include some large numbers with many zeros. They can be represented as the product of the front part of the number multiplied by ten for each zero. An example: 6.2E+05 is the abbreviation of 620,000. This is also equivalent to the scientific notation 6.2×10^5.The units can be in sej/J if the product is divided by the energy or sej/g if the emergy of the product is divided by the mass. The total annual emergy input to the biosphere (derived for example from solar radiation, rain, wind, tidal momentum and geothermal energy) is named the emergy baseline. The baseline used in this study is 15.83E+24 sej yr^{-1} calculated by Odum (2000). Brown et al. (2016) updated the baseline value to 1.20E+25 sej yr^{-1}. To convert data obtained with analyses performed under an earlier baseline to this new baseline, the data should be multiplied by the ratio of the new baseline to the older one. In this study the scaling factor of 0.76 can be used to update the results.
Total amount of stored emergy of environmental resources is calculated from the sum of the emergy of all inputs, according to emergy algebra (see chapter 3).
Once the system has been quantified in emergy units, the data have been analyzed by means of emergy signature. Emergy signatures of a system show the magnitude of environmental and economic inflows and outflows of a system on a synoptic plot that is useful in characterizing and classifying systems.
Finally, emergy indicators are calculated in order to summarize and relate emergy flows of the economy with those of the environment.

In this study emergy indicators performed were:

- ✓ **Emergy Density (U/A)** that shows the concentration of the emergy use, it is a measure of spatial concentration of emergy flow within a system;
- ✓ The **Emergy Yield Ratio (EYR)** that indicates the ability of the system to exploit local resources;
- ✓ The **Environmental Loading Ratio (ELR)** that represents a measure of impact that non-renewable emergy (including purchased emergy) has on the system;
- ✓ The **Emergy sustainability index (ESI)** that points out yield, renewability and environmental load of the system;
- ✓ The **Emergy investment ratio (EIR) that** represents the ratio of emergy fed back from outside a system to the indigenous emergy inputs (both renewable and non-renewable).

Finally, Emergy-to-money ratio (EMR) procedure has been applied to obtain economic value of the environmental flows. The EMR represents the ratio of emergy flows of a nation to its Gross Domestic Product and it is expressed in sej €$^{-1}$. The Emergy-euros (em€) value of goods and service of the whole system has been calculated by dividing the emergy of the local renewable and non-renewable resource by EMR of Italy of 9.60E+11 sej €$^{-1}$according to Pereira et al. (2013). The em€ value expresses the amount of economic activity that can be supported by a given emergy flow of storage. It represents the buying power as the average amount of emergy that circulates in the economy for every euro. All inputs has been converted to monetary terms to estimate the economic value of the total ecosystem services provided by the reserve.The total emergy of the output is the sum of the emergy inputs, and the tranformity of the output is its emergy divided by its energy value (see emergy algebra). Low value of transformity indicates that the productive process of the output concentrate renewable energies across time and space to produce yields. As a general rule, the transformities of similar products are compared to obtain information about production efficiency. Transformities of different classes of product can also be compared. In this case, transformities indicate the relative 'position' in the global hierarchy of processes.

All energy transformations can be represented in sequence and the position of each energy flow in the sequence is indicated by the transformity. Outputs data have been obtained with the procedure described in chapter five (trophodynamic analysis).

6.1.2 Results and discussion

Figure 21 provides the energy flow diagrams of MPA "*IsoleCiclopi*". Diagram give a general picture of the inputs and outputs of the ecosystem and illustrates all the connection between the various components.

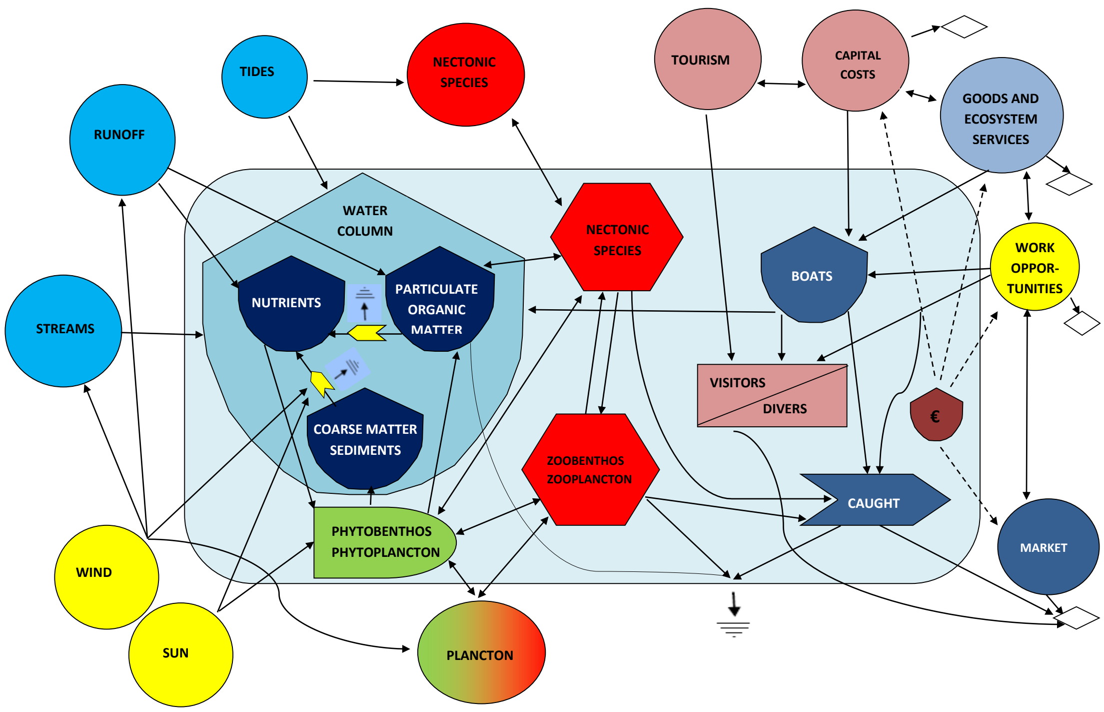


Figure21. Energy system diagram of MPA "*Isole Ciclopi*".

The total Emergy evaluation for the environmental and purchased inputs of MPA "*Isole Ciclopi*" is reported in table 3.The total emergy value is 3.99E+17sej/yr.

Note	Item	Units Units (g, J, €)	Amount (Unit/year)	Reference	Emergy/Unit (sej/unit)	Solar Emergy (sej/yr)	Emergy %	Emeuros (Em€)
NATURAL INPUTS								
Local Renewable Resou								
1	**Solar radiation**	J	2.57E+15	[1]	1.00E+00	2.57E+15	0.11	2.68E+03
2	**Rain**							
	Chemical potential	J	8.94E+12	[1]	3.05E+04	2.73E+17	11.22	2.84E+05
	Kinetic energy	J	8.87E+10	[1]	1.45E+05	1.29E+16	0.53	1.34E+04
3	**Wind**	J	5.56E+10	[1]	2.45E+03	1.36E+14	0.01	1.42E+02
4	**Geothermal heat**	J	9.81E+12	[2]	1.20E+04	1.18E+17	4.85	1.23E+05
5	**Tide**	J	3.78E+11	[3]	2.36E+04	8.93E+15	0.37	9.30E+03
6	**Runoff**	J	2.49E+09	[4]	6.31E+04	1.57E+14	0.01	1.63E+02
TOTAL LOCAL RENEWABLE RESOURCES, R (3,4,5,6)[a]						**3.99E+17**	**16.44**	**4.16E+05**
Note	**Item**	**Units Units (g, J, €)**	**Amount (Unit/year)**	**Reference**	**Emergy/Unit (sej/unit)**	**Solar Emergy (sej/yr)**	**Emergy %**	**Emeuros (Em€)**
ECONOMIC INPUTS								
Imports Non-Renewable Resources (F)								
7	**Fishing boat (materials)**							
	Wood	g	1.25E+08	[5]	2.40E+09	3.00E+17	12.36	3.13E+05
	Steel	g	3.00E+06	[6]	6.97E+09	2.09E+16	0.86	2.18E+04
	Fiberglass	g	1.50E+07	[6]	7.87E+09	1.18E+17	4.86	1.23E+05
	Metal	g	5.20E+06	[7]	1.78E+09	9.26E+15	0.38	9.64E+03
	Paint	g	1.20E+05	[6]	2.55E+10	3.06E+15	0.13	3.19E+03
8	**Goods and services (fishing sector)**							
	Human labor	J	1.20E+11	[8]	4.45E+06	5.36E+17	**22.04**	5.58E+05
	Fuel	J	5.60E+11	[9]	5.30E+04	2.97E+16	1.22	3.09E+04
	Capital cost	€	8.00E+04	[4]	2.75E+12	2.20E+17	9.05	2.29E+05
	Tax insurance	€	3.52E+03	[10]	3.04E+12	1.07E+16	0.44	1.11E+04
	Maintenance costs	€	3.46E+03	[11]	1.40E+12	4.84E+15	0.20	5.05E+03
TOTAL IMPORTS NON-RENEWABLE RESOURCES							56.43	
for fishing sector, F_f(7, 8, 12, 13)						**1.37E+18**	**1.43E+06**	

[a] According to Odum (Odum 1996), the first three renewable inputs are co-products of the same source so, to avoid double counting, we consider only the largest one (in this study rain). For this reason, the total renewable contribution is the sum of rain, geothermal heat, tide and runoff (see emergy algebra chapter 2).

Note	Item	Units Units (g, J, €)	Amount (Unit/year)	Reference	Emergy/Unit (sej/unit)	Solar Emergy (sej/yr)	Emergy %	Emeuros (Em€)
9	**MPA boat**							
	Boat materials							
	Rubber	g	2,00E+05	[7]	7,22E+09	1,44E+15	0,06	1,50E+03
	Plastic, plexiglass	g	2,00E+05	[6]	5,85E+09	1,17E+15	0,05	1,22E+03
	Fiberglass	g	4,10E+06	[6]	7,87E+09	3,23E+16	1,33	3,36E+04
	Steel	g	1,51E+06	[6]	6,97E+09	1,05E+16	0,43	1,10E+04
	Metal	g	1,74E+06	[7]	1,78E+09	3,10E+15	0,13	3,23E+03
	Iron	g	5,00E+05	[6]	2,05E+09	1,03E+15	0,04	1,07E+03
	Wood	g	3,00E+05	[5]	2,40E+09	7,20E+14	0,03	7,50E+02
	Lead	g	1,00E+06	[12]	3,33E+09	3,33E+15	0,14	3,47E+03
	Paint	g	6,00E+03	[6]	2,55E+10	1,53E+14	0,01	1,59E+02
10	**Goods and services (MPA boat)**							
	Fuel	€	1,37E+11	[9]	5,30E+04	7,24E+15	0,30	7,54E+03
	Capital cost	€	2,27E+04	[4]	2,75E+12	6,23E+16	2,57	6,49E+04
	Maintenance costs	€	8,00E+03	[11]	1,40E+12	1,12E+16	0,46	1,17E+04
	Tax insurance	€	6,12E+02	[10]	3,04E+12	1,86E+15	0,08	1,94E+03
	Human labor	J	3,66E+07	[13]	7,38E+06	2,70E+14	0,01	2,81E+02
11	**Goods and services (MPA)**							
	Tourists	J	3,87E+09	[14]	1,50E+07	5,81E+16	2,39	6,05E+04
	Human labor	J	2,82E+09	[13]	7,38E+06	2,08E+16	0,86	2,17E+04
11a	Divers	J	2,94E+10	[14]	1,50E+07	4,41E+17	**18,14**	4,59E+05
	Human labor	J	1,03E+09	[13]	7,38E+06	7,61E+15	0,31	7,93E+03
12	**Infrastructure materials (buyos)**							
	Iron	g	5,38E+04	[6]	2,05E+09	1,10E+14	0,00	1,15E+02
	Plastic	g	8,81E+06	[6]	5,85E+09	5,15E+16	2,12	5,37E+04
	Cement	g	1,20E+07	[12]	1,97E+09	2,36E+16	0,97	2,46E+04
13	**Goods and services (Infrastructure)**							
	Human labor	J	4,44E+07	[13]	7,38E+06	3,28E+14	0,01	3,41E+02
	Maintenance costs	€	5,00E+03	[11]	1,40E+12	7,00E+15	0,29	7,29E+03
	Capital cost	€	1,33E+04	[4]	2,75E+12	3,65E+16	1,50	3,80E+04
TOTAL IMPORTS NON-RENEWABLE RESOURCES for whole tourism, F_T (9, 10, 11,11a,12, 13)						**7,83E+17**	32,22	**8,16E+05**
TOTAL IMPORTS NON-RENEWABLE RESOURCES for tourists, F_t (9, 10, 11,12, 13)						**3,35E+17**	13,77	**3,49E+05**
TOTAL IMPORTS NON-RENEWABLE RESOURCES for divers, F_d (9, 10, 11a,12, 13)						**7,04E+17**	28,98	**7,33E+05**
TOTAL IMPORTS NON-RENEWABLE RESOURCES, F (7-13)						**2,03E+18**	83,66	**2,12E+06**

Table 3. Emergy table for R and F inputs of MPA “*Isole Ciclopi*”.

The last bar graph (Fig. 22) shows the emergy inputs as a percentage of the total emergy value, called "emergy signature" of the system, that can be summarize using a bar graph. Renewable (**R**) and Non-renewable resources (**F**) of MPA represent respectively 16.44% and 83.66% of the total emergy use (**U**) within the area (2.43E+18). The total emergy use suggest a measure of potential standard of life, intended as availability of resources and goods. Chemical potential of rain is the major environmental contribution to MPA, which accounts for 11.22% of the total renewable inputs with geothermal heat (4.85%); the results highlight the importance of both chemical potential of rain and geothermal heat for the primary production. Among the purchased inputs, human labor in fishing sector and divers present the major values respectively with 22.04% and 18.14% of all purchased emergy.

If clusters analysis is considered, the major value are related to the fishing sector $\mathbf{F_f}$(56.43%), following by 32.22% of whole tourism $\mathbf{F_T}$. The partition of whole tourism into the two category, tourists $\mathbf{F_t}$ and divers $\mathbf{F_d}$, highlights the different incidence between the users with the percentage respectively of 13.77% and 28.98%.

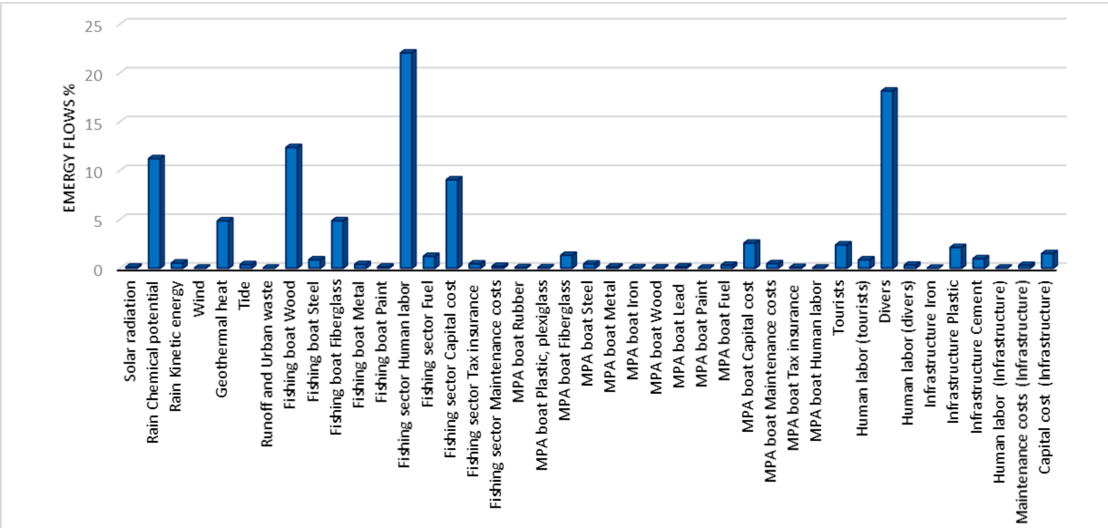


Figure 22. Emergy signature of the MPA "*Isole Ciclopi*"

In addition, also performance indicators are calculated considering the four categories ($\mathbf{F_f}$, $\mathbf{F_T}$, $\mathbf{F_t}$, **and** $\mathbf{F_d}$) to obtain the final indicators for each ecosystem service.

Table 4 summarizes selected emergy-based indicators calculated for the MPA.

Table 4. MPA "*Isole Ciclopi*" emergy-basedindicators

Indicators	Expression function	Unit	Quantity
Area	**A**	m^2	6.23E+06
LOCAL RENEWABLE RESOURCES	**R**	seJ/yr	3.99E+17
IMPORTS NON-RENEWABLE RESOURCES	**F**	seJ/yr	2.03E+18
IMPORTS NON-RENEWABLE RESOURCES (for fishing sector)	F_f	seJ/yr	1.37E+18
IMPORTS NON-RENEWABLE RESOURCES (for whole tourism)	F_T	seJ/yr	7.83E+17
IMPORTS NON-RENEWABLE RESOURCES (for tourists)	F_t	seJ/yr	3.35E+17
IMPORTS NON-RENEWABLE RESOURCES (for divers)	F_d	seJ/yr	7.04E+17
Total Emergy	**U=R+F+N**	seJ/yr	2.43E+18
Emergy density	**U/A**	$seJ/yr/m^2$	3.90E+11
Emergy density (without stress factors)	**R/A**	$seJ/yr/m^3$	6.41E+10
Emergy Yield Ratio	**EYR=U/F**		1.20
Emergy Yield Ratio (fishing sector)	$EYR_f=(F_f+R+N)/F_f$		1.30
Emergy Yield Ratio (whole tourism)	$EYR_T=(F_T+R+N)/F_T$		1.51
Emergy Yield Ratio (tourists)	$EYR_t=(F_t+R+N)/F_t$		2.19
Emergy Yield Ratio (divers)	$EYR_d=(F_d+R+N)/F_d$		1.57
Environmental Loading ratio	**ELR=N+F/R**		5.10
Environmental Loading ratio (fishing sector)	$ELR_f=N+F_f/R$		3.43
Environmental Loading ratio (whole tourism)	$ELR_T=N+F_T/R$		1.96
Environmental Loading ratio (tourists)	$ELR_t=N+F_t/R$		0.84
Environmental Loading ratio (divers)	$ELR_d=N+F_d/R$		1.76
Emergy Sustainability Index	**ESI=EYR/ELR**		0.24
Emergy Sustainability Index (fishing sector)	$ESI_f=EYR_f/ELR_f$		0.38
Emergy Sustainability Index (whole tourism)	$ESI_T=EYR_T/ELR_T$		0.77
Emergy Sustainability Index (tourists)	$ESI_t=EYR_t/ELR_t$		2.61
Emergy Sustainability Index (divers)	$ESI_d=EYR_d/ELR_d$		0.89
Emergy investment ratio	**EIR=F/R+N**		5.09
Emergy investment ratio (fishing sector)	$EIR_f=F_f/R+N$		3.43
Emergy investment ratio (whole tourism)	$EIR_T=F_T/R+N$		1.96
Emergy investment ratio (tourists)	$EIR_t=F_t/R+N$		0.84
Emergy investment ratio (divers)	$EIR_d=F_d/R+N$		1.76

The **Emergy Density(U/A)**shows the concentration of the emergy use, it is a measure of spatial concentration of emergy flow within a system. The value for MPA is 3.90E+11 sej/yr/m^2. The value is a clear indicator of area as a limiting factor: there is the need to investing resources much beyond the area-based carrying capacity of the MPA. Emergy density value, calculated without stress factors (fishery, whole tourism, tourists and divers) is 6.41E+10 sej/yr/m^2. The lowest value focus on the necessity to review some of the activities to a more sustainable economic management of the reserve in the long end.The **Emergy Yield Ratio (EYR)** indicates the ability of the system to exploit local resources. The lowest possible value of EYR is 1 by definition and it means that the local emergy converging to generate the product is equal to the imported emergy. The EYR for MPA is 1.20 (Fig. 23). The value is low and close to the unit, so the ability of the system to exploit local resources is small, with imported inputs contributing most of the emergy used. This highlight the dependence of the MPA on imports to generate goods and service. The indicator calculated for the different categories confirms this observation. In fact, EYR for fishing sector is 1.30, for whole tourism is 1.51, showing the increasing dependence and use of imported goods, if only ecosystem services are considered. Among whole tourism, tourists and divers present very different values of EYR, respectively 2.19 and 1.57. The higher value of diversunderlines a disadvantageous condition for the MPA, where this activity, more than fishery or tourists, overworks local resources without reinvesting in the area.Therefore, the low values recorded indicate a system that decrease its ability to rely on local resources, converting resources imported from outside.

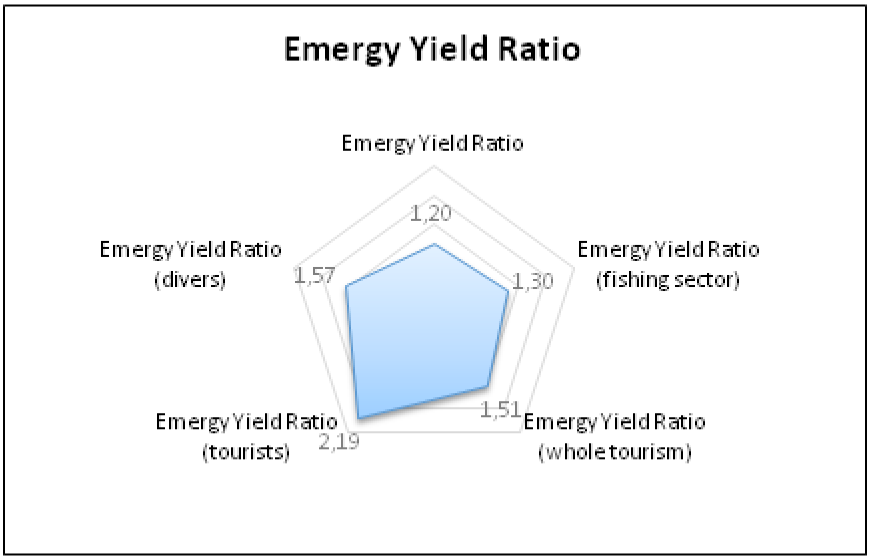


Figure 23. Emergy Yield Ratio of MPA "*IsoleCiclopi*".

The **Environmental Loading Ratio (ELR)** represents a measure of impact that non-renewable emergy (including purchased emergy) has on the system. Taking into account that a wilderness area would have an ELR near zero, an ELR of 1.0 could be considered as an appropriate ecological-economic balance (Tilley and Swank, 2003). The environmental costs of dependence more on purchased resources, pointed out by EYR, and is also reflected in the ELR of 5.10 (Fig. 24). The value recordered means that the consumption of non-renewable resources is 5.10 times higher than the renewable ones. High rates of ELR also reflect a condition of environmental stress. To better understand what could be the main source of stress,it is important to analyzethe different categories. ELR for fishing sector is 3.43 while for whole tourism is 1.79. Both values are over 1.0 but fishing sector seems to be the major liable of the unsatisfactory balance between local and imported resources.The results are supported by the emergy percentage of 56.43% related to this sector. These values indicate the necessity to improve economic self-sufficiency of the fishing activity in order to gain performance of the system as a whole. For instance, implementation of ecotourism, not so developed in the MPA, or similar activities could manage to cover all the needed investments. For tourism sector 1.79 value underline a more balanced condition, even if the indicator is higher than satisfying rate. It is interesting to compare the different results for the two categories of tourism investigated: ELR of tourist is 0.84 and

ELR for divers is 1.76. The findings point out an appropriate ecological-economic balance for users of MPA activities and it shows a load that fit perfectly on the local environment. Moreover, this state could allow an improvement of services without affecting ecological capacity of the area. On the contrary, divers reflect an economic management that trades on local resources without a real support in terms of economic return for the MPA and they represent an environmental stress factor for the system. In fact, a service that causes a great load on the environment,may seriously affect long-term sustainability. On other hands, divers' activity should be reduced or restructured taking into account an incoming from this activity able to be invested, at local level, for the maintenance of the reserve.

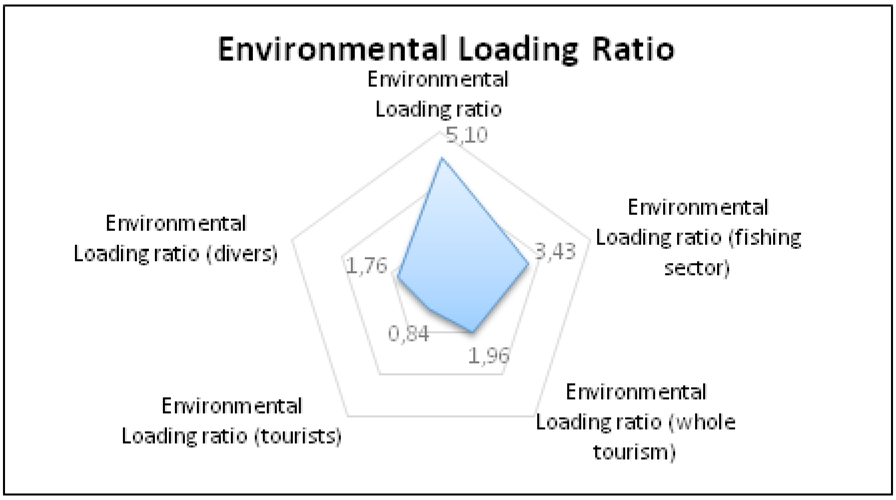


Figure 24. Environmental Loading Ratio of MPA "*IsoleCiclopi*".

The **Emergy sustainability index (ESI)** points out yield, renewability and environmental load of the system. A negative ESI is indicative of a process that depends entirely on non-renewable resources, has a great load on the environment and on a long run it could threat sustainability.The ESI value calculated for the MPA is 0.24 (Fig. 25). The index highlights a low sustainability level of the system and it indicates a high use of non-renewable energy with large imports of purchased energy and materials. It can be also considered as an indicator of a state of environmentalstress. Clusters analysis shows similar values, indicative of consumer processes: ESI for fishing sector is 0.38, for tourism is 0.77. The only difference, already observed for previous indices, is the contribution of tourists. ESI for divers is consistent with the other results, the same index calculated for tourists is indicative of a process that have net contributions to society and of developing economy. Once again, MPA services are configured as the most sustainable activities.

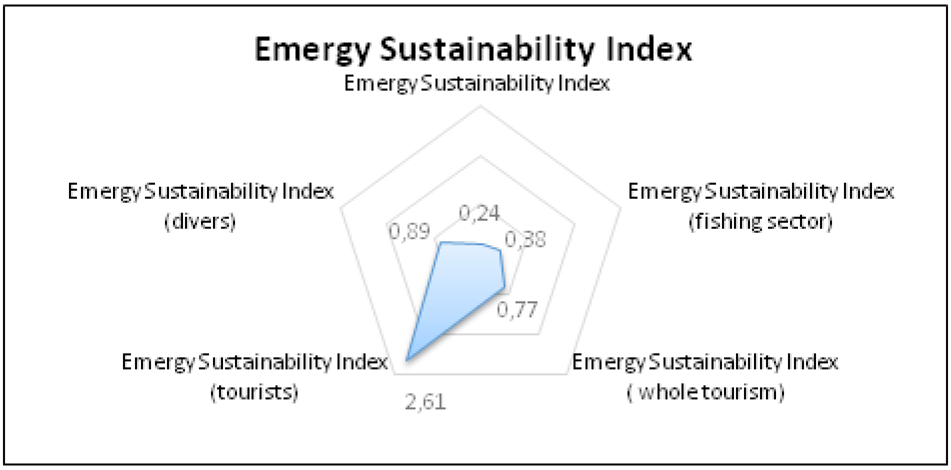


Figure 25. Emergy Sustainability Index of MPA "*IsoleCiclopi*".

The **Emergy investment ratio (EIR)** is ratio of emergy fed back from outside a system to the indigenous emergy inputs (both renewable and non-renewable). It evaluates if a process is a good user of the emergy that is invested, in comparison with alternatives. It is not an independent index, but it is linked to the above EYR (Brown and Ulgiati, 1997). High values indicates large inputs from the outside. As a consequence, with a strength relianceon the outside, the failure of the exporter system could carry back also the dependent one.The EIR for entire MPA is 5.09 (Fig. 26), for fishing sector 3.43 and 1.96 for whole tourism. The category, tourists and divers have respectively values of 0.84 and 1.76. These results outline the same trend observed and described particularly for EYR and for other indices.

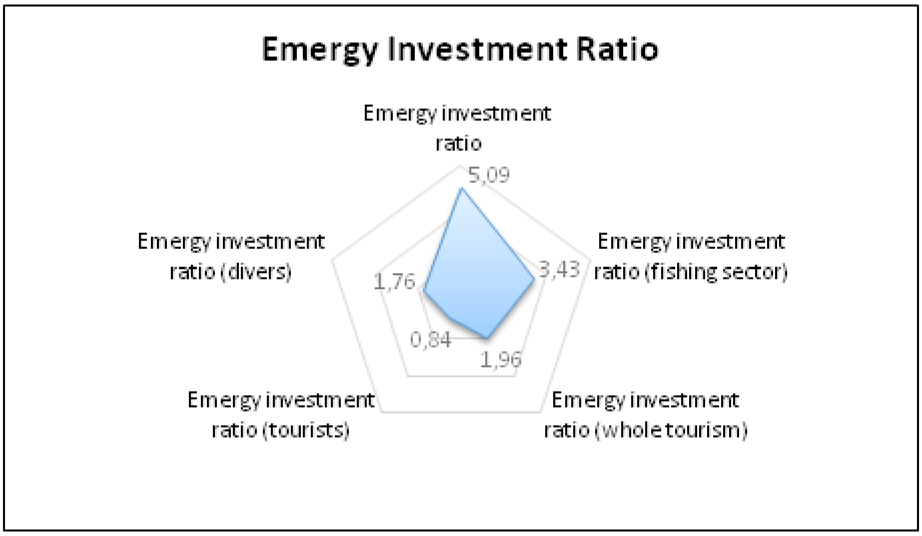


Figure 26. Emergy Investment Ratio of MPA "IsoleCiclopi".

Emergy-to-money ratio (EMR) procedure has been applied to obtain economic value of the environmental flows. The total emergy-euros value of renewable inputs is 4.16E+05 em€/yr. The em€ value expresses the amount of economic activity that can be supported by a given emergy flow of storage. It represents the buying power as the average amount of emergy that circulates in the economy for every euro. All inputs have been converted to monetary terms to estimate the economic value of the total ecosystem services provided by the reserve. The em€ value of natural renewable inputs is reported in figure 27. The em€ value of rain chemical potential (2.84E+05 em€ y^{-1}) is the higher input to the system, followed by geothermal heat (1.23E+05 em€ y^{-1}).

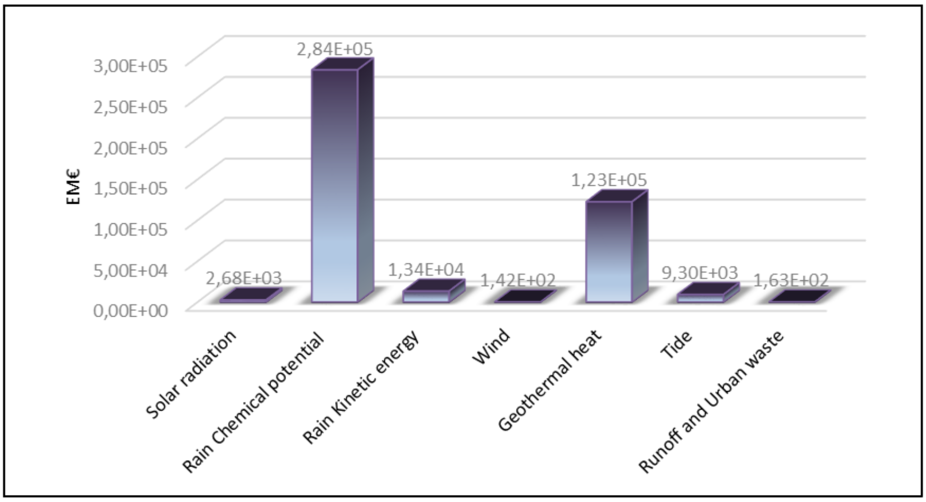


Figure 27. Em€ value of natural renewable inputs of MPA "*IsoleCiclopi*".

Table 5 shows the output of the marine reserve. Transformity value of each output has been calculated by the ratio between the total emergy contribution of all inputs in output's formation and the energy flux of the product.

Note	Item	Units (g, J, €)	Amount (Unit/yr)	Emergy/Unit (sej/unit)	Solar Emergy (sej/yr)
OUTPUTS PRODUCTS of MPA					
1	**Primary producers**				
	Phyto-benthic biomass	J	5.47E+21		3.99E+17
	Posidoniaoceanica	J	1.35E+19		3.99E+17
	Phytoplankton	J	2.91E+08		3.99E+17
				7.26E-05	
2	**Primary consumers**				
	Zoo-benthic biomass	J	2.44E+21		3.99E+17
	Zooplankton	J	1.81E+09		3.99E+17
				1.64E-04	
3	**Secondary consumers**				
	Fish	J	1.73E+11	**2.31E+06**	3.99E+17

Table 5. Emergy flows and transformities value calculated for outputs of MPA "*IsoleCiclopi*".

The lowest transformity value (7.26E-05sej/J) has been recordered for primary producers (phyto-benthic biomass, *Posidoniaoceanica*, and phytoplankton) then, progressively increasing,primary consumers (zoo-benthic biomass and zooplankton) with an amount of 1.64E-04 sej/J and secondary consumers (fish) corresponding to 2.31E+06 sej/J. Low values correspond to more efficiency (less emergy per unit of product); the higher the transformity, the greater the demand for energy to make that flow or product. Emergy is the same along food web (from producers to consumers), whereas available energy decreases after each transformation and the transformity increases. The findings confirm the trend among the reserve the food web: autotrophs transfer their solar-derived energy to the heterotrophs. The heterotrophs' transformities are greater because of their low energy with respect to the solar energy that has been used for it. Organisms receiving feedback from other organisms further down the food chain are reinforced by a small energy flow of high quality, that is, more concentrated and therefore more capable of doing work.

Chapter 7

Biophysical accounting

The biophysical accounting of MPA "*Isole Ciclopi*" starts with the trophodynamic analysis, that provides the primary productivity of the reserve, considered as the basis for the successive evaluation of Natural Capital and Environmental flows.

7.1 Trophodynamic perspective

The biomass data collected for each biocenosis are the basis to provide a biophysical accounting through the evaluation of a dynamic framework for the primary productivity of each system. Such a trophodynamic perspective would provide the biomass data to assess i) Natural Capital, ii) environmental flows and finally iii) ecosystem services.

7.1.1 Materials and methods

Sampling campaign

The evaluation of MPA outputs begins with the estimation of phytobenthic biomass. It represents a good starting point for the environmental assessment because is the basis of the ecological pyramid on which the whole food chain depends, in a more or less direct way. In this study biomass estimation for benthic organisms is based on dry weight. During past studies, all biocenoses of MPA "*Isole Ciclopi*" were identified and they have been used to create a biocenotic map according to Meinesez et al(1983). The following scheme presents the correspondence between biocenosesaccording to Meinesez et al (1983) and habitat according toRelini and Giaccone (2009).

Biocenoses (Meinesez et al., 1983)	Habitat (Relini and Giaccone, 2009)
Posidonia oceanica Meadows (Hp)	Priority Habitat III. 5.1. (EUR 27:1120)
Biocenosis of Infralittoral Photophilic Algae (Ripc)	Habitat III. 6.1. (EUR 27:1170)
Semi-Photophilic Biocenosis of Infralittoral Rock in Sheltered Waters (Rihc)	Habitat III. 6.1.18 Habitat III. 6.1.19
Precoralligenous Biocenosis (Pc)	Priority Habitat IV. 3.1.10 Priority Habitat IV. 3.1.11
Coralligenous Biocenosis (C)	Priority Habitat IV. 3.1.13 Priority Habitat IV. 3.1.15

To simplify biomass evaluation, the main benthic biocenosis of MPA, taken into account, have been grouped as follows:

1. ***POSIDONIA OCEANICA* MEADOWS (HP)**

- Association with *Caulerpa* on rocky-sandy bottom
- *Posidonia oceanica* meadow on rocky-sandy bottom
- *Posidonia oceanica* meadow on rocky substrata
- *Posidonia oceanica* semi-meadow on rocky substrata
- *Posidonia oceanica* meadows (HP)

2. **BIOCENOSIS OF INFRALITTORAL PHOTOPHILIC ALGAE (RIPC)**

- Biocenosis of infralittoral rock in environmentwith high hydrodynamics(RIPB)
- Biocenosisof infralittoral rock in sheltered waters without*Cystoseira* or*Sargassum* (RIPC/0)
- Biocenosiswith encrusting Rodophiceae and sea urchins (RCEO)
- Mosaic-typeof infralittoral rock in sheltered waters and encrusting Rhodophyceae and sea urchins areas

3. **SEMI-PHOTOPHILIC BIOCENOSIS OF INFRALITTORAL ROCK IN SHELTERED WATERS(RIHC)**

4. **PRECORALLIGENOUS BIOCENOSIS (PC)**

- Hard substrata communities without biological constructions: Precoralligenous (PC)
- Soft bottomswith precoralligenous developing on various size rocks

5. **CORALLIGENOUS BIOCENOSIS (C)**

- Biocenosis of the coralligenous bottoms (C)
- Soft bottomswith coralligenous developing on various size rocks

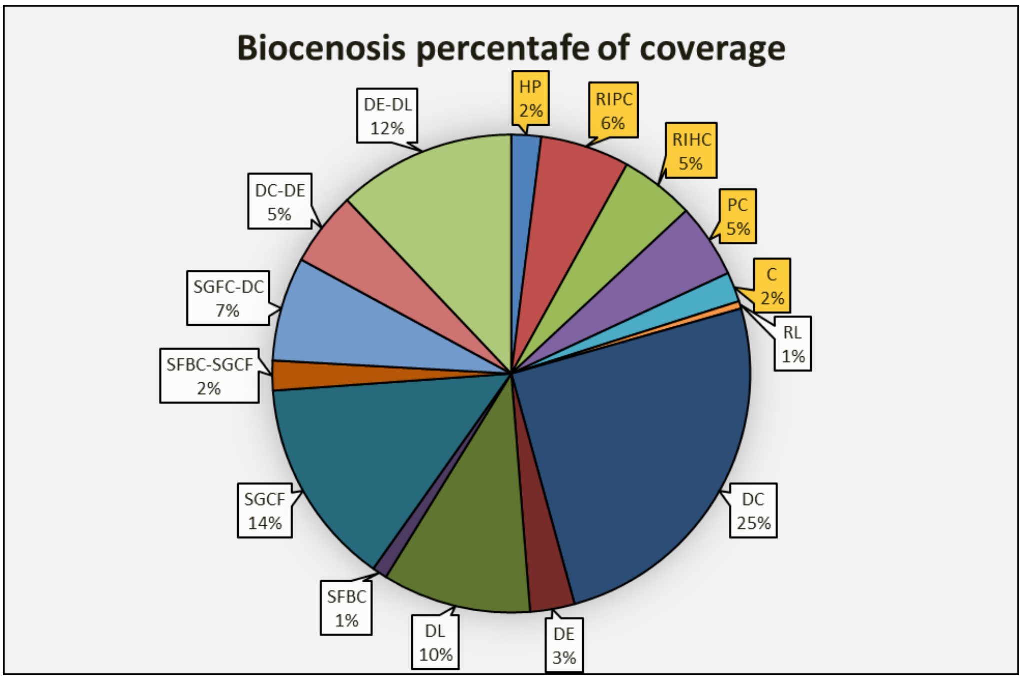


Figure 28. Percentage coverage of each biocenoses in MPA. Yellow labels identified the five biocenosis selected for sampling and analysis.

The five groups identified, through the analysis of biocenotic map (appendix A), consist in 13 biocenoses and they occupy 197.440 m^2 out of a total of 6.230.000 m^2. Some considerations should be taken into account to better understand the choice of each biocenosis. We considered the most representative biocenoses in terms of organisms ‘assemblage, presence and abundance. In fact, the remaining biocenoses, are mainly represented by detritus and sandy bottom (table 6) with a scarce component of organisms, documented through previous studies, despite their surface extension (Fig. 28).

Excluded biocenosis
Biocenosis Of Offshore Rocky Bottoms (RL)
Biocenosis Of Coastal Detritic (DC)
Biocenosis Of Muddy Detritic Bottoms (DE)
Biocenosis Of The Shelf-Edged Detritic (DL)
Biocenosis Of The Fine-Grained, Well Sorted Sands (SFBC)
Biocenosis Of Coarse Sands And Fine Gravels Under The Influence Of Bottom Currents (SGCF)
SGFC-DC Ecotone
DC-DE Ecotone
DE-DL Ecotone

Table 6. Biocenoses excluded from the analysis.

Furthermore, *in situ* observations detected the difference between the actual surfaces of each biocenosis and those reproduced in cartography.In fact, the cartographic representation, due to its characteristics, returns the area occupied by each biocenosis in two-dimensional surfaces, without taking into account the three-dimensionality of the seabed.This feature is particularly evident in very steep seabed and in submerged cliffs (as the one of biocenosis considered in our work). To overcome these differences, comparing the bathymetric and the bionomics paper, the extent of the various biocenoses has been increased according to these percentages here:

Biocenoses	Percentage increase
Posidonia oceanica meadow (HP)	2%
Biocenosis of infralittoral photophilic algae (RIPC)	2%
Semi-photophilic biocenosis of infralittoral rock in sheltered waters (RIHC)	5%
Precoralligenous biocenosis (PC)	10%
Coralligenous biocenosis (C)	10%

As a result, the real extension of the five group of biocenosis is greater than the one reported in the biocenotic maps. This procedure cannot be applied for the excluded biocenosis because of the different morphology and composition of the seabed.

Benthos

Sampling of benthic organisms were conducted in June / July / August 2016 and March 2017. Sampling planning has been based on the identification of different sites of MPA that could be representative of the five biocenosespreviously illustrated.

Below the sampling sites (Fig. 29) with methodological characterization, diving point and biotic communities:

1. "*Il Castello*" – Sampling on transept perpendicular to the coastline in each of the subsequent biocoenosis:

- Mosaic-type of infralittoral rock in sheltered waters and encrusting Rhodophyceae and sea urchins areas
- semi-photophilic biocenosis of infralittoral rock in sheltered waters

2. "*Pietra del Lido*" – Point sampling.

- *Posidonia oceanica* meadows

3. "*Piazza Bambini del Mondo*" – Sampling on transept perpendicular to the coastline in each of the subsequent biocoenosis:

- Biocenosis of infralittoral rock in sheltered waters without *Cystoseira* or *Sargassum*

4. "*Spinosa*" – Sampling on transept perpendicular to the coastline in each of the subsequent biocoenosis:

- Hard substrata communities without biological constructions: Precoralligenous
- Biocenosis of the coralligenous bottoms

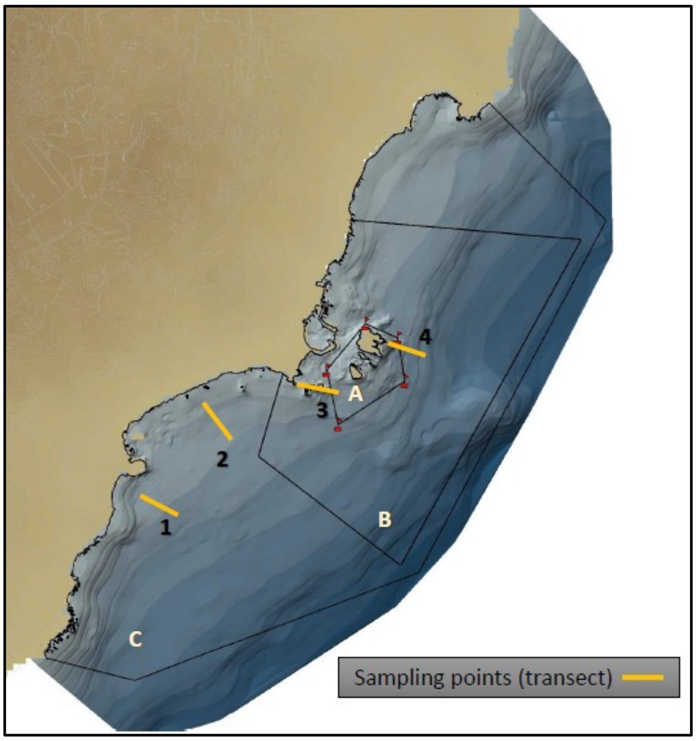


Figure 29. Sampling sites

The transect sampling (Fig. 30) involves the use of grating methodology.The technique states the removal of the entire surface population of a predetermined area. The sampling area is bounded by a metallic square. For each site, in the two different sampling campaigns, six replicates have been made. In this study, we used a 25*25 cm square to limit environmental impact due to the samples removal. The phytobenthic biomass includes macro algae and *Posidonia oceanica*, the only sea grass existing in the MPA "*Isole Ciclopi*". Regarding*P. oceanica*, it was necessary to use two different squares; a larger square (50 * 50 cm) for the beam count and a second one of 25 * 25 cm for the collection of the whole plant starting from the rhizome. Each sample has been recorded on the operator's card with an identification number, location, site features, water temperature and depth.

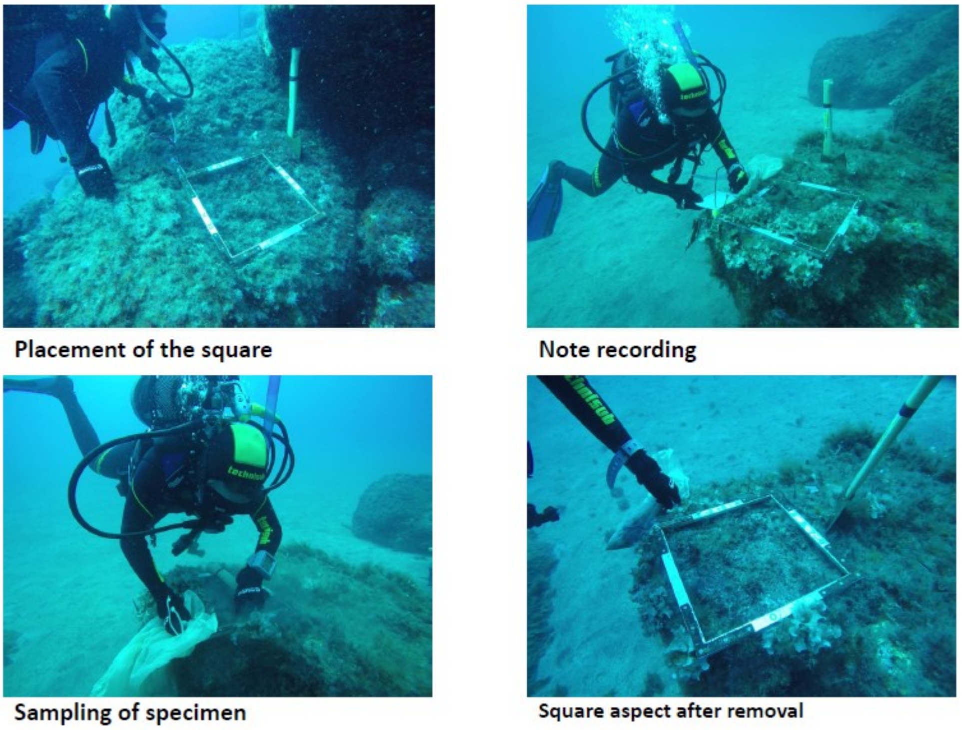


Figure 30. The transect sampling approach and its phases

7.1.2 Laboratory activities

Laboratory activities have been carried out in line with in fieldwork. Specimen treatment involves the sorting of the collected material to remove sediments and separate vegetal components from animal ones.The sorting is useful to obtain, with the same samplings, also the zoo-benthic organisms. In particular, zoo-benthic component has been identified and clustered in main taxonomic groups, to achieve a more accurate analysis of heterotrophic organisms. After, the samples have been driedup to reach dry weight (Fig. 31). Biomasses of different taxa of benthic organisms, expressed as dry weight (DW) have been turned into ash free dry weight (AFDW) using conversion factors from literature (Palmerini and Bianchi 1994; Ricciardi and Bourget, 1998; Touissaint and Schneider 1998). The AFDW metric is recommended because it represents thereal organic biomass value that joins the trophic food chain, avoiding an overestimation of the energy contribution of taxa with shells or cases (Morante et al., 2012). Then, the energy value, with the appropriate conversions, must be transformed in joules to be included in the emergy tables for the calculation of the singleemergy value per unit (transformity); this value will indicate the solar emergy required to produce a Joule of vegetal and animal benthic biomass.

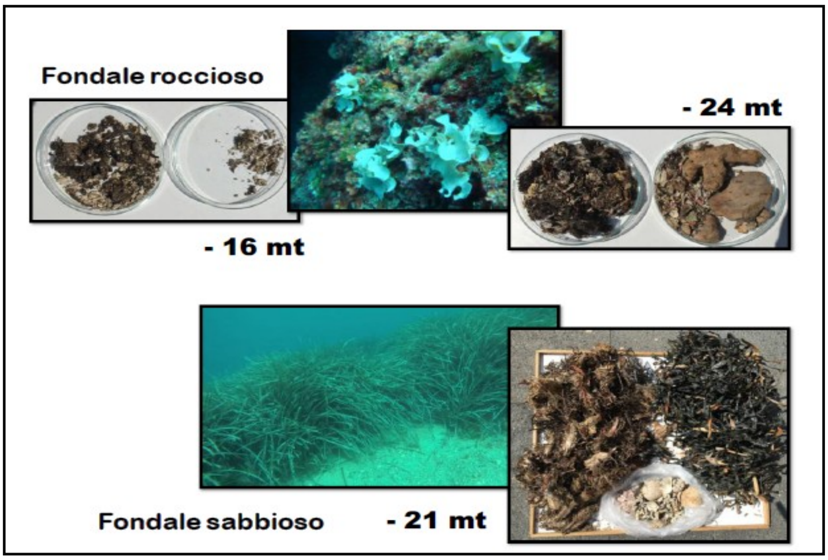


Figure31.Sorted and dried samples

The phytobenthic biomass transformation from grams into Joule was carried out using the following formula (Odum, 1996):

(Dry weight g/yr)*(4 Kcal/g)*(4186 J/Kcal)

and the zoobenthic biomass transformation (Odum, 1996) using:

(Dry weight g/yr)*(5 Kcal/g)*(4186 J/Kcal)

Then, in order to convert AFDW into C equivalents it was assumed that 45 % of the AFDW is particulate organic carbon (0.45 gC/gAFDW ratio) (Berger et al., 1996).

After the evaluation of benthic biocenosis, other components must to be accounted to complete the natural capital assessment:

Phytoplankton

Chlorophyll-a (Chl-a) is the main pigment used by phytoplankton to capture light energy and convert that energy into biomass. Because Chl-a is unique to plants and easy to quantify, it is a convenient biomass proxy for phytoplankton (Jakobsen and Markager, 2016). The Chl-aaccounting has been performed with a multiparametric probe, sampling in different sites of MPA. After obtaining the average value, it was converted from wet weight to dry weight (*0.2) (Berrios et al., 2017). The ash fraction in dry weight was assumed to be, on average, 0.549 (Wolnomiejski and Witek, 2013). Thenthe rate must be transformed in Joules (as for benthic biomass) using the following formula (Odum, 1996):

(Dry weight g/yr)*(4 Kcal/g)*(4186 J/Kcal)

The ash free dry weight to carbon conversion is 1g ASDW = 0.526 gC (Wolnomiejski and Witek, 2013).

Zooplankton

According to Elton (1927), on average only 10% percent of the energy stored as biomass in one trophic level (e.g., primary producers) gets stored as biomass in the next trophic level (e.g., primary consumers). In another way, net productivity usually drops by a factor of ten from one trophic level to the next. For this reason, zooplanktonic biomass can be achieved from average value got with phytoplanktonic biomass and with the biomass value of the fish stock supported. So,after whole fish biomass calculation, only the species including a zooplanktonic diet have been selected and a new biomass value has been calculated. After obtaining the average value, it has been converted from wet weight to dry weight (*0.2) (Berrios et al., 2017). The conversion factor from dry weight to ash free dry weight was 0.434(Boonruang, 1985). Then the rate must be transformed in Joules (as for benthic biomass) using the following formula (Odum, 1996):

(Dry weight g/yr)*(5 Kcal/g)*(4186 J/Kcal)

The ash free dry weight to carbon conversion is 1g ASDW = 0.45 gC (Thorson 1957; Crisp 1984).

Fish

The fish biomass has been retrieved from scientific studies performed in the past years in MPA (Strano A., 2004-2005; Seminara M.C., 2005-2006; Toscano F., 2005-2006;Cristaudo R., 2008-2009;). This was collected by *visual census*, a method widely adopted for the studies of fish communities (particularly in protected habitat) thanks to its ability to reduce environmental impact.Past and recent data, obtained with the last *visual census*campaigns of monitoring, has been compared to check and update data set. For each species observed records include number of individualsm^{-2} divided by size classes. Weigh-length relationship (WLR) (Froese and Pauly, 2011; www.fishbase.com) has been used to convert the abundance of fish into biomass (wet weight).According to Ikeda (1996), Parsons et al. (1984), McLusky and Eliot (1981) and Cohen and Grosslein (1987), values of gC in fish biomass (wet weight) range from 5.3% to 12.5%.For this reason, biomass was converted to gC m^{-2} using a ratio of carbon to wet weight for fish of 8.3%.

Finally, it has been converted from wet weight to dry weight (*0.2) (Berrios et al., 2017) and then the rate must be transformed in joules using the following formula (Odum, 1996):

(Dry weight g/yr)(5 Kcal/g)(4186 J/Kcal)

Regarding to fish biomass assessment, we need to clarify that a lack of information might be due to the sampling technique adopted. Sometimes, using visual census, it can be difficult identified cryptic species or some pelagic fishes.

After the biomass assessment of the main taxonomic groups, distributed in the main biocenosis of MPA, the autotrophic and heterotrophic stocks have been calculated. The amount of autotrophic biomass (Ba), expressed in gC m^{-2}, of each biocenosis has been obtained throughthe sum of the biomass of the primary producers. Then, according to the equation derived from Pauly and Christensen (1995), the biomass of heterotrophic groups (B) for the different biocenosis, has been transformed into the primary biomass required for its formation:

$$Be_i = B_i * 7^{(Tli-1)} \qquad i = 1, 2, 3, \ldots\ldots n$$

Be_i = autotrophic biomass supporting the i-th heterotrophic group
B_i = biomass of the i-th heterotrophic group
Tl_i = trophic level of the i-th heterotrophic group

The total primary biomass (Be) required for the formation of all the heterotrophic groups considered has been calculated with the equation:

$$Be = \sum_i Be_i \qquad i = 1, 2, 3, \ldots\ldots n$$

Then, the total primary biomass (B_T), supporting stock formation, in each biocenosis is calculated as the sum of Be and Ba:

$$B_T = Ba + Be$$

At the same time, once the annual Carbon flow has been determined, according to the ratio C:N:P of 41:7:1 (Redfield et al., 1963) the annual flows of Nitrogen an Phosphorus have been estimated.
Environmental flows of MPA benthic ecosystems involve the assessment of annual primary production of autotrophic group and the annual consumption by heterotrophic organisms. According to Vassallo et al (2017), the annual primary production density value (Pp) for each biocenosis has been calculated as follows:

$$Pp_i = Ba_i * (P/B)_i$$

Ba_i = biomass of the i-th autotrophic group
$(P/B)_i$ = ratio between production and biomass of the i-th autotrophic group

The annual total primary production has been calculated with the equation:

$$Pp = \sum_i Pp_i \qquad i = 1, 2, 3, \ldots\ldots n$$

Pp = total primary production (gC m^{-2} yr^{-1})
Pp_i = primary production of the i-th autotrophic group

Then, the annual consumption by heterotrophic group (C_i) has been obtained as follows:
$C_i = B_i * (Q/B)_i$

B_i = biomass of the i-th hetetrophic group
$(Q/B)_i$ = Consumption per unit of biomass of the i-th hetetrophic group

P/B and Q/B ratios (see appendix G) have been taken from the literature (Corrales et al., 2015).

The consumption by heterotrophic group (C_i) has been converted into required primary biomass (Pc_i) supporting the consumption of the i-th heterotrophic group according to the following equations:

$$Pc_i = C_i * 7^{(Tli-1)} \qquad i = 1, 2, 3, \ldots\ldots n$$

C_i = consumption of the i-th heterotrophic group
Tl_i = trophic level of the i-th heterotrophic group

Finally, the total primary production (Pc) supporting the consumption in each biocenosis and expressed in gC m^{-2} yr^{-1} is calculated as follows:

$$Pc = \sum_i Pc_i \qquad i = 1, 2, 3, \ldots\ldots n$$

Pc_i = primary biomasssupporting the annual consumption of the i-th heterotrophic group

A balance between the annual primary production (Pp) and the consumption (Pc) has been calculated to assess the capacity of the reserve to support its internal consumption. The same evaluation can be made for each biocenosis and for the whole MPA. If the value of Pp > Pc the system is able to sustains the internal consumption and primary production can be exported on the outside. On the contrary, when Pp < Pc the system is not able to support itself. In this last condition, the system required an additional contribution, which can be imported by external areas. Consequently, the supporting areas make the real area of the biocenosis bigger than the physical one.

7.1.3 Results and discussion

The assessment of the trophic web begins with the identification of the main benthic biocenosis of MPA, based on the biocenotic maps. The comparable biocenosis have been clustered into five groups to simplify the investigation as reported in the following scheme:

Biocenosis
Posidonia oceanica meadow **(HP)**
Biocenosis of infralittoral photophilic algae **(RIPC)**
Semi-photophilic biocenosis of infralittoral rock in sheltered waters **(RIHC)**
Precoralligenous biocenosis **(PC)**
Coralligenous biocenosis **(C)**

Then, for each biocenosis, benthic autotrophic and heterotrophic groups have been analyzed in terms of biomass per unit surface (Fig. 32). The biomass values for both autotrophic and heterotrophic components can be found in attachments (appendix E and F).

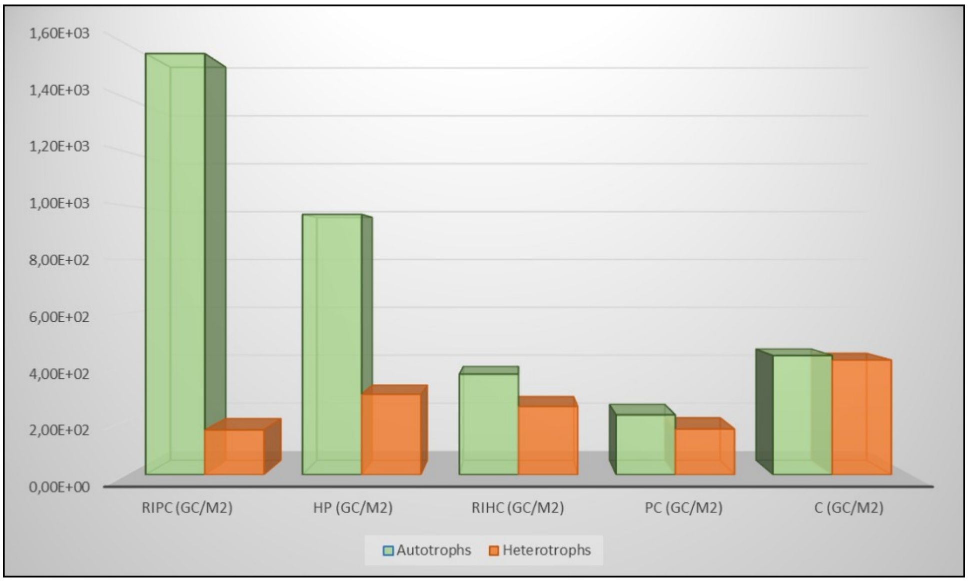


Figure 32. Biomass benthic autotrophic and heterotrophic components per unit area within the different biocenosis of MPA.

The results follow a predictable trend according to the biophysical and environmental conditions of these biocenoses. Biomasses highlight the net dominance of autotrophic organisms in photophilous environment (biocenosis of infralittoral photophilic algae and *Posidonia oceanica* meadow) that became less evident in the more sciaphilous one (semi-photophilic biocenosis of infralittoral rock in sheltered waters, precoralligenous biocenosis and coralligenous biocenosis) where animal componentincreases. This is due to the change of environmental conditions that make animal component more competitive on a trophic approach.Primary production and primary biomass required for the heterotrophic stocks' formation have been obtained from biomasses values.Finally, the annual total primary production (Pp) and the annual total primary production supporting the consumption of heterotrophs (Pc) have been calculated to assess the capacity of the reserve to support its internal consumption.This remark is possible through the balance between the annual primary production and the consumption, recordered in each biocenosis and for the whole MPA. The evaluation of the balance between Pp and Pc managed us to understand if the system or the biocenosis are able to support themselves. Figure 33 shows the balance between Pp and Pc within the different biocenoses investigated.

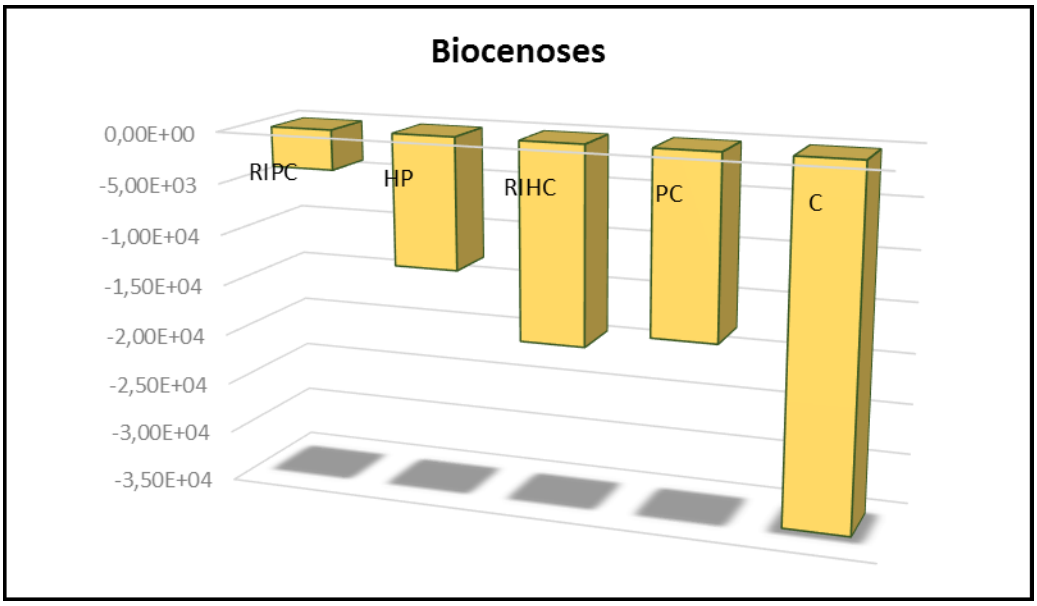


Figure33.Balance between Pp and Pc within the different biocenoses investigated

All the biocenosis considered appear to be in a deficit condition: this means that the primary production is not able to sustain the internal consumption and supporting areas are needed to satisfy the requirements. C and RIHC are the biocenosis that present the most deficit respectively -1.92E+04 gCm^{-2} and -3.47E+04 gC m^{-2}. Following PC with -1.77E+04 gC m^{-2}, HP corresponding to -1.28E+04 gC m^{-2} and RIPC whit the higher value of -3.88E+03 gC m^{-2}.As a consequence, a balance realised at MPA level shows a deficit condition (total amount of -8,83E+04 gC m^{-2}) that highlights the necessity for the reserve to import resources, in terms of primary production, from the outside. The results obtained are conceivable taking into account the small surface of the system examined. In particular, they demonstrate that MPA, due to its small area, cannot be considered really as a close system. On the contrary, despite of its legal and administrative boundaries, the reserve is an open system that needs a continue exchange with outside to sustain itself. Moreover, according to Jørgensen (2012), ecosystems are open systems in the sense that they are open for mass and energy transfers. A system that is closed for inputs and outputs of energy and mass is called an isolated system, while a system that is closed to inputs and outputs of mass, but open to energy transfers, is denoted a closed system. A non-isolated system is a closed or open system. If ecosystem is isolated, it would inevitably move toward thermodynamic equilibrium and become a dead system with no gradients to do work. The openness explains why an ecosystem can maintain life and stay far from the thermodynamic equilibrium, because maintenance of life requires input of energy, which of course only is possible if an ecosystem is at least non-isolated. Following this principle, we can state thatthe MPA examined is a non-isolate system that receive energy from the outside. This energy is a necessary condition for the system to support itself.

7.2 Natural Capital assessment

Natural Capital can be seen under different perspectives: anthropocentric, that considers it as something useful to produce or generate goods and services to humans and a more ecological standpoint, that define it as the storage of matter and energy generating resources, flows and ecosystem services. Obviously, ecosystems with their natural capital are able to generate goods and services necessary for human well-being. On the other hand, the exploitation of the natural storage of resources and the impact generated by anthropic activities should be taken into account, since they are not unlimited. Moreover, the consumption of natural capital stocks may affect the stability of biosphere, declining services fundamental to maintain biodiversity, supporting soil, climate and species at global level. It becomes evident the need to measure and calculate the amount of natural capital of an ecosystem to reach a more comprehensive understanding of stock natural assets and elements supporting it. To ensure a whole assessment of the system considered, natural capital and ecosystem services generated by it, have to be evaluated also from an economic perspective. In this context, emergy analysis ensures an integrated approach from an ecological-economic point of view, allowing to measure costs of production of biophysical flows and the costs due to their exploitation.

7.2.1 Materials and methods

The evaluation of the Natural Capital of MPA starts with the identification of all natural inputs that support the biomass production.

The inputs identified are:

- Nutrients (Carbon, Phosphorus and Nitrogen);
- Solar radiation;
- Rain (chemical potential and kinetic energy);
- Wind;
- Geothermal heat;
- Tide;
- Runoff.

Inputs represent the natural flows of the reserve and they have been calculated with the same references considered for the whole MPA system, according to Odum (1996).

Annual flows of Carbon and Nutrients (Phosphorus and Nitrogen) have been estimated according to the Redfield Ratio C:N:P of 41:7:1 (Redfield, 1958: Redfield et al., 1963). Emergy tables have been made for each biocenosis and the inputs have been determined and converted in emergy units with the same formulas previously described in chapter 6. All natural flows have been accounted both for autotrophic and heterotrophic groups, then the evaluation has been made related to time of stocks formation. Time for stocks formation has been obtained as primary biomass (Ba for autotrophs and Be for heterotrophs) divided by average productivity of the surrounding benthic system. Then emergy inputs have been summed, according to emergy algebra, to assess the emergy value of the different biocenosis in order to evaluate their natural stock. The last step is to obtain the total emergy value of the natural capital within MPA, through the sum of all values found for each biocenosis. Furthermore, to evaluate emergy per unit area, Emergy Density for each biocenosis has been calculated. The natural capital has been expressed not only in emergy unit (sej) but also in monetary equivalents (em€), to estimate the corresponding economic value for each biocenosis and for the entire MPA. According to Pereira (2013), the EMR of 9.60E+11 has been employed for monetary conversion (more details on monetary and economic evaluations are described in chapter 3).

7.2.2 Results and discussion

Table 7 shows the natural capital of MPA expressed in emergy and monetary units for each biocenosis. The emergy tables for both autotrophic and heterotrophic inputs can be found in attachments (appendix H).

	Natural Capital					
	Autotrophic		Heterotrophic		Total	
Biocenoses	Solar Emergy (sej)	EmEuros (em€)	Solar Emergy (sej)	EmEuros (em€)	Solar Emergy (sej)	EmEuros (em€)
RIPC	4.06E+16	4.23E+04	4.47E+16	4.66E+04	8.53E+16	8.89E+04
HP	8.37E+15	8.72E+03	2.95E+16	3.07E+04	3.79E+16	3.94E+04
RIHC	3.75E+15	3.91E+03	2.92E+16	3.04E+04	3.30E+16	3.43E+04
PC	2.10E+15	2.19E+03	1.60E+16	1.67E+04	1.81E+16	1.89E+04
C	3.04E+15	3.17E+03	3.03E+16	3.16E+04	3.33E+16	3.47E+04
Total	**5.82E+16**	**6.03E+04**	**1.46E+17**	**1.56E+05**	**2.08E+17**	**2.16E+05**

Table 7. Natural capital of MPA expressed in emergy (sej) and monetary units (em€) for autotrophs and heterotrophs in each biocenosis and in the whole MPA.

The emergy supporting autotrophic component presents its higher values for photophilous biocenoses, respectively RIPC with 4.06E+16 sej and HP with 8.37E+15 sej. Following, in descending order, RIHC (3.75E+15 sej), C (3.04E+15 sej) and PC with the lower value of 2.10E+15 sej. The higher values of emergy supporting heterotrophic component are recordered for RIPC (4.47E+16 sej). Then, C and HP with almost the same value respectively 3.03E+16 and 2.95E+16 sej, followed by RIPC (2.92E+16). PC presents the lower value of 1.60E+16 sej. Total emergy value of natural capital of the resevr is 2.08E+17 sej. High values achieved for both autotrophic and heterotrophic components of RIPC may be related to the larger extension of the area compared to the others biocenosis (Fig. 34). The statement is confirmed by the total emergy supporting the autotrophic and heterotrophic stocks of RIPC (8.53E+16 sej). Although their small area, HP and C show high total emergy value that highlight the importance of the two biocenoses in ecological system of the MPA.

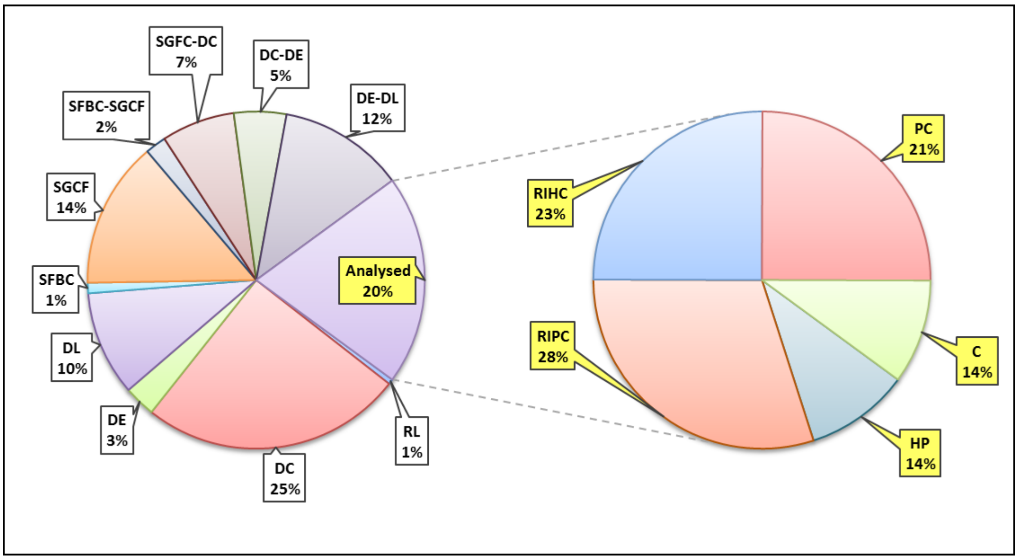


Figure 34. Percentage coverage of all MPA biocenoses. Yellow labels identified the five biocenoses selected for sampling and analysis.

The use of emergy density (total emergy concentrated per unit of area) indicator allows us to make comparison between biocenoses, despite their different extension in MPA. The highest levels of emergy density (table 8) have been recordered for *Posidonia* meadow and Coralligenous, which share more than one order of magnitude of difference with the emergy values of RIPC, RIHC and PC, confirming the key role of these biocenoses in marine ecosystem functioning.

Biocenoses	Emergy density A	Emergy density E
RIPC	9.68E+02	1.07E+03
HP	4.13E+04	1.46E+05
RIHC	1.10E+02	8.39E+02
PC	6.11E+02	4.66E+03
C	1.41E+04	1.40E+05
Total	**7.22E+02**	**1.82E+03**

Table 8. Emergy density (sej m^{-2}) for autotrophs and heterotrophs in each biocenosis

Posidonia meadows, as other seagrasses, are ecosystems with high biodiversity. There are organisms living permanently, others reproduce or refuge there. In addition, algae and animals can live attached to the leaves or rhizomes, and represent the food for small animals such as crustaceans, gastropods, polychaetes, flatworms, nematodes and echinoderms. The large bivalve *Pinna nobilis* is a strictly protected species (Annex IV of Habitats Directive) with very slow growth rates. The collection of this species is forbidden and control measures and information campaigns have to be further developed. However, the most important measure to conserve the species is the maintenance of healthy seagrass meadows with which it is strongly associated. Moreover, thanks to the peculiar morphology of the plants (one square meter can contain 10.000 leaves), the particles that fall to the bottom are trapped and form what is known in Italian as "*Matte*". This compacted substrate, in addition to underground rhizomes, acts as a barrier against the waves favouring protection for the coast and the formation of beaches dunes and dunal forests.Finally, a lot of organic matter is dispersed by currents and waves to other ecosystems. In the same way, in marine environment, there are animal-dominated ecosystems with high concentration of biodiversity, called animal forests. In the Mediterranean Sea, the concept of animal forest is mainly associated with the Coralligenous biocenosis. The three dimensional and heterogeneous structure of these environments could host a large number of sessile species (bryozoan. ascidian. bivalves and hydrozoans), being a nursery or refuge area for necto-benthonic and pelagic fishes, molluscs and crustaceans. The ability of animal forest to reduce the current flow velocity, modifying the surrounding habitat, lead to decreasing of suspension, stabilization of soft substrata, intensification of local accumulation of fine particles and increase residence of food particles in the environment. For these reason, it is obvious that these biocenoses need to be protected and preserved. In MPA "*Isole Ciclopi*" *Posidonia* meadow and Coralligenous are the less extended biocenoses.

Their small areas are located in the three different protection zones A, B and C of the reserve. Coralligenous is difficult to reach because of the depth (> 20 mt), while *P. oceanica* is more achievable with a vertical gradient ranging from few to about 20 mt. Taking into account the outcome of this study, fine-scale knowledge of these sensitive biocenoses is fundamental for their effective management and conservation.Some actions can be proposed in order to help local managers in their conservation policy. The peculiar features of these habitats, in the system investigated, suggest two different possible strategies. Regarding Coralligenous, conservation strategies require good quality distribution information. For this reason, the annual monitoring and mapping campaign could be useful to check good environmental status and other parameters related to biodiversity amount. As a result, timely intervention can be realized towards endangered species or biodiversity loss. At the same time, these takeovers are also critical to decision-makers and managers that try to move towards sustainable development, minimizing negative impacts of human activities. Coralligenous may also be susceptible to invasive alien species, so specific knowledge on its populations and continuous monitoring can be useful.

Even *Posidonia* meadows would need a steady monitoring system. *P. oceanica* monitoring programmers are a fundamental tool for measuring the status and trends of meadows and are essential to assess the effectiveness of any protective or recovery initiatives. Moreover, meadow maps are basic managerial tools, providing an overview of the habitat's status to administrators and the public to identify conspicuous impacts. For these reasons, conservation management should be oriented primarily on a monitoring program, throughout the annual assessing distribution patches, environmental parameters, growing rate and associated species. In particular, the control of invasive species (as for example *Caulerpa taxifolia. C. racemosa*) should be performed. The distribution of the *P. oceanica* meadows in MPA "*Isole Ciclopi*" is restricted to one small patch and a heterogeneous meadow, falling in the three different protection zones. They are located in areas with possible pressure given by human activities so, other safeguards should be implemented such as installation of artificial reefs and seagrass-friendly moorings for boats. As well as anchors, traditional fishing and diver frequentation may cause its degradation. Implementation of controls through the setting of a vigilance system and a policy of educating at various level (citizens. students. diving staff and users) may be a helpful support. Furthermore, because of the small percentage of coverage occupied by this biocenosis in MPA, a restoration programs could be take into account. Finally, Coralligenous and *P. oceanica* meadows are not only “hotspots” of biodiversity, but they also represent socio-economic stakes. They produce goods and services for several sectors. Activities such as small-scale fishing and scuba diving highly depend on them. Fishermen look for species of high commercial value such as red coral, crustaceans, fishes and other kind of seafood. Divers look for the landscapes beauty, offered by colored and erect species such as gorgonian corals, algae and bryozoans (Martins et al., 2013; Noisette, 2013). That is why, an integrate system of ecological protection and sustainable human activities is an important trade-off between human actions (job, food, tourism and economy) and good ecological status of environment. Fig. 35 shows the (non-market) monetary value accounting for the five biocenoses. The highest monetary value per unit area is recordered for RIPC (8.89E+04 em€)accounting forabout 41% of the total value of MPA, followed by HP (3.94E+04 em€) and C (3.47E+04 em€) that are respectively 18% and 17% of whole value. Finally, RIHC (2.43E+04 em€) and PC (1.89E+04 em€) show the lowest value corresponding to 16% and 8% of the overall monetary value of the reserve. The em€ value of the total natural capital of the MPA, which is the sum of the values of all biocenoses, is 2.16E+05 em€.

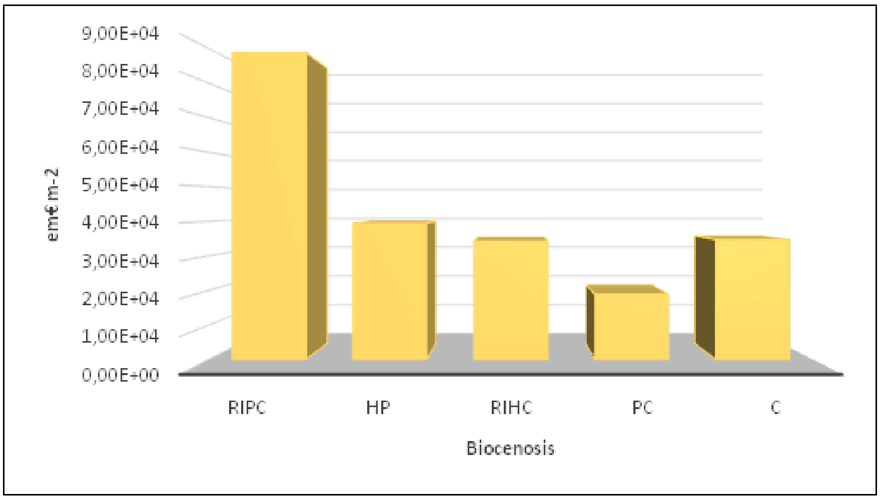


Figure. 35 Monetary value expressed in em€ m^{-2} for the five biocenoses

These results corroborate overall the high value of photophilous environment and for HP and C biocenoses, despite their extension in MPA. The same statement emerge from the observation of emergy percentage contribution (fig. 36) and interesting remark can be achieved by the comparison of this parameter with the percentdistribution of the five biocenoses (fig. 35). RIPC maintains the same trend with high value of coverage (28%) together with high level of emergy contribution (41%). On the contrary, the important emergy contribution of HP (18%) and C (17%) is not related to their extension, equal to 14% for both. Despite its significant coverage surface of 23%, RIHC is similar to the smaller biocenosis (HP and C) in terms of emergy percentage contribution (16%). Finally, the lowest contributes is that of PC (8%), although the large area occupied (21%).

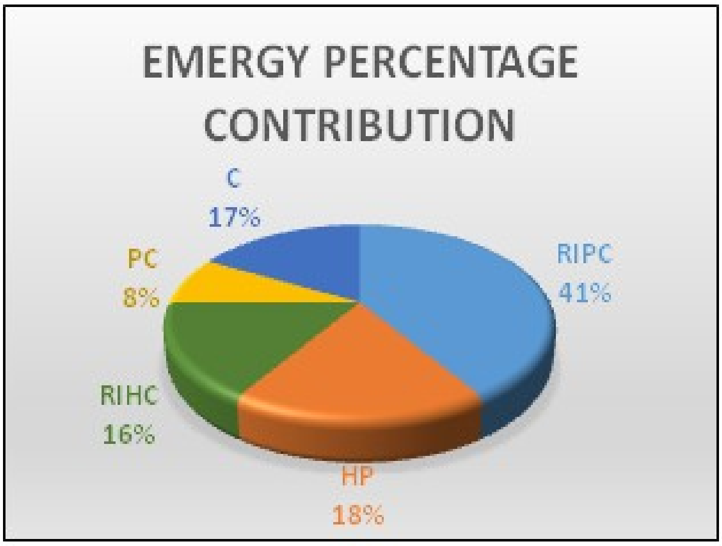


Figure 35. Percentage coverage of each analysed biocenosis in MPA

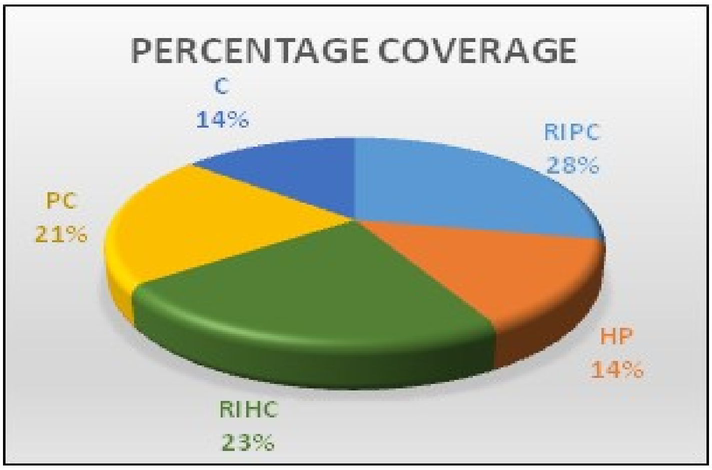


Figure 36. Emergy percentage contribution of the five biocenoses to MPA Natural Capital

Natural Capital assessment suggests that the emergy and monetary values are higher for photophilous biocenoses covering the widest surface of the marine reserve. Despite their small extension, *Posidonia* meadow and Coralligenous show high level of emergy density and monetary value as confirm of their fundamental ecological role; they represent environments able to maintain high levels of biodiversity and a large amount of key species. For thisreason, the two biocenoses should be involved in conservation policies where the main objectives is to preserve biodiversity. In this regard, it is interesting to evaluate the distribution, in terms of percent coverage, of the two biocenoses in the zones of the MPA with different degrees of protection (Fig. 37). Both of them seems to follow almost the same trend: are mainly concentrated in the zone with the higher degree of protection (A zone), less in general reserve area (B zone) and finally the value increases slightly, compared to the latter, in the area of partial reserve (C zone). This statements confirm the efficacy of zonation in safeguarding biocenoses of particular interest with regard to the A zone, but highlight that the distribution of the two remaining zones should be attend. Indeed, C zone presents higher value of distribution for both biocenoses (Coralligenous and *P.oceanica*) compared to B zone in which the protective measures are more restrictive.

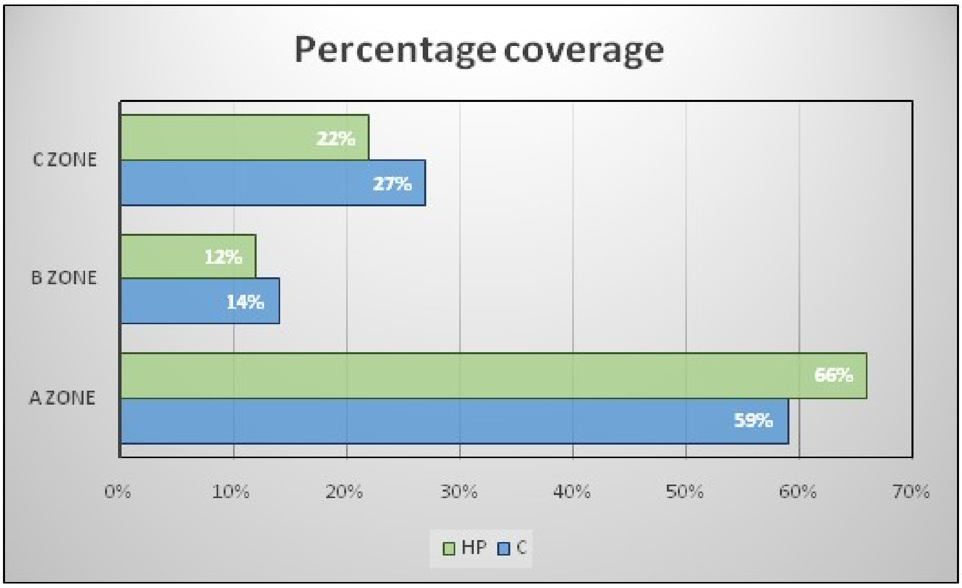


Figure 37. Percent coverage of Coralligenous (C) and *Posidonia oceanica* (HP) in each zone of MPA

The safeguard of these biocenoses could be improved by an enlargement or reshaping of B zone, and consequently C zone, in order to ensure them more severe protection. It agrees with the general idea to expandreserve surface and to assume as real MPA areas those adjacent areas of surplus.

7.3 Environmental flows assessment

Environmental flows assessment is useful to estimate the annual environmental flows supporting natural capital.

7.3.1 Materials and methods

The same biomass data, collected for the natural capital assessment, have been employed to evaluate environmental flows. Inputs have been calculated with the same references considered for the whole MPA system and natural capital assessment, according to Odum (1996). Phosphorus and nitrogen flows have been calculated according to Redfield (1958) and Redfield et al. (1963) from carbon flow assessment. Emergy tables have been made for each biocenosis and the inputs have been determined and converted in emergy units with the same formulas previously described in chapter 6. Environmental flows of MPA benthic ecosystems involve the assessment of annual primary production of autotrophic group and the annual consumption by heterotrophic organisms to evaluate the capacity of the reserve to support its internal consumption. Annual primary production density value (Pp) and primary biomass (Pc_i) supporting the consumption of the i^{th} heterotrophic group for each biocenosis has been calculated according to Vassallo et al. (2017) as described in paragraph 7.1.2. The ability of the system or of the biocenosis in supporting themselves can be evaluated through the balance between the annual primary production and the consumption, recordered in each biocenoses and for the whole MPA. Environmental flows have been calculated regarding "supporting areas". Biocenoses is not always able to sustain itself in terms of internal consumption; some areas need an additional contribution to generate the whole amount of primary biomass required. For this reason, the real area of biocenosis can be larger than its physical area. Supporting areas have been obtained taking into account the percentage of Pp-Pc balance on whole biocenosis amount. Finally, emergy inputs have been summed, according to emergy algebra, to assess the total annual emergy flow maintaining natural capital in each biocenosis and in the whole MPA.

7.3.2 Results and discussion

Fig. 37 shows the balance between Pp and Pc within the different biocenoses investigated.

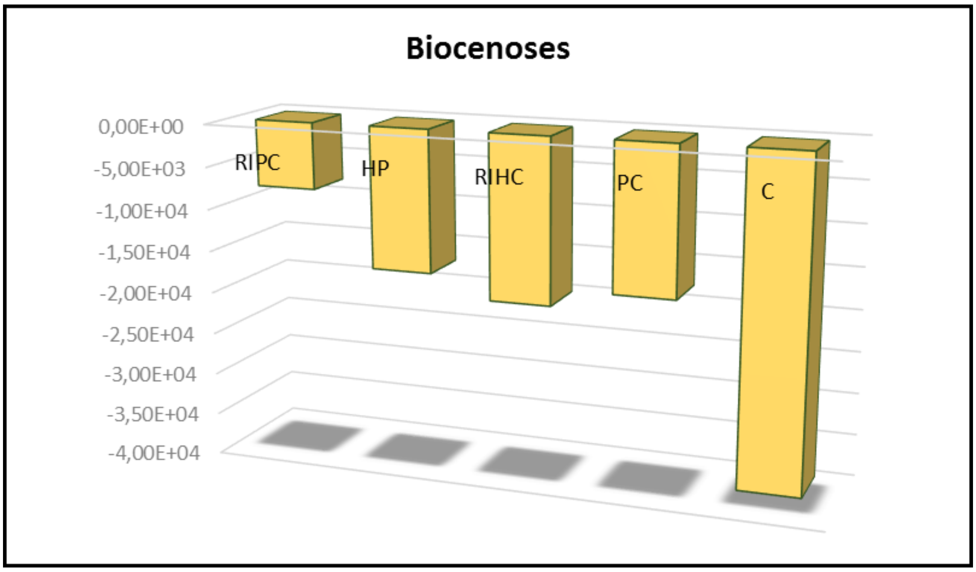


Fig. 38. Balance between Pp and Pc within the different biocenoses investigated

All the biocenoses considered appea to be in a deficit condition: this means that the primary production is not able to sustain the internal consumption and supporting areas are needed to satisfy the requirements. C and RIHC are the biocenoses that present higher deficit respectively3.87E+04 gC m^{-2} and -1.94E+04 gC m^{-2}. Follow PC with -1.74E+04 gC m^{-2}, HP(-1.68E+04 gC m^{-2}) and RIPC with the valueof -7.85E+03 gC m^{-2}. That condition highlights the necessity for the reserve to import resources, in terms of primary production, from the outside. The results obtained are conceivable taking into account the small surface of the system examined. Despite the recorded deficit conditions, the presence of surrounding surplus areas allows the marine protected area to ensure its livelihood with a continuous supply of resources.

Environmental flowsassessment							
Item	**Units (g, J, €)**	**Emergy/Unit (sej/unit)**	**Biocenoses (sej)**				
			RIPC	**HP**	**RIHC**	**PC**	**C**
Solar radiation	J		3.25E+14	4.15E+14	5.191E+14	4.71E+14	8.43E+14
Rain							
Chemical potential	J	3.05E+04	1.13E+12	1.44E+12	1.803E+12	1.64E+12	2.93E+12
Kinetic energy	J	1.45E+05	1.12E+10	1.43E+10	1.788E+10	1.62E+10	2.91E+10
Wind	J	2.45E+03	7.01E+09	8.95E+09	1.121E+10	1.02E+10	1.82E+10
Geothermal heat	J	1.20E+04	1.24E+12	1.58E+12	1.979E+12	1.8E+12	3.22E+12
Tide	J	2.36E+04	4.77E+10	6.1E+10	7.634E+10	6.93E+10	1.24E+11
Runoff	J	6.31E+04	3.14E+08	4.01E+08	502315858	4.56E+08	8.16E+08
Carbon	g	1.02E+08	1.19E+04	1.90E+04	1.96E+04	1.79E+04	3.98E+04
Nitrogen	g	7.40E+09	2.03E+03	3.25E+03	3.34E+03	3.06E+03	6.79E+03
Phosphorous	g	2.86E+10	2.91E+02	4.64E+02	4.77E+02	4.37E+02	9.71E+02
			3.26E+14	**4.16E+14**	**5.21E+14**	**4.73E+14**	**8.47E+14**

Table 9. Environmental flows assessment of MPA for each biocenosis expressed in emergy values (sej).

The environmental flows table (table 9) presents its higher values for C with 8.47E+14 sej. Following, in descending order, RIHC (5.21E+14 sej)PC (4.73E+14 sej) and HP (4.16E+14 sej). The lowest value is recordered for RIPC (3.26E+14). The total annual emergy flow maintaining natural capital in each biocenosis and in the whole MPA is 2.58E+15. These results reflect the differences among the biocenoses considered in terms of autotrophic and heterotrophic biomass amount. The statement is evident comparing Natural Capital and Environmental flows assessment (table 10). HP and RIHC show high capital value but lowest environmental flows.

Biocenoses	Natural Capital (sej)	Environmental flows (sej)
RIPC	8.57E+16	3.26E+14
HP	3.83E+16	4.16E+14
RIHC	2.87E+16	5.21E+14
PC	1.82E+16	4.73E+14
C	3.38E+16	8.47E+14

Table 10. Natural Capital and Environmental flows of MPA for each biocenosis expressed in emergy values (sej).

On the contrary, C reveals high value for both natural capital and environmental flows. This is because of the dominance of primary producers in RIHC and PC (photophilous biocenoses) stocks rather than consumers. In fact, in a system the more heterotrophic components there are, the more resources are needed to maintain them. In particular, Coralligenous biocenosis presents a great amount of heterotrophic biomass generated by primary producers. Moreover, C shows the highest value of deficit (fig. 38) so, resources for the primary production are also imported from other biocenoses of MPA. In addition, monetary values of environmental flows, expressed as em€ m^{-2} (fig. 39), show the highest rate for Coralligenous biocenosis.

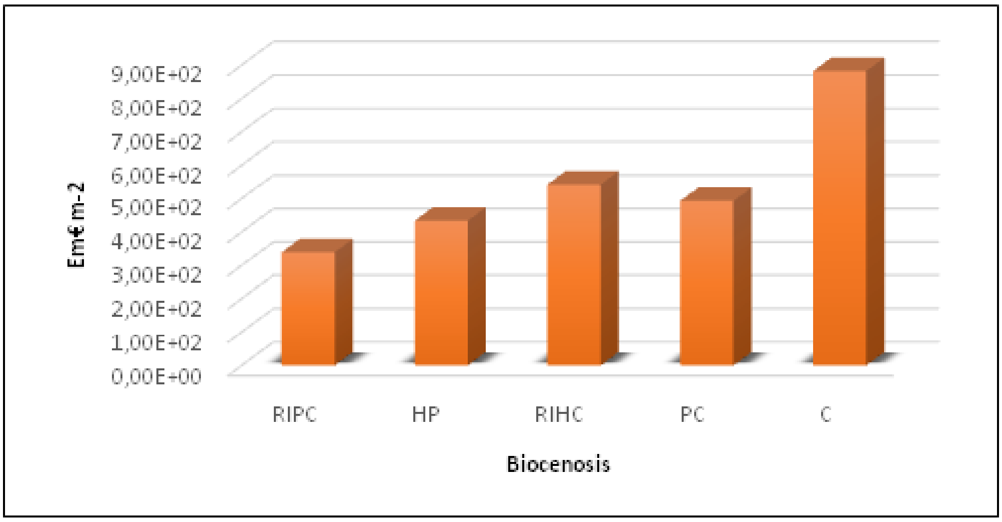


Fig. 39 Monetary value of environmental flows in each biocenosis of MPA

Environmental flows, expressed in monetary unit (em€ m^{-2}), required to maintain the different biocenoses, are represented in fig. 39. The total amount of annual investment of biosphere to sustain the natural capital of the different biocenoses of MPA is 2.69E+03 em€ m^{-2}. Coralligenous shows the highest monetary value (8.82E+02 em€ m^{-2}), followed by RIHC with 5.43E+02 em€ m^{-2} and PC (4.93E+02 em€ m^{-2}). The lowest values are recordered for photophilous biocenosis: HP and RIPC respectively with 4.33E+02 and 3.39E+02 em€ m^{-2}. Among them, HP presents the highest value (as for emergy flow) confirming its fundamental role as tanks of primary production supporting the whole food chain and regardless its extension on MPA. The high values recordered for Coralligenous biocenosis reflect the great costs sustained by biosphere, in terms of environmental flows, to generate and maintain the considerable structural complexity of the coralligenous bioconstruction: this biocenosis is considered as the second benthic ecosystem in the Mediterranean with regard to biodiversity.

Chapter 8

Ecosystem services

Ecology and economy have followed different paths in history, which have often seen them in opposition; economic development was a negative condition for the protection and safeguarding of the environment.The “Ecological Economics” (for more detail see chapter 2) has tried to combine the two terms, using them to create a model of economic development focused on the sustainable use of available environmental resources and respecting their ability to support themselves.The context wherein ecology and economy relate is the ecosystem. Ecosystems are shaped by the interaction of communities of living organisms with the abiotic environment. Biodiversity the variety of all life on earth - plays a key role in the structural set-up of ecosystems that is essential to maintaining basic ecosystem processes and supporting ecosystem functions. The good functioning of natural systems (ecosystems) ensures the production of stocks and flows directly or indirectly useful to meet human needs and activities (De Groot, 1987). People benefit from ecosystem are known as "goods" (water, food, fuel…) and "services" (climate regulation, carbon cycle…). Environmental goods and services are commonly referred to as ecosystem services. The focus on benefits, as key target of managing the socio-economic systems (fig. 40), implies that ecosystem services are open to economic valuation. Not all benefits to people from ecosystems can be measured in monetary terms. Therefore, it is important to include all values as well, such as health value, social value or conservation value. Policies concerning natural resource management aim to integrate socio-economic-ecological evaluation in order to better understand how institutions,stakeholders and users of ecosystem services affect state of ecosystems.

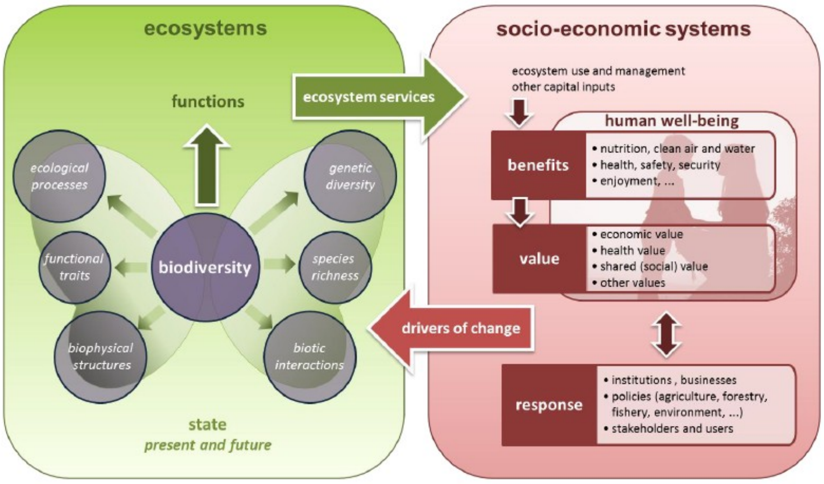


Figure 40. Conceptual framework for ecosystem assessments (from MAES working paper 2013).

8.1 Reference framework

The EU 2020 Biodiversity Strategy, which includes 6 targets and 20 associated actions, responds to both European and global mandate, to obtain comprehensive and complete information concerning the status of biodiversity, ecosystems and ecosystem services across Europe and to improve the capacity to monitor changes. The headline target overarching the EU Biodiversity Strategy to 2020 is the following: "*Halting the loss of biodiversity and the degradation of ecosystem services in the EU by 2020, and restoring them in so far as feasible, while stepping up the EU contribution to averting global biodiversity loss*". The information and knowledge base upon which the Biodiversity Strategy is developed will integrate and streamline the latest outcomes from the reporting under the Birds and Habitats Directives, the Water Framework Directive, the Marine Strategy Framework Directive, and other relevant data flows reported under environmental legislation, including spatial data such as the Natura 2000 network, river basins, marine regions, etc. Reliable data on the status of species and habitats such as European Red-Lists or independent scientific reports on the status of different taxonomic groups such as birds and butterflies will also be taken into account. Action 5 of the EU Biodiversity Strategy to 2020 foresees that

Member States will map and assess the state of ecosystems and their services, in their national territory by 2014 with the assistance of the European Commission. This procedure in useful to support the maintenance and restoration of ecosystems and their services, assess the economic value of such services and promote the integration of these values into accounting and reporting systems at European and national level by 2020. A Working Group on Mapping and Assessment on Ecosystems and their Services (MAES) was set up to implement Action 5 by Europe and its Member States. In 2012, the working group developed ideas for a coherent analytical framework to ensure consistent approaches are used. The report, adopted in April 2013, proposes a conceptual framework linking biodiversity, ecosystem condition and ecosystem services to human well-being. Furthermore, it develops a typology for ecosystems in Europe and promotes the Common International Classification of Ecosystem Services (CICES) to classify ecosystem services. Following the adoption of the analytical framework, the Working Group MAES decided to test it and in order to do so set up six thematic pilots. Four of the pilots focused on the main ecosystem types: agro-ecosystems (cropland and grassland), forest ecosystems, freshwater ecosystems (rivers, lakes, groundwater and wetlands), and marine ecosystems (transitional waters and marine inlets, coastal ecosystems, the shelf, the open ocean). A further pilot focused on the use of conservation status assessment data (cf. under Article 17 of the Habitats Directive) for assessing the condition of ecosystems and of the associated delivery of services. The final pilot addressed the challenge of natural capital accounts, which is an important part of Action 5 of the EU 2020 Biodiversity Strategy. These themes were in line with the recommendations from the 2012 MAES Stakeholder workshop where Member States expressed their priorities for activities under Action 5 of the EU 2020 Biodiversity Strategy. All pilots build on the MAES Analytical Framework and the proposed ecosystem typology and ecosystem service classification and on the activities and information available from Member States, the European Commission Services and the European Environment Agency (EEA). In the short-term, the essential challenge of Action 5 is to make the best use of and to operationalize the information and scientific knowledge currently available on ecosystems and their services in Europe to guide policy decisions. MAES work with action 5 plans is important in pursuing biodiversity objectives but also to improve the knowledge of the related policies. Figure 41 shows inputs to action 5 into other policies.

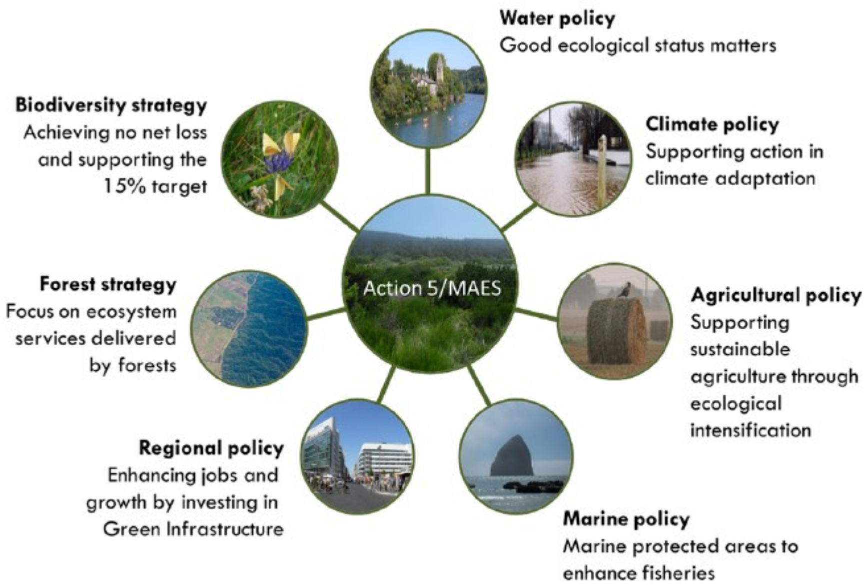


Figure 41. Inputs of action 5 into other policies (from MAES working paper 2014)

8.2 Importance on mapping Ecosystems and role of Biodiversity

Maps are useful for spatial definition and problem identification, especially in relation to synergies and trade-offs among different ecosystem services, and between ecosystem services and biodiversity. Further, maps can be used as a communication tool to initiate discussions with stakeholders, visualizing the locations where valuable ecosystem services are produced or used andexplaining the relevance of ecosystem services to the public in their territory. Maps can contribute to the planning and management of biodiversity protection areas and implicitly of their ecosystem services. At the European level, mapping can assist decision makers in identifying priority areas, and relevant policy measures. As we already said, ecosystems and maintaining their services builds on the premise that ecosystem services are dependent on biodiversity. There are evidences demonstrating the dependency of specific ecosystem services and ecosystem functions on biodiversity. Figure 42 summarize the different roles of biodiversity in supporting ecosystem functions and ecosystem services.

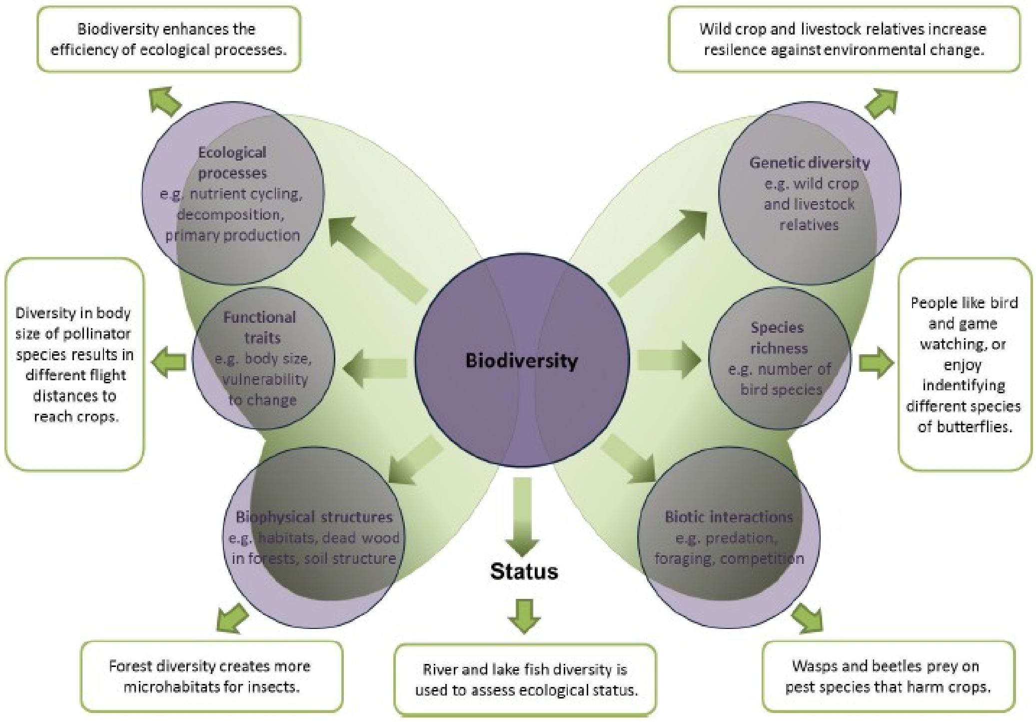


Figure 42. The multi-faceted role of biodiversity to support ecosystem services and to assess the status of ecosystems (from MAES working paper 2013).

The figure highlight six dimensions of biodiversity that connect biodiversity to ecosystem functioning and ecosystem services:

1. Biodiversity enhances the efficiency of ecological processes such as primary production and decomposition that are determinant key sof ecosystem functions.
2. Functional diversityis the variation in the degree of the expression of multiple functional traits. Functional traits are those that define species in terms of their ecological roles - how they interact with the environment and with other species.
3. Biodiversityhas a key role in structuring habitats, ecosystems and landscapes thatare necessary for many other species, and hence ecosystem services, to exist.

4. Genetic diversity is the diversity of the gene pool of single species. Both different varieties and wild crop and livestock relatives are considered crucial to maintain a genetically diverse stock as this diversity makes food production systems more resilient against future environmental change or diseases.The probability that some varieties are adapted to future conditions increases with diversity.
5. Species richness (or the total number of species) and taxonomic diversity (the total number of species of certain groups, e.g. the total number of mammals) is often used as indicator for biodiversity.
6. The diversity of specific biotic interactions in a food web or in species networks such as predation and foraging provides in some cases a regulating service. Bees, when foraging on nectar carrying plants, help pollinate agricultural crops. Predatory insects help keep pests on agricultural crops under control.

Connecting biodiversity to ecosystem state but also to particular ecosystem functions and ecosystem services entails thus defining multivariate combinations of these different dimensions of biodiversity and using them for mapping and assessment.

8.3 Mapping ecosystems

An ecosystem is usually defined as a complex of living organisms with their (abiotic) environment and their mutual relations. Although this definition applies to all hierarchical levels, for the practical purposes of mapping and assessment, an ecosystem is here considered at the scale of habitat/biotope or landscape. A practical approach to the ‘spatial delimitation of an ecosystem’ is to build up a series of overlays of significant factors, mapping the location of discontinuities, such as in the distribution of organisms, the biophysical environment (soil types, drainage basins, depth in a water body), and spatial interactions (home ranges, migration patterns, fluxes of matter). A useful ecosystem boundary is the place where a number of these relative discontinuities coincide. Ecosystems within each category share a suite of biological, climatic, and social factors that tend to differ across categories (MAES, 2013).

Therefore, each ecosystem type should include similarity about:

- climatic conditions;
- geophysical conditions;
- dominant use by humans;
- surface cover (based on type of vegetative cover in terrestrial ecosystems or on fresh water, brackish water, or salt water in aquatic ecosystems);
- species composition;
- resource management systems and institutions.

Ecosystem mapping is the spatial delineation of ecosystems following an agreed ecosystem typology (ecosystem types), which strongly depends on mapping purpose and scale. Ecosystem mapping also has to satisfy a management perspective and is largely determined by data availability. MAES, following the EU 2010 Biodiversity Baseline, proposed ecosystem classification shown in table 11. The present typology separates three major ecosystems: terrestrial systems, fresh water and the marine environment. Table 11 below shows ecosystem types classification with a brief description.

Major eco-system category (level 1)	Ecosystem type for mapping and assessment (level 2)	Representation of habitats (functional dimension by EUNIS)/MSFD for marine ecosystems)	Representation of land cover (spatial dimension)	Benefits of mapping	Problems of mapping	Listed as ecosystems, major habitat types or reporting categories in	Spatial data availability
Terrestrial	**Urban**	Constructed, industrial and other artificial habitats	Urban, industrial, commercial and transport areas, urban green areas, mines, dump and construction sites	Urban areas represent mainly human habitats but they usually include significant areas for synanthropic species	CLC's coarse resolution that needs to be complemented e.g. by Urban atlas (ca. 300 cities) and HRL Imperviousness but see (23)	EUNIS (SEBI) UNEP/CBD[*] MA[‡]	CLC Urban Atlas HRL Imperviousness
	Cropland	Regularly or recently cultivated agricultural, horticultural and domestic habitats	Annual and permanent crops	Main food production areas, intensively managed ecosystems	Habitat classification (e.g. EUNIS) includes permanent crops into Heathland and scrub	EUNIS (SEBI, Baseline) UNEP/CBD MA	CLC
	Grassland	Grasslands and land dominated by forbs, mosses or lichens	Pastures and (semi-) natural grasslands	Areas dominated by grassy vegetation of two kinds – managed pastures and natural (extensively managed) grasslands	Distinction between intensively used and more natural grasslands requires additional datasets (Art. 17)	EUNIS (SEBI, Baseline) UNEP/CBD WWF[*] MA	CLC HRL grasslands
	Woodland and forest	Woodland, forest and other wooded land	Forests	Climax ecosystem type on most of the area supporting many ecosystem services	Missing information on quality and management requires additional datasets (Art. 17, HRL forest)	EUNIS (SEBI, Baseline) UNEP/CBD WWF MA	CLC HRL forests (EFDAC)
	Heathland and shrub	Heathland, scrub and tundra (vegetation dominated by shrubs or dwarf shrubs)	Moors, heathland and sclerophyllous vegetation	Mostly secondary ecosystems with unfavourable natural conditions	Mapping the condition of these areas requires combination with Art.17	EUNIS (SEBI, Baseline) WWF MA	CLC
	Sparsely vegetated land	Unvegetated or sparsely vegetated habitats (naturally unvegetated areas)	Open spaces with little or no vegetation (bare rocks, glaciers and beaches, dunes and sand plains included)	Ecosystems with extreme natural conditions that might support valuable species. Includes coastal ecosystems on (beaches, dunes) affected by marine ecosystems	Becomes a conglomerate of distinctive rarely occurring ecosystems, often defined by different geographical location	EUNIS (SEBI, Baseline) UNEP/CBD MA	CLC

Major eco-system category (level 1)	Ecosystem type for mapping and assessment (level 2)	Representation of habitats (functional dimension by EUNIS)/MSFD for marine ecosystems)	Representation of land cover (spatial dimension)	Benefits of mapping	Problems of mapping	Listed as ecosystems, major habitat types or reporting categories in	Spatial data availability
	Wetlands	Mires, bogs and fens	Inland wetlands (marshes and peatbogs)	Specific plant and animal communities, water regulation, peat-related processes	Separation from grasslands (temporary inundation) and forests (tree canopy), HRL wetlands	EUNIS (SEBI, Baseline) UNEP/CBDMA	CLC HRL wetlands
Fresh water	**Rivers and lakes**	Inland surface waters (freshwater ecosystems)	Water courses and bodies incl. coastal lakes (without permanent connection to the sea)	All permanent freshwater surface waters	Underestimation of water courses and small water bodies needs application of external datasets (ECRINS, (HRL Small lakes)	EUNIS (SEBI, Baseline) WWF MA	CLC HRL small water bodies ECRINS
Marine[†]	**Marine inlets and transitional waters**	Pelagic habitats: Low/reduced salinity water (of lagoons) Variable salinity water (of coastal wetlands, estuaries and other transitional waters) Marine salinity water (of other inlets) Benthic habitats: Littoral rock and biogenic reef Littoral sediment Shallow sublittoral rock and biogenic reef Shallow sublittoral sediment	Coastal wetlands: Saltmarshes, salines and intertidal flats Lagoons: Highly restricted connection to open sea, reduced, often relatively stable, salinity regime Estuaries and other transitional waters: Link rivers to open sea, variable, highly dynamic salinity regime. All WFD transitional waters included Fjords/sea lochs: Glacially derived, typically elongated and deep; marine salinity regime Embayments: Non-glacial origin, typically shallow, marine salinity system Pelagic habitats in this type include the photic zone, benthic habitats can include it or not	Spatial representation of the land-sea interface, and of the relative proportion of habitats and related services. Interface limited by the WFD landward boundaries of transitional and coastal waters	Use of relevant CLC classes would lead to mapping geographically distinct entities rather than benthic habitats EUSeaMap[††] provides broad-scale seabed habitat maps, which are based on predictive modelling with partial validation. But these cannot be used for all ecosystems in this class	EUNIS (SEBI, Baseline) UNEP/CBC WWF MA WFD transitional water bodies MSFD water column predominant habitat types: Variable salinity (estuarine), Reduced salinity and Marine salinity MSFD's seabed predominant habitats	CLC (allows mapping of lagoons, saltmarshes, salines, intertidal flats and estuaries) GIS layer of WFD lake water bodies and transitional water bodies EUSeaMap is now only available for the Baltic, North, Celtic and western Mediterranean seas. Remaining seas to be covered by new projects (over 2013-2014) Marine water column habitats are not mapped by EUSeaMap

Major eco-system category (level 1)	Ecosystem type for mapping and assessment (level 2)	Representation of habitats (functional dimension by EUNIS)/MSFD for marine ecosystems)	Representation of land cover (spatial dimension)	Benefits of mapping	Problems of mapping	Listed as ecosystems, major habitat types or reporting categories in	Spatial data availability
	Coastal	Pelagic habitats: Coastal waters Benthic habitats: Littoral rock and biogenic reef Littoral sediment Shallow sublittoral rock and biogenic reef Shallow sublittoral sediment	Coastal, shallow-depth marine systems that experience significant land-based influences. These systems undergo diurnal fluctuations in temperature, salinity and turbidity, and are subject to wave disturbance. Depth is up to 50-70 meters. Pelagic habitats in this type include the photic zone, benthic habitats can include it or not	Spatial representation of the marine coastal zone and of the relative proportion of habitats and related services	No European common scheme exists for mapping of pelagic habitats nor for combined pelagic/benthic systems EUSeaMap broad-scale seabed habitat maps are based on predictive modelling with partial validation	WFD coastal water bodies MSFD's water column predominant habitats with marine salinity MSFD's seabed predominant habitats	GIS layer of WFD coastal water bodies EUSeaMap is now only available for the Baltic, North, Celtic and western Mediterranean seas. Remaining seas to be covered by new projects (over 2013-2014) Marine water column habitats are not mapped by EUSeaMap
	Shelf	Pelagic habitats: Shelf waters Benthic habitats: Shelf sublittoral rock and biogenic reef Shelf sublittoral sediment	Marine systems away from coastal influence, down to the shelf slope. They experience more stable temperature and salinity regimes than coastal systems, and their seabed is below wave disturbance. Depth is up to 200 meters. Pelagic habitats in this type include the photic zone, benthic habitats are beyond the photic limit (aphotic)	Spatial representation of the marine shelf zone and of the relative proportion of habitats and related services	No European common scheme exists for mapping of pelagic habitats nor for combined pelagic/benthic systems EUSeaMap broad-scale seabed habitat maps are based on predictive modelling with partial validation	MSFD's water column predominant habitats with marine salinity MSFD's seabed predominant habitats	EUSeaMap is now only available for the Baltic, North, Celtic and western Mediterranean seas. Remaining seas to be covered by new projects (over 2013-2014) Marine water column habitats are not mapped by EUSeaMap
	Open ocean	Pelagic habitats: Oceanic waters Benthic habitats: Bathyal (upper, lower) rock and biogenic reef Bathyal (upper, lower) sediment Abyssal rock and biogenic reef Abyssal sediment	Marine systems beyond the shelf slope with very stable temperature and salinity regimes, in particular in the deep seabed. Depth is beyond 200 meters. Pelagic habitats in	Spatial representation of the marine open ocean zone and of the relative proportion of habitats and related services	No European common scheme exists for mapping of pelagic habitats nor for combined pelagic/benthic systems EUSeaMap broad-scale seabed habitat	MSFD's water column predominant habitats with marine salinity MSFD's seabed predominant habitats	EUSeaMap is now only available for the Baltic, North, Celtic and western Mediterranean seas. Remaining seas to be covered by new projects (over

Major eco-system category (level 1)	Ecosystem type for mapping and assessment (level 2)	Representation of habitats (functional dimension by EUNIS)/MSFD for marine ecosystems)	Representation of land cover (spatial dimension)	Benefits of mapping	Problems of mapping	Listed as ecosystems, major habitat types or reporting categories in	Spatial data availability
			this type are, in proportion, mostly aphotic, benthic habitats are aphotic		maps are based on predictive modelling with partial validation		2013-2014) Marine water column habitats are not mapped by EUSeaMap

Table 11. Typology of ecosystems (from MAES working paper 2013).

8.4 Classification of ecosystem services

There are three international classification systems to classify ecosystem services: The Millennium Ecosystem Assessment (MA), the Economics of Ecosystems and Biodiversity (TEEB) and the Common International Classification of Ecosystem Services (CICES) (Table 12). Each classification has its own advantages and disadvantages due to the specific context within which they were developed. MA was the first large scale ecosystem assessment and provides a framework that has been adopted and further refined by TEEB and CICES. The MA organizes ecosystem services into four well known groups:

1. provisioning services

2. regulating services

3. cultural services

4. supporting services

TEEB proposes a typology of 22 ecosystem services divided in 4 main categories, mainly following the MA classification:

1. provisioning services

2. regulating services

3. habitat services

4. cultural and amenity services

An important difference TEEB adopted was the omission of supporting services, which are seen in TEEB as a subset of ecological processes. Instead, habitat services have been identified as a separate category to highlight the importance of ecosystems to provide habitat for migratory species and gene-pool "protectors". CICES builds on the existing classifications but focusses on the ecosystem service dimension. In the CICES system services are either provided by living organisms (biota) or by a combination of living organisms and abiotic processes. Abiotic outputs and services, e.g. provision of minerals by mining or the capture of wind energy, can affect ecosystem services but they do not rely on living organisms for delivery. They are therefore considered as part of overall natural capital (which comprises sub-soil assets, abiotic flows and ecosystem capital and services). The individual types of natural capital possess different key characteristics (e.g. renewable or not) that translate into specific management challenges. Maintaining ecosystem capital stocks and functions is essential to ensure continued production of the flows of ecosystem services that societies and economies benefit from every day. The ecosystem capital accounts aim to estimate the increase or decrease in the availability or supply of ecosystem services as well as the underlying status of ecosystems that determine their functioning.

MA categories	TEEB categories		CICES v4.3 group
Food (fodder)	Food	**Provisioning services**	Biomass [Nutrition]
			Biomass (Materials from plants, algae and animals for agricultural use)
Fresh water	Water		Water (for drinking purposes) [Nutrition]
			Water (for non-drinking purposes) [Materials]
Fibre, timber	Raw Materials		Biomass (fibres and other materials from plants, algae and animals for direct use and processing)
Genetic resources	Genetic resources		Biomass (genetic materials from all biota)
Biochemicals	Medicinal resources		Biomass (fibres and other materials from plants, algae and animals for direct use and processing)
Ornamental resources	Ornamental resources		Biomass (fibres and other materials from plants,
			Mechanical energy (animal based)
Air quality regulation	Air quality regulation	**Regulating services (TEEB)** **Regulating and supporting services (MA)** **Regulating and maintenance services (CICES)**	[Mediation of] gaseous/air flows
Water purification and water treatment	Waste treatment (water purification)		Mediation [of waste, toxics and other nuisances] by biota
			Mediation [of waste, toxics and other nuisances] by ecosystems
Water regulation	Regulation of water flows		[Mediation of] liquid flows
	Moderation of extreme events		
Erosion regulation	Erosion prevention		[Mediation of] mass flows
Climate regulation	Climate regulation		Atmospheric composition and climate regulation
Soil formation (supporting service)	Maintenance of soil fertility		Soil formation and composition
Pollination	Pollination		Lifecycle maintenance, habitat and gene pool protection
Pest regulation Disease regulation	Biological control		Pest and disease control
Primary production Nutrient cycling (supporting services)	Maintenance of life cycles of migratory species (incl. nursery service)		Lifecycle maintenance, habitat and gene pool protection
			Soil formation and composition
			[Maintenance of] water conditions
	Maintenance of genetic diversity (especially in gene pool protection)		Lifecycle maintenance, habitat and gene pool protection
Spiritual and religious values	Spiritual experience	**Cultural services**	Spiritual and/or emblematic
Aesthetic values	Aesthetic information		Intellectual and representational interactions
Cultural diversity	Inspiration for culture, art and design		Intellectual and representational interactions
			Spiritual and/or emblematic
Recreation and ecotourism	Recreation and tourism		Physical and experiential interactions
Knowledge systems and educational values	Information for cognitive development		Intellectual and representational interactions
			Other cultural outputs (existence, bequest)
MA provides a classification that is globally recognised and used in sub global assessments.	*TEEB provides an updated classification, based on the MA, which is used in on-going national TEEB studies across Europe.*		*CICES provides a hierarchical system, building on the MA and TEEB classifications but tailored to accounting.*

Table 12. Ecosystem services categories in MA, TEEB and CICES

From the comparisonof the classifications of marine and coastal ecosystem services, as reported by Liquete et al. (2013) (Fig. 43) in which the main classifications (MA, Beaumont, TEEB, CICES) are described, the CICES classification system was chosen for the environmental accounting of the MPA "*Isole Ciclopi*".This was because it offers a taxonomy of ecosystems that is more appropriate for the system investigated. For this reason, a focus on the main features of CICES procedure and a more detailed description are given below.

	This paper	MA	Beaumont	TEEB	CICES
Provisioning	**Food provision**	Food	Food provision	Food	Terrestrial plant and animal Freshwater plant and animal Marine plant and animal
	Water storage and provision	Fresh water	N/A	Water	Potable water Water flow regulation Water quality regulation
	Biotic materials and biofuels	Ornamental resources Genetic resources Biochemicals Fiber	Raw materials	Ornamental resources Genetic resources Medicinal resources Raw materials	Biotic materials Renewable biofuels
Regulating and maintenance	**Water purification**	Water purification and waste treatment Nutrient cycling	Bioremediation of waste Nutrient cycling	Waste treatment	Bioremediation Water quality regulation Dilution and sequestration of wastes
	Air quality regulation	Air quality regulation	Gas and climate regulation	Air quality regulation	
	Coastal protection	Natural hazard regulation Water regulation Erosion regulation	Disturbance prevention	Moderation of extreme events Regulation of water flows Erosion prevention	Mass flow regulation Water flow regulation Air flow regulation
	Climate regulation **Weather regulation**	Climate regulation	Gas and climate regulation N/A	Climate regulation	Atmospheric regulation
	Ocean nourishment	Soil formation Nutrient cycling	Nutrient cycling	Maintenance of soil fertility	Pedogenesis and soil quality regulation
	Life cycle maintenance	Pollination	Biologically mediated habitat	Maintenance of life cycles of migratory species Maintenance of genetic diversity Pollination	Lifecycle maintenance and habitat protection Gene pool protection
	Biological regulation	Pest regulation Disease regulation	N/A	Biological control	Pest and disease control
Cultural	**Symbolic and aesthetic values**	Spiritual and religious values Cultural heritage values Cultural diversity Sense of place Aesthetic values	Cultural heritage and identity Feel good or warm glow	Spiritual experience Aesthetic information	Spiritual Aesthetic, heritage
	Recreation and tourism	Recreation and ecotourism Social relations	Leisure and recreation	Opportunities for recreation and tourism	Recreation and community activities
	Cognitive effects	Inspiration Knowledge systems Educational values	Cognitive effects	Inspiration for culture, art and design Information for cognitive development	Information and knowledge

Figure 43. Classifications of marine and coastal ecosystem service (From Liquete et al. 2013)

8.4.1 CICES framework

The general framework developed by CICES is proposed to be used for the integration of valuesof ecosystems in accounting frameworks so that cross-reference can be made between ecosystem services and the other instruments for environmental accounting (i.e. Natural Capital assessment). The original aim for developing CICES was to facilitate the more consistent approach for constructing information and databases for ecosystem accounts. However, the need to integrate ecosystem mapping, environmental accounting and economic valuation and the potential benefits that can deliver has led to the classification providing a useful platform for the characterization and assessment of ecosystem services.For the purposes of CICES, ecosystem services are defined as the contributions that ecosystems make to human well-being. They are seen as arising from living organisms (biota) or the interaction of biotic and abiotic processes, and refer specifically to the 'final' outputs or products from ecological systems. That is, the things directly consumed, used or enjoyed by people. Following common usage, the classification recognizes these outputs to be provisioning, regulating and cultural services, but it does not cover the so-called 'supporting services' originally defined in the MA (MAES, 2013). The supporting services are treated as part of the ecosystem processes and ecosystem functions that characterize ecosystems.

CICES has a five level hierarchical structure (Fig. 44):

- Section
- Division
- Group
- Class
- Class type

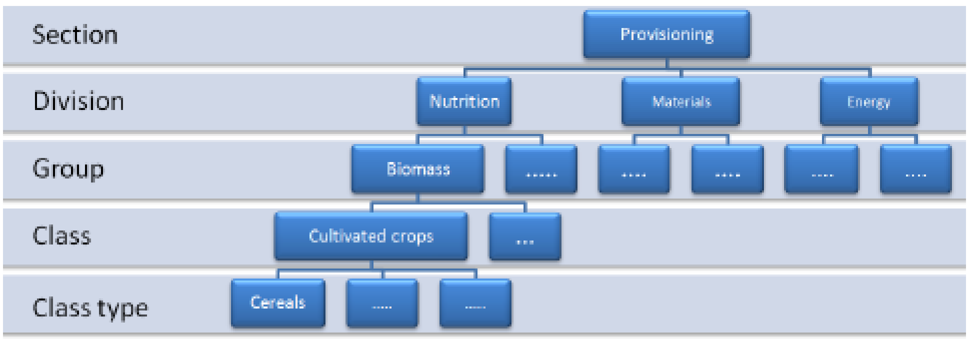


Figure 44. Illustration of proposed hierarchical structure of CICES V4.3

The more detailed class types makes the classification more user-friendly and provides greater clarification on what ecosystem services are included within each class. Using a five-level hierarchical structure is in line with United Nations Statistical Division (UNSD) best practice guidance as it allows the five level structure to be used for ecosystem mapping and assessment, while the first four levels can be employed for ecosystem accounting without reducing the utility of the classification for different users.At the highest level, the three familiar sections of provisioning, regulating/maintenance, and cultural (Table 13). The labels used in CICES have been selected to be as generic as possible, so that other more specific or detailed categories can progressively be defined, according to the interests of the user.

Section	Division	Group	Class	Class type
This column lists the three main categories of ecosystem services	*This column divides section categories into main types of output or process.*	*The group level splits division categories by biological, physical or cultural type or process.*	*The class level provides a further sub-division of group categories into biological or material outputs and bio-physical and cultural processes that can be linked back to concrete identifiable service sources.*	*Class types break the class categories into further individual entities and suggest ways of measuring the associated ecosystem service output.*
Provisioning	Nutrition	Biomass	Cultivated crops	*Crops by amount, type*
			Reared animals and their outputs	*Animals, products by amount, type*
			Wild plants, algae and their outputs	*Plants, algae by amount, type*
			Wild animals and their outputs	*Animals by amount, type*
			Plants and algae from in-situ aquaculture	*Plants, algae by amount, type*
			Animals from in-situ aquaculture	*Animals by amount, type*
		Water	Surface water for drinking	*By amount, type*
			Ground water for drinking	
	Materials	Biomass	Fibres and other materials from plants, algae and animals for direct use or processing	*Material by amount, type, use, media (land, soil, freshwater, marine)*
			Materials from plants, algae and animals for agricultural use	
			Genetic materials from all biota	
		Water	Surface water for non-drinking purposes	*By amount, type and use*
			Ground water for non-drinking purposes	
	Energy	Biomass-based energy sources	Plant-based resources	*By amount, type, source*
			Animal-based resources	
		Mechanical energy	Animal-based energy	*By amount, type, source*

Regulation & Maintenance	Mediation of waste, toxics and other nuisances	Mediation by biota	Bio-remediation by micro-organisms, algae, plants, and animals	*By amount, type, use, media (land, soil, freshwater, marine)*
			Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals	*By amount, type, use, media (land, soil, freshwater, marine)*
		Mediation by ecosystems	Filtration/sequestration/storage/accumulation by ecosystems	*By amount, type, use, media (land, soil, freshwater, marine)*
			Dilution by atmosphere, freshwater and marine ecosystems	
			Mediation of smell/noise/visual impacts	
	Mediation of flows	Mass flows	Mass stabilisation and control of erosion rates	*By reduction in risk, area protected*
			Buffering and attenuation of mass flows	
		Liquid flows	Hydrological cycle and water flow maintenance	*By depth/volumes*
			Flood protection	*By reduction in risk, area protected*
		Gaseous / air flows	Storm protection	*By reduction in risk, area protected*
			Ventilation and transpiration	*By change in temperature/humidity*
	Maintenance of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Pollination and seed dispersal	*By amount and source*
			Maintaining nursery populations and habitats	*By amount and source*
		Pest and disease control	Pest control	*By reduction in incidence, risk, area protected*
			Disease control	
		Soil formation and composition	Weathering processes	*By amount/concentration and source*
			Decomposition and fixing processes	
		Water conditions	Chemical condition of freshwaters	*By amount/concentration and source*
			Chemical condition of salt waters	
		Atmospheric composition and climate regulation	Global climate regulation by reduction of greenhouse gas concentrations	*By amount, concentration or climatic parameter*
			Micro and regional climate regulation	

Cultural	Physical and intellectual interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Physical and experiential interactions	Experiential use of plants, animals and land-/seascapes in different environmental settings	*By visits/use data, plants, animals, ecosystem type*
			Physical use of land-/seascapes in different environmental settings	
		Intellectual and representative interactions	Scientific	*By use/citation, plants, animals, ecosystem type*
			Educational	
			Heritage, cultural	
			Entertainment	
			Aesthetic	
	Spiritual, symbolic and other interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Spiritual and/or emblematic	Symbolic	*By use, plants, animals, ecosystem type*
			Sacred and/or religious	
		Other cultural outputs	Existence	*By plants, animals, feature/ecosystem type or component*
			Bequest	

Table 13. CICES Ecosystem services for Ecosystem Accounting (From www.cices.eu)

Provisioning, Regulation/Maintenance and Cultural Services have specific characteristics depending on the type of environment in which they are applied: agro-ecosystems (cropland and grassland), forest ecosystems, freshwater ecosystems (rivers, lakes, groundwater and wetlands), and marine ecosystems (transitional waters and marine inlets, coastal ecosystems, the shelf, the open ocean). Below,the three main categories of services aredeveloped with regard to their application in the marine environment, due to the specificity of this work. The typology of marine ecosystems was defined to encompass all marine waters, including all waters at the land/sea interface. Four ecosystems were considered: 1) marine inlets and transitional waters (including, among others, coastal lagoons, estuaries and fjords); 2) coastal waters (up to a depth of 70 m); 3) shelf waters (up to a depth of 200 m); and 4) open ocean (depth above 200 m).

Provisioning services

Marine ecosystems are major providers of food and feed. Thus, in the provisioning service section, only the divisions related to “Nutrition” and “Materials” have been filled out. “Energy” provision has been considered as not applicable for the most part, except for plant-based energy, which has been considered as relevant only at local scale. Within “Nutrition” and “Materials”, “Water” provision with both “Nutrition” and “Materials” has not been considered, as this service is not dependent on the biotic component of the ecosystem. In terms of food for nutrition and feed (related mostly to provision of fish-meal and the aquaculture industry), indicators proposed are available at national and European level from the Common Fisheries Policy reporting.

Regulating/Maintenance services

For the service division on “Mediation of waste, toxic and other nuisances” nutrient loads to coastal areas are available at European level through the FATE28 initiative from JRC on pollutants in terrestrial and aquatic ecosystem. For the service division on “Mediation of flows”, information is available at European level as illustrated in Liquete et al. (2013). For the service division on “Maintenance of physical, chemical, biological conditions”, some indicators are available at national level from reporting requirements under the Habitat Directive (e.g. “Maintaining nursery populations and habitats”), and are therefore available at national level, but not harmonized at European level. Some others resulting from modelling activities and are available within the JRC/EMIS datasets. “Chemical conditions of salt water” is bundled with indicators under the “Mediation of waste, toxic and other nuisances” division.

Cultural services

Only a few services under the “Physical and intellectual interactions with biota, ecosystems, and land-/seascape environmental settings” division have available datasets or proxies harmonized at European level. Most datasets would only be available at local sites, and would not be harmonized. For the “Spiritual, symbolic and other interactions with biota, ecosystems, and land-/seascapeenvironmental settings” the outlook for available indicators is quite similar.

Chapter 9

Ecosystem services assessment in Marine Protected Area "*Isole Ciclopi*"

Once the ecological value of the system has been evaluated it is necessary identify the functions that characterize it and the ecosystem services derived from them.Thisaccounting is essential in order to
identify the correct relationships between the ecosystem and the anthropic system and quantify resource flows between them.The mapping of ecosystem services has been conduct according to the ministry guidelines indicated by the documents "Environmental Accounting in Marine Protected Area" *Federparchi*, 2014. Functions and services have also been identified based on in-depth knowledge of the entire bibliography of reference, paying particular attention to the marine environment (i.e. Liquete et al., 2013; De Groot et al., 2012; MA, 2005), the MAES working group procedures (Mapping and Assessment on Ecosystems and their Services). Finally, CICES classification system was chosen and general procedures have been adapted to obtain a classification of functions and services specifically designed for MPA "*Isole Ciclopi*".

9.1 Materials and methods

The acquired data derive from surveys conducted at different levels and with different methods, depending on the type of users of reference. Some indicators of use, such as the number of bathers, divers, boats and users of various recreational activities, derive from the administration of questionnaires (appendix I), suitably prepared and designated according to the different subjects interested, carried out during the months of June, July and August 2016, 2017 throughout the territory of the MPA. Information on the MPA's monetary balance sheet, national and European funded projects, documents produced (documentaries, scientific and didactic-educational publications), exhibitions and scientific/artistic activities was collected through consultation of the MPA's archives from its establishment until 2017 and with direct interviews to MPA operators. The same applies to data on use by schools and by other types of visitors. The questionnaires were divided into sections, in order to obtain the maximum possible information for each individual interviewed, according to the following scheme:

Section 1. General data:

Personal data, frequency of visits, residence and, in the case of non-resident users, time spent in the MPA.

Section 2. Awareness:

Questions to understand if the user was aware of being in a MPA, how and how much he knows about the zonation and regulation. It was also asked to express personal opinions on the usefulness of the reserve as a guarantor of environmental protection.

Section 3. Satisfaction:
It was asked to express opinions on the experience conducted within the MPA and to give an assessment of the services offered and the work done by the managing body.

Section 4. Use of resources/use activities:

It is required to specify:

- ✓ Activity carried out within the reserve;
- ✓ Frequency;
- ✓ Preference for the MPA (for activities not strictly related to it);
- ✓ Knowledge of the rules governing the activity(s) carried out in the reserve;
- ✓ Awareness of any impacts that the activity(s) may cause to the marine environment;
- ✓ Willingness to submit to greater limitations in case of confirmed environmental damage caused by the presence / activity of users.

The section is further divided, depending on the category of user interviewed, in order to obtain more information. The categories considered are as follows:

- o Bathing and/or hiking tourism
- o Boating (pleasure craft and boats)
- o Divers

- Sport fishing

If the user belonged to more than one category, he was asked to complete all the sections.

Section 5. Willingness to pay:

It was asked to pay a fee to access the reserve and if so, to quantify in monetary terms this availability. It was also investigate the costs incurred to reach the MPA and to practice a specific activity, trying to find out how users consider the amount paid and if they would be willing to pay a higher one. The latter section is of fundamental importance in the economic evaluation of environmental assets. In fact, environmental goods and services are not always associated with market value and often there can be uncertainty about their real value and meaning. The attribution of a monetary value is based on a measure of willingness to pay in circumstances where markets fail to disclose this information. Currency is thus the unit of measure in terms of which individuals express their preferences. The willingness to pay for a service also gives back information relative to the future existence of that good: the individual could be willing to pay to guarantee the availability of the environmental service later. Estimating the "cost of travel" is one of the indirect techniques of monetary evaluation and is particularly useful for estimating the value of recreational and tourist services offered by protected natural areas. The method refers to the total costs incurred by users to reach a given location, and it is assumed that these represent the actual value that individuals attribute to the site. It is important to point out that the information derived from the questionnaires, described above, have been compared, cross-checked and re-elaborated on the basis of data already in the possession of the MPA that refer to previous scientific studies (from 2007 onwards). For this reason, the previous models have been taken into account in the drafting of the questions, while not neglecting the development of new indicators never considered in previous works. As far as data on the professional fishing sector is concerned, the methodology provided for the integration of information from several sources: material from previous studies in the possession of the MPA, interviews with professional fishermen working in the reserve and interviews with the operators.The data, collected with the different methods described above, were used to compile ecosystem services table, according to CICES, that has been customized for the system investigated with the following descriptors:

1. Provisioning services

Wild animals and their outputs

Examples: fish resources, crustaceans, molluscs, echinoderms
Indicators:

- Capacity indicator: fish resources: species, density (t)
- Flow indicator: catch of fish resources/crustaceans/molluscs/echinodermata (t/a), CPUE (catch/fishing effort)
- Indicator of benefit: Market value sale of fish resources (€/y)

Notes: It was decided that for the estimation of the capacity indicator "fish resources", visual census data should be used; for the estimation of the catch flow indicator, the data from the fishery shall be used.

2. Regulation and maintenance services

Mass stabilization and control of erosion rates

Class: risk reduction, protected area
Examples: protection against erosion, landslides and sediment flows; plant coverings to protect, stabilize terrestrial, coastal and marine ecosystems, coastal wetlands, dunes; plant coverings on slopes to prevent snow and rock avalanches, protection against erosion of coastal strips and sediments provided by, sea grasses, micro and macro algae meadows, etc.
Indicators:

- Capacity indicator: extent of emerged, submerged and intertidal habitats (seagrass/seaweeds coverage (%), coastline slope and coastal geomorphology)
- Flow indicator: tidal regimes, tidal excursions, relative sea level, storms
- Benefit indicator: population density, infrastructure, artificial surfaces, UNESCO sites, replacement cost for damaged infrastructure, avoided

costs for the protection of the coastline, loss of human life avoided (€/ha, €/y)

Notes: It was proposed to limit the analysis to capacity indicators "extension of emerged, sub emerged and intertidal habitats (seagrass/seaweeds coverage (%), coastline slope and coastal geomorphology).

Flood protection

Class: risk reduction, protected area
Examples: coastal flood prevention from grasslands and macroalgae (additional to the service provided by wetlands and dune systems)
Indicators:

- Capacity indicator: composite indices based on the extent of emerged, submerged and intertidal habitats (seagrass/seaweeds coverage (%), vegetative coverage and properties (density, rigidity, height), coastline slope and coastal geomorphology)
- Flow indicator: index based on tidal regimes, tidal excursions, relative sea level, storms
- Benefit indicator: index based on population density, infrastructure, artificial surfaces, UNESCO sites, replacement cost for damaged infrastructure, avoided costs for coastline protection, loss of life avoided (€/ha, €/y)

Global climate regulation by reduction of greenhouse gas concentrations

Class: quantity, concentration or climatic parameters
Examples: Carbon sequestration in biomass through chlorophyll photosynthesis
Indicators:

- Capacity indicators: C sequestration potential (gC/y), carbon stored in biomass (t/y)
- Flow indicators: primary productivity ($gC/m^2/y$), algae ($gC/m^2/y$)
- Benefit indicator: carbon market value (€)

3. Cultural services

Experiential use of plants, animals and land/sea-scapes in different environmental settings

Class: flow of visitors, types of ecosystems, flora and fauna
Examples: snorkeling, diving, fish/whale/bird-watching, walking, hiking, climbing
Indicators:

- Capacity indicator: extent of marine protected area (ha/km^2), presence of iconic species
- Flow indicator: number of whale-watching, snorkeling, divers, swimming, rowing users, annual number of recreational visits, number of visitors to the visitor center, number of fishing permits, number of beach and club users (number(s)), annual rate of enjoyment of recreational activities (% of population),
- Benefit indicator: willingness to pay/travel cost

Note: It was decided that the questionnaires have to be submitted to the following categories of users:
- Nautical
- Divers
- Sport fishing
- Bathing

Physical use of land/sea-scapes in different environmental settings

Class: flow of visitors, types of ecosystems, flora and fauna
Examples: swimming facilities, diving centers, clubs, sport fishing and hunting associations
Indicators:

- Capacity indicator: extent of marine protected area (ha/km^2)
- Flow indicator: number of beaches in concession, number of diving clubs and nautical clubs, sport fishing activities (t/y), number of ecotourism enterprises, size of the area. observation points for watching activities,

spatial distribution of recreational activities, intensity, physical distribution of recreational activities (number/km^2)
- Benefit indicator: employment rate (human resources employed), estimated economic impact on the territory

Scientific

Class: use/quotations, types of ecosystems, flora and fauna
Examples: On-site and remote search object
Indicators:
- Capacity indicator: scientific studies (number), scientific publications - ISI (number)
- Flow indicator: national and European funded projects (number)
- Benefit indicator: national and European funded projects (budget, human resources)

Educational

Class: use/quotations, types of ecosystems, flora and fauna
Examples: On-site and remote search object
Indicators:
- Capacity indicators: documentaries and educational publications (number)
- Flow indicator: Entrances to scientific exhibitions (number), school visits (number)
- Benefit indicators: Admissions to scientific exhibitions (budget), School visits (budget)

Notes: with reference to this service, it was proposed to administer a questionnaire for the evaluation of the effectiveness of the educational activity at the end of the visit.

Entertainment

Class: use/quotations, types of ecosystems, flora and fauna
Examples: vision and experience of the nature site through the media

Indicators:

- Capacity indicators: number of documentaries and scientific publications (number)
- Flow indicator: number of visits to scientific and artistic exhibitions (number)

Aesthetic

Class: use/quotations, types of ecosystems, flora and fauna

Examples: atmosphere (sense of place), artistic representations of nature

Indicators:

- Capacity indicators: number of documentaries and scientific publications (number)
- Flow indicator: number of visits to scientific and artistic exhibitions (number)

9.2 Results and discussion

Table 14 shows Ecosystem functions and the services identified in MPA "*Isole Ciclopi*" and benefited by MPA users.

Regulation and Maintenance	Mediation of flows	Mass flows	Mass stabilization and control of erosion rates	*Risk reduction, protected area*	**Capacity:** Extent of emerged, submerged and intertidal habitats: 32.015 m^2 Seagrass/seaweedcoverage (%): - *Posidonia oceanica* meadowon rocky-sandy bottom 2,5% - Association *Caulerpa/Posidonia* on rocky-sandy bottom 0,4% Coastline slope and coastal geomorphology: In the stretch between *Punta Aguzza* and the Norman Castle of *Aci Castello*, the MPA is made up of high basaltic cliffs, sometimes formed by active cliffs overhanging directly into the sea, sometimes by dead cliffs protected at the base by beaches with a variable width of about ten square meters. These strips of land are made up of heterometric blocks and pebbles. In the coastal stretch north of the castle of *Aci Castello* up to the port of *Capo Molini*, the coast consists of low cliffs with beaches of blocks and lava flows, while between the pier of *Capo Molini* and the lighthouse of the same name you can see lava cliffs with high cliffs that form a very indented coast. Along the entire stretch of coastline under consideration, numerous outcropping rocks emerge from the sea, which, in correspondence with the inhabited center of *Aci Trezza*, reach considerable dimensions, constituting an archipelago of eight smaller islands and islets called *Faraglioni* or *Isole dei Ciclopi*. Proceeding from north to south, the Cyclop archipelago is formed by the *Lachea* island, with an area of about two hectares, by the *Faraglione Grande* or island of *Santa Maria* (38.8 m above sea level), *Faraglione di Mezzo*, *Faraglione degli Uccelli* and two other smaller formations below the coast. Finally, it is composed by a series of smaller rocks that end directly on the coast. The eruptive formations emerging in the coastal stretch of *Aci castello-Aci Trezza* consist mainly of Tholeiitic basalts poured into the middle Pleistocene (about 500-600,000 years ago). The presence of these formations is still relevant, you can see: - expansion of lava and breaches to pillows originated during

					underwater eruptions; - columnar basalts with pentagon-hexagonal section and variable size; - volcanoclastic deposits, given by hyaloclastic breaches or real hyaloclasts produced, in general, underwater effusions occurred in shallow environment or by explosive breaches. **Flow:** Tidal regime, tidal excursions and relative sea level: In the southernMediterranean Sea, the maximum tidal range is 45 cm on average and the tidal oscillations are of the mixed semi-diurnal type, with two maximums and two minimums during the day, which follow one another with different values during the month with lower and higher tides. On the Italian coasts, the tides have an average frequency of 6 hours between low and high tide and the excursions are quite limited, ranging on average between 30-70 cm. In 2014, the annual average vertical excursion measured in Catania station was 96 mm. The vertical excursion is strongly conditioned by the conformation of the coast and the wave motion. The statistical study of the characteristic directions of the waves is called "wave climate". The wave climate in the Ionian is bimodal (spread over two or more directional sectors). From the survey of the average number of storms per year and the maximum heights recorded, it can be said that the Ionian Sea is characterized by 8-15 annual events with return heights of about 6 m. [5] **Benefit:** Population density: 2.144,96 ab./km² Infrastructure and artificial surfaces: 4 Elastic beacons Buoys e 1 *Meda* (A zone), 5 Docking buoy and 8 Signaling driftwood (diving point). Replacement cost for damaged infrastructure: 5.000,00 euro/y Avoided costs for the protection of the coastline: 35.000,00 euro/y
	Maintenance of physical, chemical, biological conditions	Water conditions	Global climate regulation by reduction of greenhouse gas concentrations	*Quantity, concentration of climatic parameters*	**Capacity:** Carbon sequestration potential: 6.302.400 gC/y[6] Carbon stored in biomass 1,76E+14 t/y O_2 4,9 ml/l**Flow:** Primary productivity 5,48E+21 gC/y Microalgae and macroalgae 5,47E+21 gC/y **Benefit:** Carbon market value: euro 7/tons

Section	Division	Group	Class	Class Type	Indicators
Provisioning	Nutrition	Biomass	Reared animals and their products	*Species and individuals amount*	**Capacity:** fish resources Number of species: 72 [*visualcensus*][1] Density: 4 ind/m^2 [*visualcensus*][1] **Flow:** Capture (t/y)[2]: Fish[3] - valuable 13 t/y - common 9 t/y Crustaceans 0,10 t/y Mollusks 7 t/y Sea urchins [4] **Benefit:** Market value sale of fish resources 238.250,00 Euro/y
Cultural	Physical and intellectual interactions with biota, ecosystems and land/sea-scapes (environmental settings)	Physical and experiential interactions	Experential use of plants, animals and land/sea-scapes in different environmental settings	*Flow of visitors, types of ecosystems, flora and fauna*	**Capacity:** Extent of MPA :623 ha Presence of iconic species: *Cystoseira sp.pl.* *Epinephelus costae* *Epinephelus marginatus* *Hippocampus hyppocampus* *Homarus gammarus* *Lithophyllum byssoides* *Pinna nobilis* *Posidonia oceanica* *Sygnatus typhle* **Flow:** Annual number of recreational visit: 2964[7] Number of divers:[8] - Resident 290 - Non-resident 95 Number of beach users:107[9] Number of boat users: 245 Number of fishing permits: - Resident 3495 - Non-resident (daily permits required /year) 784 Annual rate of enjoyment of recreational activities (% of population):[9] - Divers 16% - Sport fishing 56%: o Shore 25% o Boat 67% o Both shore and boat 70% **Benefit:** Willingness to pay[9] - Willingness to pay for entrance ticket: 49% yes; 51% No - Average cost of the hypothetical daily admission ticket that the user would be willing to pay: 10 € - Willingness to pay more than the amount already provided for the use: 40% yes; 60% No Travel cost (average cost): 39 €[10]

			Material use of terrestrial or marine landscapes in different environmental contexts		**Capacity:** Extent of MPA 623 ha **Flow:** Number of beaches in concession (CDM):74 Number of diving clubs: 2 Number of nautical clubs: 2 Capture amount form sport fishing: 12 t/a Number of ecotourism enterprises: - fisheries tourism: 1 - boat trips: 2 - Boats for tourist transport coast/*Lachea* Island: 6 Extent of diving area: 5740 km^2 Spatial distribution of recreational activities: 5740 km^2; including bathing and snorkeling 5909 Km^2 Intensity, physical distribution of recreational activities: 53/5740Km^2 **Benefit:** Employment rate (human resources employed): 25
			Scientific		**Capacity:** Scientific study and publications (including graduate/doctoral theses): 40 **Flow:** National and European funded projects: 22 **Benefit:** National and European funded projects: - Budget: 1.509.447,00 €[11] (annual average: 107.817 €/y) - Human resources (average number of operators involved per project:) 11
			Educational	*By use citation, plants, animals, ecosystem type*	**Capacity:** Documentaries and educational publications: 19 **Flow:** Entrance to scientific exhibitions: 23 School visits: -Excursions with the glass-bottom boat: 1586[7] - Guided tours and snorkeling: 97[7] - internships with schools: 118[7] **Benefit:** Admissions to scientific exhibitions: 392.809,00 €[11] School visits: - Excursions with the glass-bottom boat: 11.000,00 €/annui[12] - Guided tours and snorkeling: 770 €/annui[13] - internships with schools: tax- free convention[13]

			Heritage, cultural		**Capacity:** Citation in historical documents: none Coastal communities whose identity and culture are closely linked to the survival of the marine environment: fishermen, boatmen (tourist transport service by boat from the coast to *Lachea* Island)
			Entertainment		**Capacity:** Numbers of documentaries and scientific publications: 18[11] **Flow:** Number of visits to scientific and artistic exhibitions: 13[11] **Benefit:** Profit: 146.500 €[11]
			Aesthetic		**Capacity:** Numbers of documentaries and scientific publications: 11[11] **Flow:** Number of visits to scientific and artistic exhibitions: 10[11] **Benefit:** Profit: 263.309 €[11]

Table 14. Ecosystem and function services of MPA "Isole Ciclopi".

Notes

1- The values obtained derive from the processing of all data relating to the Visual Census campaigns conducted within the marine protected area from its establishment to the present day.
2- The catch values refer both to professional boat fishing (gaff and harpoon fishing boats, boats with gillnets, trespass and longline and occasional fishing boats) and to sport fishing from the shore and from the boat.
3- Common species are seasonal species that are fished for one month/20 days a year and have a much lower market value.
4- The collection of sea urchins is prohibited within the marine protected area.
5- Data from the National Mareographic Network (NMR) and the National Wave Network (RON).
6- The most recent value reported by Taillandier et al. (2012) is 1.01 tC/Km^2.
7- Data refer to an annual average of use derived from registrations made from 2006 to 2016.
8- Data refer to the number of permits issued in the year 2016.
9- Data refer to the results of the administration of questionnaires within the reserve in the year 2017, which integrates a previous data collection campaign since 2007, the total number of respondents is 352.
10- Data refer to the sample of respondents for the year 2017, because the prices of means of transport may vary annually and therefore the previous data are not comparable.
11- The monetary value has been obtained from the average of all the induced from the projects carried out from 2002 to 2013.
12- Data refer to an annual average of use/induced use derived from registrations made between 2006 and 2016.
13- Data refer to the fruition/induced in the year 2016.

Data provided by the ecosystem services table of MPA highlights several aspects. At first the importance of the natural heritage of the area. The geomorphology of the basaltic coast and its formations, shaped over the centuries by eruptive manifestations, affect the characteristics of the seabed and the biodiversity of fauna and flora. In fact, classical literature has powered the spread of myths and legends about the birth of the territory and its natural monuments. This heritage therefore has a double value because, on the one hand it is a great attraction for tourists and on the other hand a source of inspiration from the artistic, spiritual and aesthetic point of view. Identity and culture of coastal communities are strictly linked to the survival of the marine environment.The closeness of the reserve core to the town has created a very strong link with the population, encouraging the emergence of professionals who are dependent on the natural environment, for examplefishermen or boatmen (tourist transport service by boat from the coast to *Isola Lachea*). The livelihood and economic balance of a large part of the residents turns around the exploitation of natural resources. For this reason, the presence of a MPA that regulates the use of resources in the perspective of sustainable development is of fundamental importance. A policy based on integrating economic needs with strategies for the conservation of the natural environment is the best alternative to manage the reserve.As concerns the activities related to the managing body, the evaluation of the ecosystem services shows a good level of organization regarding tourist services (guided tours, visits with the glass-bottom boat, snorkeling, activities and projects with schools). These activities guarantee economic incomes that can be useful for the supply of MPA as well as for the maintenance of the activities themselves. However, compared to operating costs, these gains are not always sufficient to obtain a positive economic balance. The most lacking features have been found in external collaborations, such as those with fishermen, for example. Fishing tourism represents a valid alternative for fishermen, which would lead, at certain levels, to a reduction in fishing effort but not in economic gain for those involved. In the reserve, there is a service of fishing tourism, which involves in particular one local boat, but it is not sufficiently valued and publicized so the demand and the use is very low. Documentaries, educational and scientific publications shouldalso be implemented. A more precise description of the fruition and of the problems connected to it is possible thanks to the analysis of the data deriving from the questionnaires, which contributed to the drafting of the table of ecosystem services.A total sample of 515 people have been interviewed. Data collected were processed according to subdividing users into categories related to the type of use.

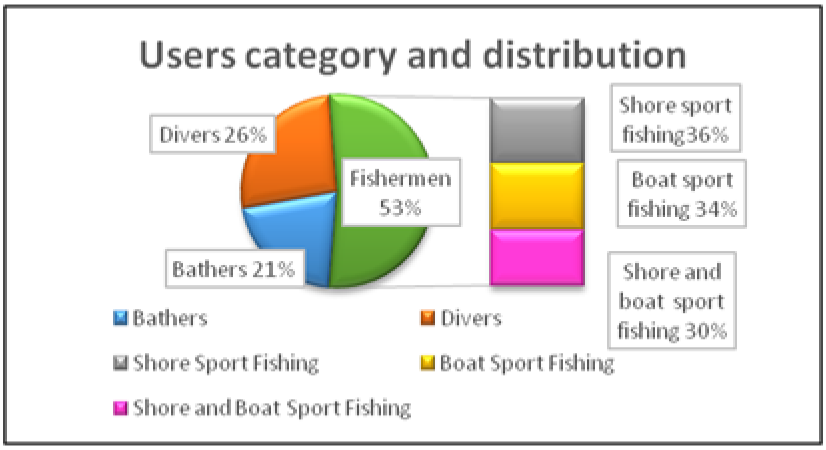


Figure 45. Distribution of respondents according to activities.

As concerns the users (Fig. 45), the most representative category is that of sportive fishermen (as already described in materials and methods for professional fishermen another survey methodhas been used) with a total of 53%. Of these, 36% fish from shore, 34% from boat and 30% use both systems, not showing a clear preference for one of the two. Then, among the categories of users, there are divers with 26% and finally bathers with 21%.

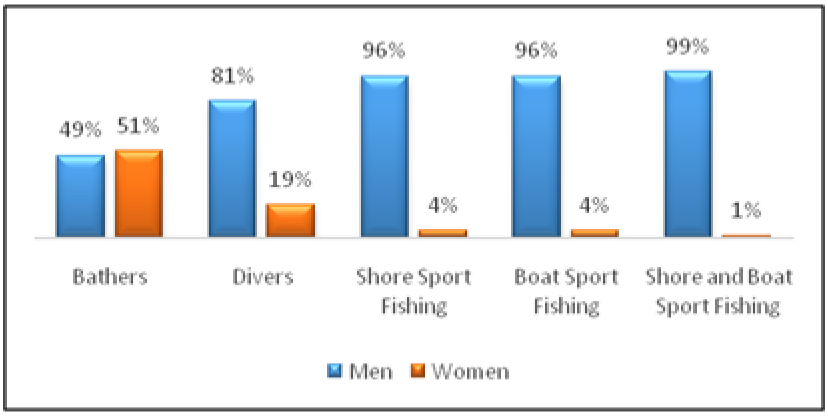


Figure 46. Gender distribution of respondents.

The users are mainly men (Fig. 46), even though it remain at low levels (19%), the incidence of women increases in the case of divers and is slightly higher among bathers. The distribution of respondents by age (Fig. 47) shows that bathers have an age range between 18 and 78 years with a higher distribution in the age range between 18 and 38 years. Divers also have a wide range, but this range is more significant between 18 and 28 years of age. Fishermen (both shore and boat fishermen) are present in all age ranges with a higher incidence between 49 and 78 years. The category of older users (> 78 years) presents only boat fishermen. From the data, it can be deduced that young people are a category of users more oriented towards bathing and diving, while for fishing activities the average age of the users increases.

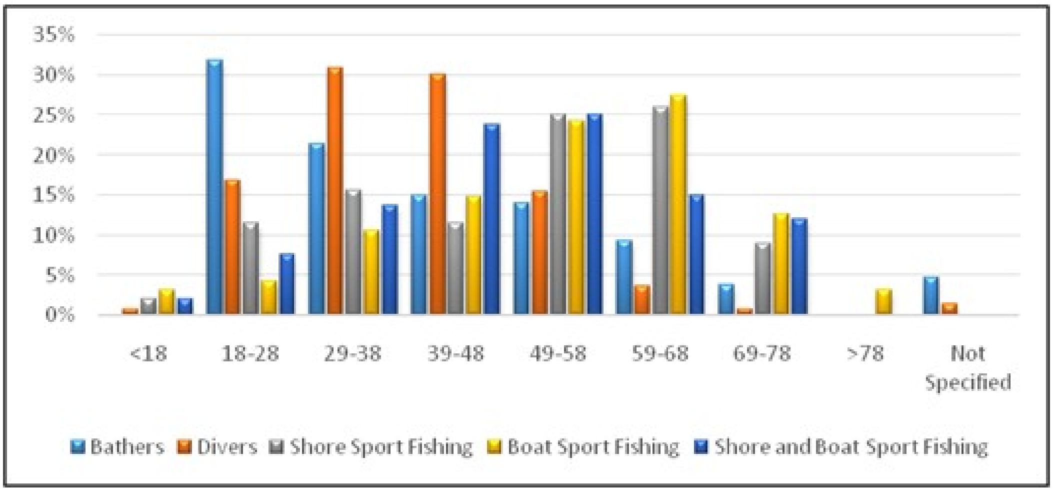


Figure 47. Age distribution of respondents

Another important feature is the distinction between users resident in the municipality of *Aci Castello* and those who are not residents (Fig. 48). In the categories of bathers, divers and shore fishermen, non-resident users predominate. On the contrary, the number of resident increase for boat fishermen and for those who use both shore and boat. In the last setting, the activity of fruition is linked to the presence of the boat and therefore it is conceivable the greater incidence of residents.

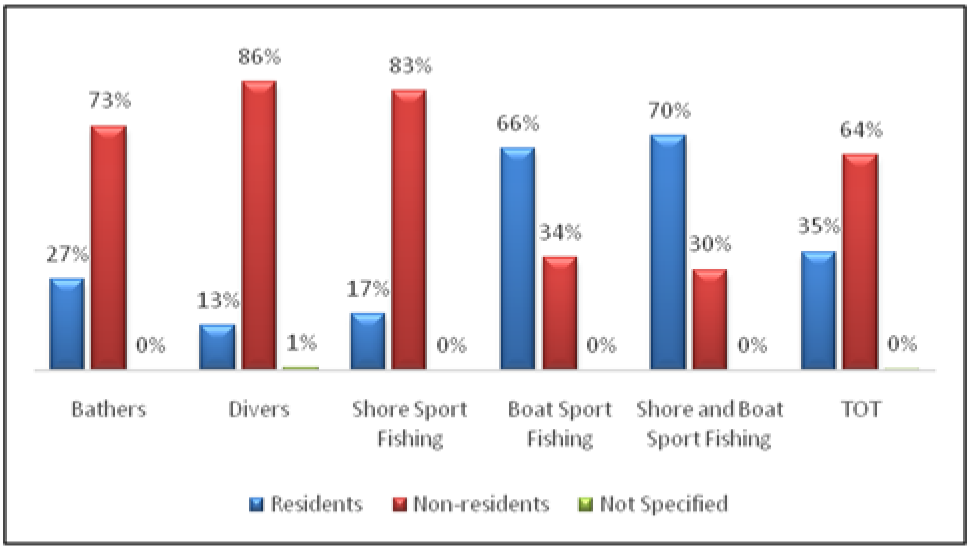


Figure 48. Distribution by residents

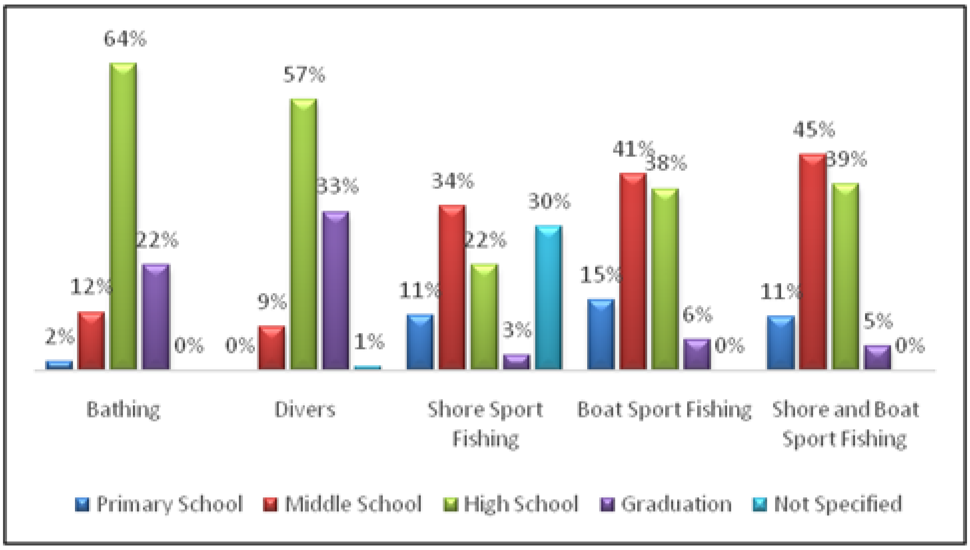


Figure 49. Distribution of users by qualification

From the questions concerning qualification (Fig. 49), it emerges that the users have obtained at least middle school license. The number of respondents with elementary school certificate is low, while graduates represent a great portion. Divers and bathers are mostly with graduation or high school license; fishermen mostly present middle school or high school license. A high percentage of shore fishermen do not specify their qualifications.

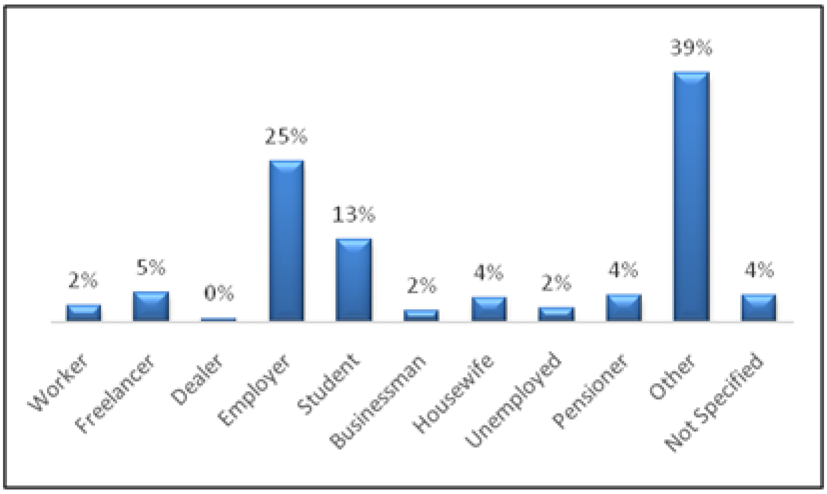


Figure 50. Distribution of respondents by profession

Compared to the profession carried out, without distinction into groups (Fig. 50), employees and students are the most frequent respectively with 25% and 13%, while 39% of respondents exercise a profession that does not fall into the categories set out in the questionnaire administered. A significant section of the questionnaire concerns the awareness of the users as knowledge of the MPA and its rules in carrying out specific activities (Fig. 51). The 91% of the interviewees state that they are aware to be in a MPA. Among these, 41% of the general users (all users except divers) reported that they were aware of it by referrals, while for divers the greatest incidence occurred by guidebooks with a percentage of 30%. Both categories show high percentages for internet and illustrative material, while the spread of information related to the visit centre of the MPA and diving centres are lacking. This reflects the need to implement advertising at local level and for activities directly or indirectly related to the reserve.Most users claim to know the rules governing the use within the MPA (Fig. 52). The only category that deviates from this result is that of bathers, of whom 66% say they are not aware of these rules.

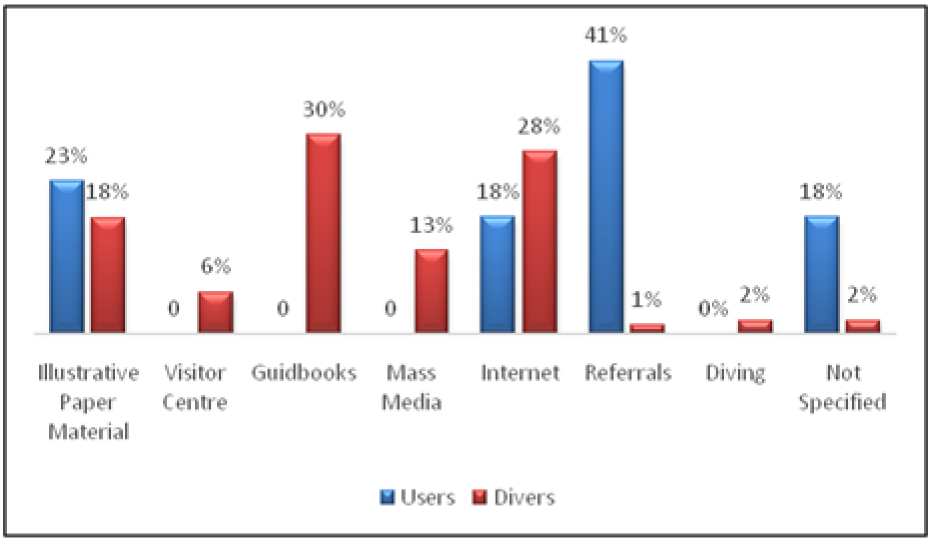


Figure 51. Distribution of respondents according to awareness

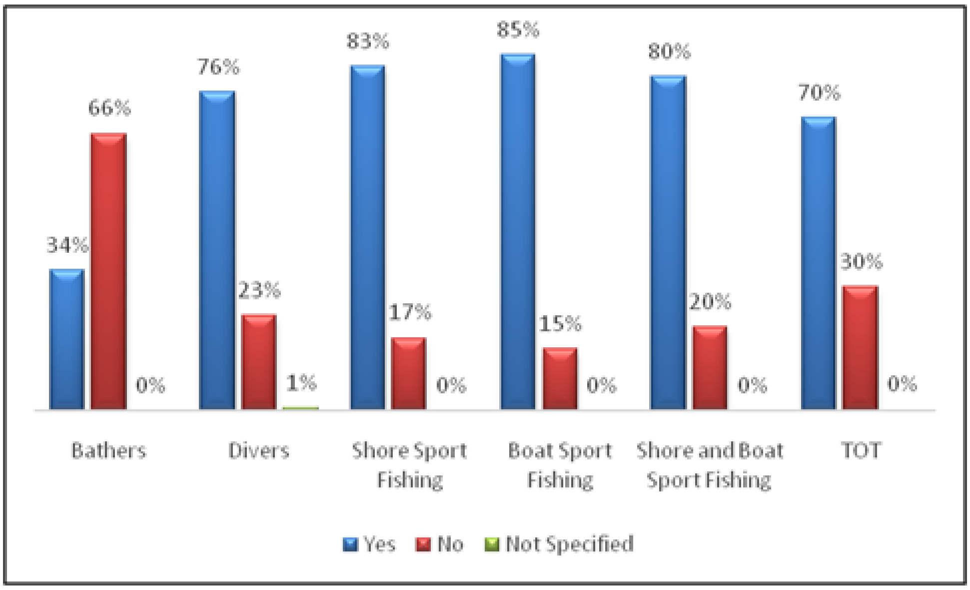


Figure 52. Distribution of respondents according to their knowledge of the rules

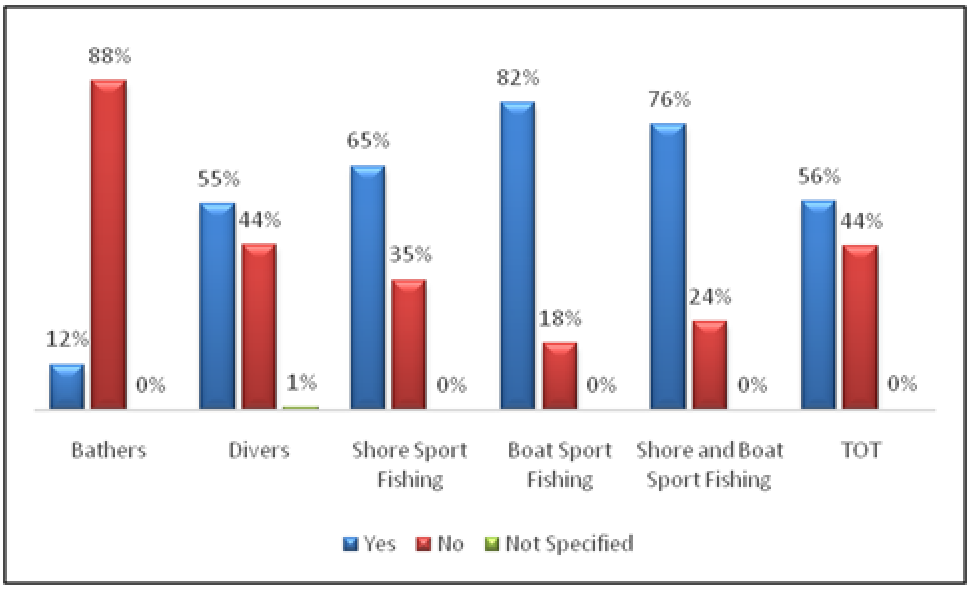


Figure 53. Distribution of respondents according to their knowledge of visitor centre.

Similarly, bathers are the least likely category to go to the MPA visitor centre, with 88% of users who have never been there before (Fig.53). The other categories show the opposite trend. This trend can be easily explained by the need for divers and fishermen to go to the visitor centre for the renewal / issuance of permits to engage in activities and then it rereads a frequency more related to the need than to the personal will.With regard to the existence of the MPA all categories of users agree in responding positively to its establishment (Fig. 54), affirming at the same time the need to introduce more restrictions for the use (Fig. 55). In addition, 44% of users respond negatively to the question of whether the current rules are sufficient to protect resources, even if 27% refrain from responding (Fig. 56).

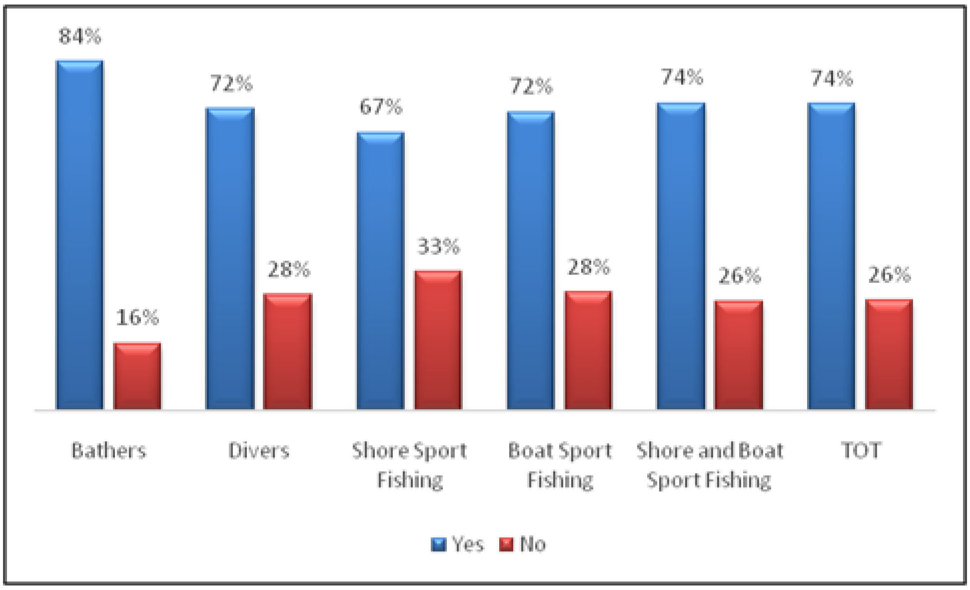


Figure 54. Support and against the existence of MPA.

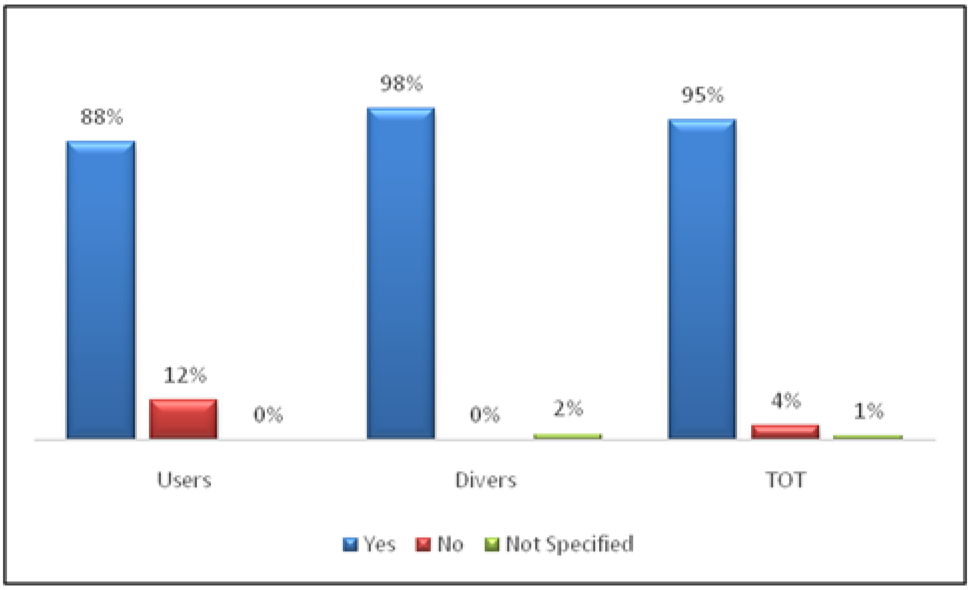


Figure 55. Support and against introducing new restrictions in MPA.

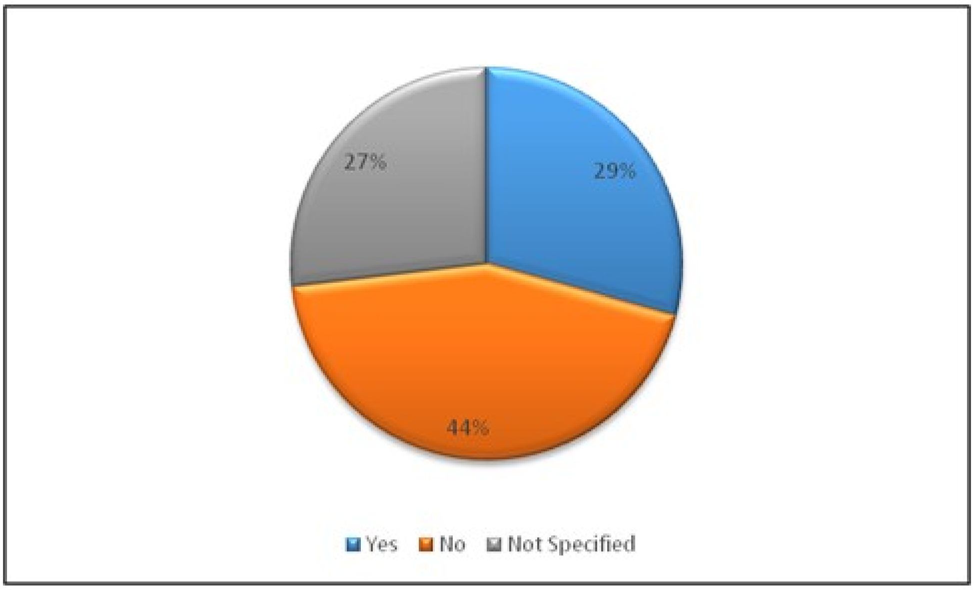


Figure 56. Usefulness of existing limitations for the protection of resources.

The 96% of the interviewees declared that prefer the water of the MPA for the fruition to the other localities, with 69% that specifically concerns only the category of bathers. With regard to frequency (Fig. 57), general users (all except bathers) present a homogeneous distribution, oriented towards a fruition of several days a week or in a month. Bathers, on the other hand, have a much higher incidence for the frequency of several days in a month.

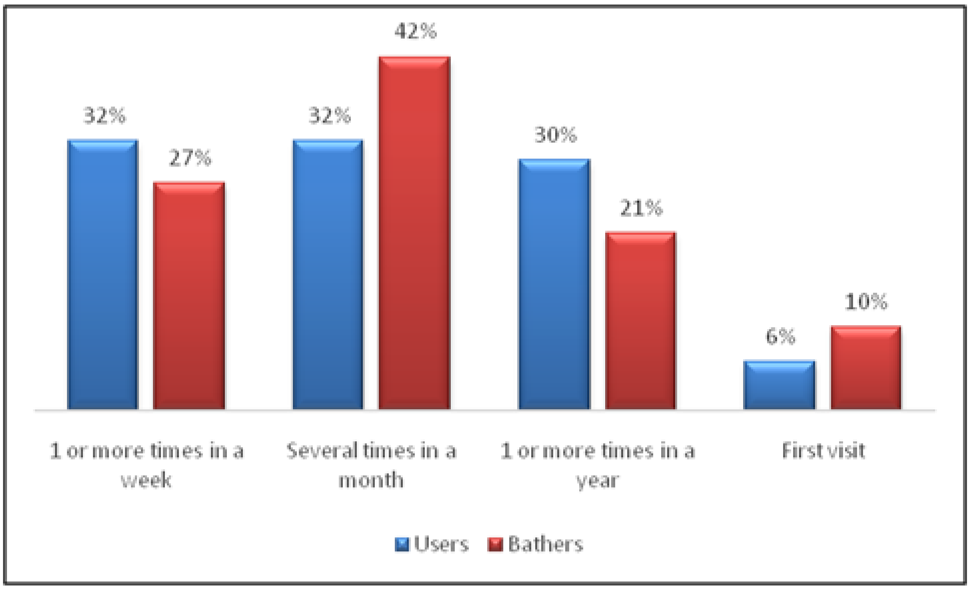


Figure 57. Frequency of fruition of MPA.

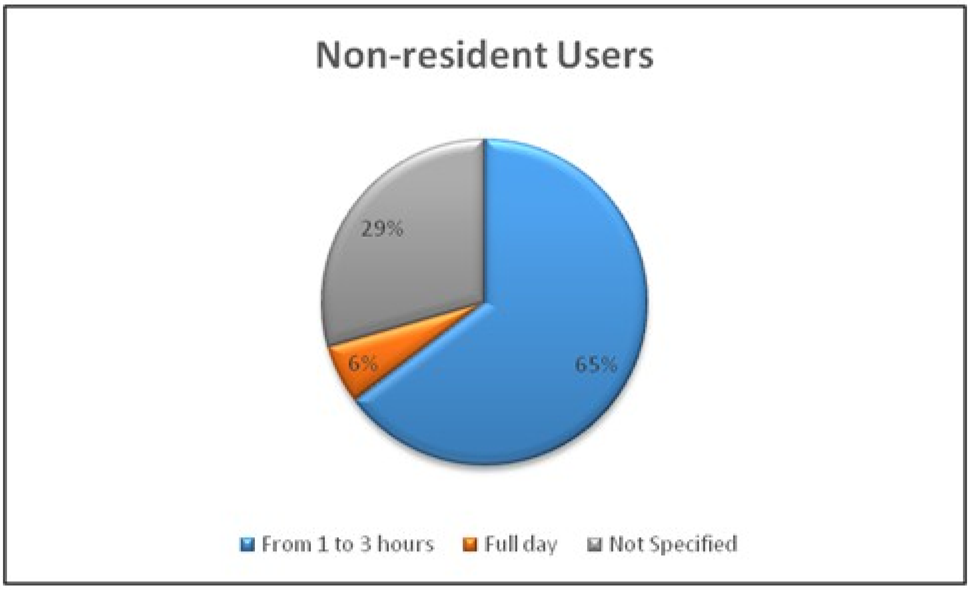


Figure 58. Permanence of non-resident users in MPA.

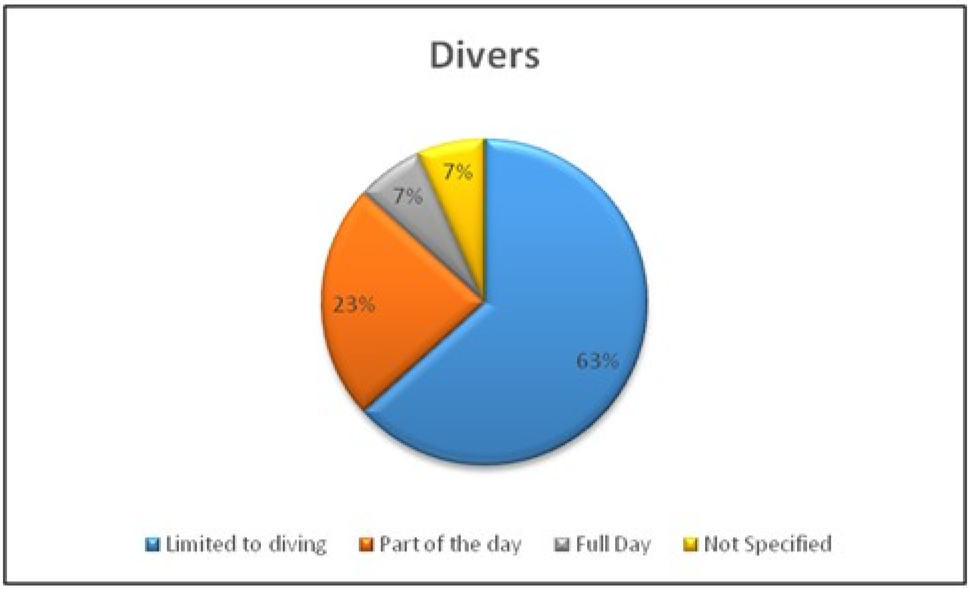


Figure 59. Permanence of divers in MPA.

Interesting results emerge from the analysis of data on stay within the MPA. 65% of non-resident users (excluding divers) say a stay time ranging from 1 to 3 hours, only 6% say to stay for the whole day (Fig. 58). Similarly, among the divers, 63% of them only dwell on the time necessary for diving and only 7% spend the whole day in the MPA (Fig.59). The trend highlighted by this analysis reflects a negative perspective for local businesses that, given the limited stay time of users, cannot increase their activity by offering their services to tourists.Information on the adequacy of the costs incurred in carrying out the activities is not significant as 79% of respondents preferred not to respond. However, 18% said the cost was adequate.With regard to the willingness to pay for an entrance ticket to the reserve, respondents are divided exactly in half: 49% yes, 50% no and 1% not specified. The trend, on the other hand, shows a greater incidence for the answer no (60%) when asked if you are willing to pay more than the costs already incurred.Finally, users are asked to express their degree of satisfaction within various aspects of the MPA (Fig. 60). Their experience in the reserve is rated as positive by all categories with a total of 76%. In the evaluation of the services, different degrees of satisfaction, which are equally distributed among the different categories of users, have been identified. Most of the respondents declared the services offered to be sufficient, few considered them to be good and a substantial portion was between insufficient or barely sufficient.

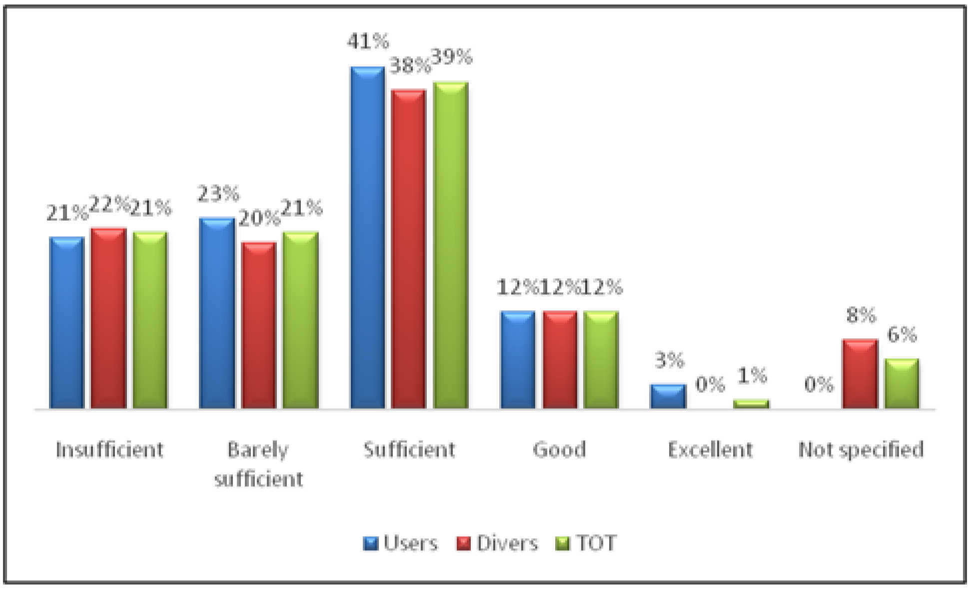


Figure 60. Degree of satisfaction.

Chapter 10

Conclusions

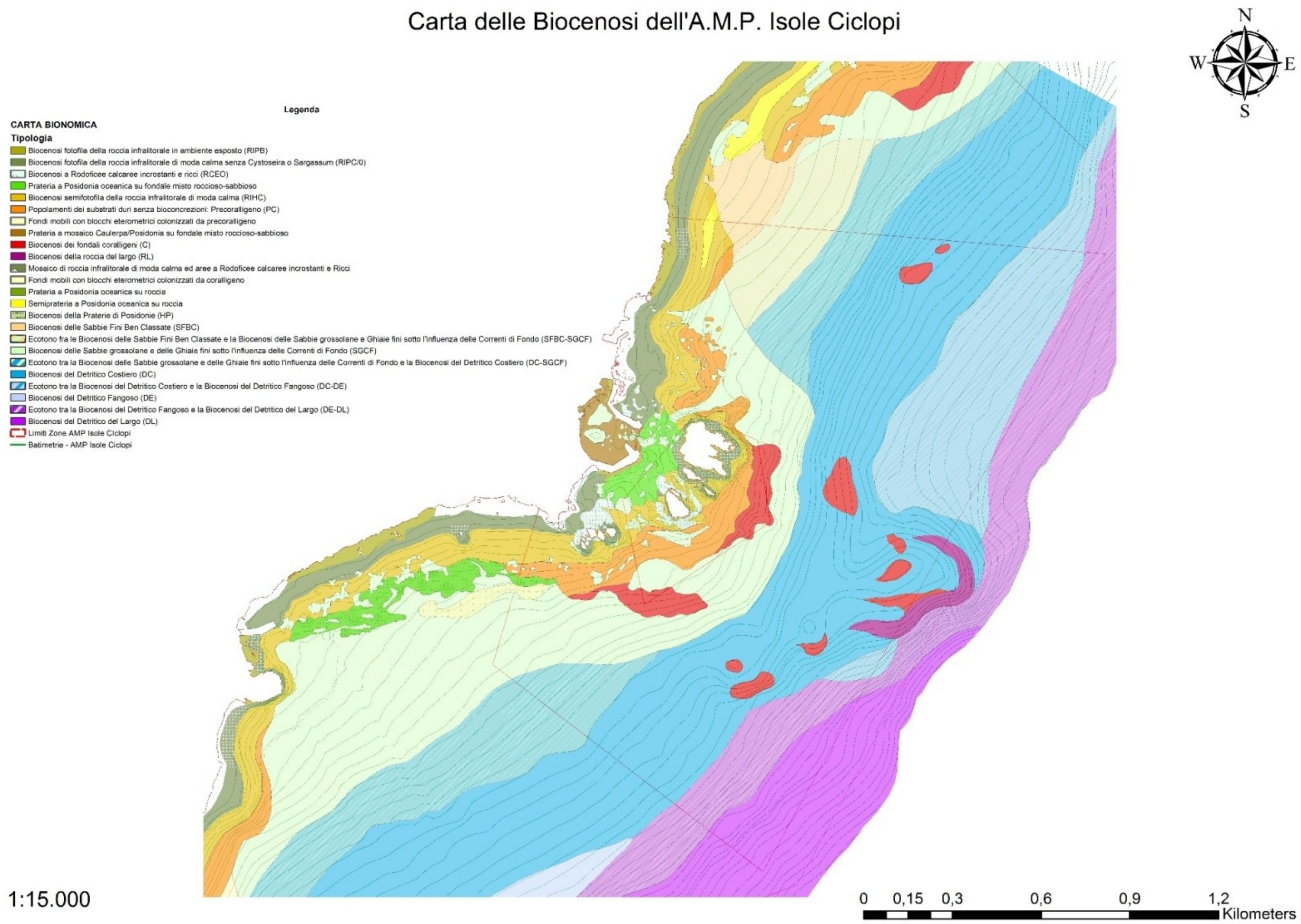
In this study, the environmental accounting, by means of emergy analysis, has been performed in MPA "*Isole Ciclopi*". This workwas conducted following a multi-year pathway, in line with the four-year project "Environmental accounting for Italian Marine Protected Areas"financed by the Italian Ministry of the Environment and Protection of Land and Sea in 2014. The investigation aim to evaluate both ecological and economic value of the reserve throughout the accounting of natural and anthropic flows (material and energy) supporting the MPA. The emergy procedure allow using a common language for natural and anthropic inputs, not possible with other traditional analysis. Moreover, specific indicators have been used in order to establish a trade-off between biological conservation and exploitation of natural resources. According to these objectives, emergy analysis shape as a procedure able to provide integrated information about natural and human-driven resources supporting ecological functions and economic activities. The cost-benefit approach can assess the productivity of investing in environmental management and conservation. This integrated methodology of the two components may also help scientists, policy-makers and local managers to implement ecosystem administration according to the principles of sustainable development.At first, in the present study, an emergy analysis has been carried out in order to provide a scenery of performance, impact and environmental sustainability of the activities carried of MPA in relation to the renewable natural resources present. The investigation demonstrates that the flows of non-renewable resources are an important component of the system (they represent about 84% of the total emergy use within the area). If natural renewable resources are considered, chemical potential of rain is the major environmental contribution to MPA, which accounts for 11.22% of the total renewable inputs with geothermal heat (4.85%); the results highlight the importance of both chemical potential of rain and geothermal heat for the primary production. Among the purchased inputs, human labor in fishing sector and divers present the major values respectively with 22.04% and 18.14% of all purchased emergy. To understand more on the effects of human activities on the system, the data were analyzed through the application of specific indicators.The high value of Emergy Density is a clear indicator of area as a limiting factor: there is the need to investing resources much beyond the area-based carrying capacity of the MPA. Emergy density value, calculated without stress factors (fishery, whole tourism, tourists and divers) is lower. The lowest value focus on the necessity to review some of the activities to a more sustainable economic management of the reserve in the long end. The value of Emergy Yield Ratio (EYR) is low and close to the unit, so the ability of the system to exploit local resources is small, with imported inputs contributing most of the emergy used. This highlight the dependence of the MPA on imports to generate goods and service. The indicator calculated for the different categories confirms this observation. In fact, EYR for fishing sector is 1.30, for whole tourism is 1.51, showing the increasing dependence and use of imported goods, if only ecosystem services are considered. Among whole tourism, tourists and divers present very different values of EYR, respectively 2.19 and 1.57. The higher value of divers underlines a disadvantageous condition for the MPA, where this activity, more than fishery or tourists, overworks local resources without reinvesting in the area, as already shown by emergy flow. The environmental costs of dependence more on purchased resources, pointed out by EYR, is reflected in the environmental Loading Ratio (ELR) value of 5.10. The high value recordered means that the consumption of non-renewable resources is 5.10 times higher than the renewable ones. High rates of ELR also reflect a condition of environmental stress. For a better understanding of what could be the main source of stress, it is important to analyze the different categories. ELR for fishing sector is 3.43 while for whole tourism is 1.79. Both values are over 1.0 (value indicators of ecological-economic balance condition) but fishing sector seems to be the major liable of the unsatisfactory balance between local and imported resources. The result is supported by the emergy percentage of 56.43% related to this sector. These values indicate the necessity to improve economic self-sufficiency of the fishing activity in order to gain performance of the system as a whole. For instance, implementation of ecotourism, not so developed in the MPA, or similar activities could manage to cover all the needed investments. Fishing tourism represents a valid alternative for fishermen, which would lead, at certain levels, to a reduction in fishing effort but not in economic gain for those involved. In the reserve, there is a service of fishing tourism, which involves in particular one local boat, but it is not sufficiently valued and publicized so the demand and the use is very low. For tourism sector 1.79 value underline a more balanced condition, even if the indicator is higher than satisfying rate. It is interesting to compare the different results for the two categories of tourism investigated: ELR of tourist is 0.84 and ELR for divers is 1.76. The findings point out an appropriate ecological-economic balance for users of MPA activities and it shows a load that fit perfectly on the local environment. Moreover, this state could allow an improvement of services without affecting ecological capacity of the area. On the contrary, divers reflect an economic management that trades on local resources without a real support in terms of economic return for the MPA and they represent an environmental stress factor for the system. In fact, a service that causes a great load on the environment, may seriously affect long-term sustainability. On other hands, divers' activity should be reduced or restructured taking into account an incoming from these activities able to be invested, at local level, for the maintenance of the reserve. The Emergy sustainability index (ESI) recordered for the reserve highlights a low sustainability level of the system and it conforms a high use of non-renewable energy to large imports of purchased energy and materials.ESI for fishing sector is 0.38, for tourism is 0.77. The only difference, already observed for previous indices, is the contribution of tourists. ESI for divers is consistent with the other results, the same index calculated for tourists is indicative of a process that give net contributions to society and of developing economy. Once again, MPA services are configured as the most sustainable activities.The high values ofEnvironmental Investment Ratio (EIR) indicates large inputs from the outside; for entire MPA is 5.09, for fishing sector 3.43 and 1.96 for whole tourism. The category, tourists and divers have respectively values of 0.84 and 1.76. These results outline the same trend observed and described particularly for EYR and for other indices. From indices observation, it is clear that among the activities, the ones related to the managing body are more sustainable while those related to diving activities are challenging. It is interesting to cross these observations with the results obtained from the analysis of ecosystem services. As concerns the activities related to the managing body, the evaluation of the ecosystem services shows a good level of organization regarding tourist services (guided tours, visits with the glass-bottom boat, snorkeling, activities and projects with schools). These activities guarantee economic incomes that can be useful for the supply of MPA as well as for the maintenance of the activities themselves. However, compared to operating costs, these gains are not always sufficient to obtain a positive economic balance. The most lacking features have been found in external collaborations, such as those with fishermen (the most representative category among users), for example. Identity and culture of coastal communities are strictly linked to the survival of the marine environment. The closeness of the reserve core to the town has created a very strong link with the population, encouraging the emergence of professionals who are dependent on the natural environment, for example fishermen. The livelihood and economic balance of a large part of the residents turnaround the exploitation of natural resources. For this reason, the presence of a MPA that regulates the use of resources in the perspective of sustainable development is of fundamental importance. A policy based on integrating economic needs with strategies for the conservation of the natural environment is the best alternative to manage the reserve. A more precise description of the fruition and the problems connected to it is possible thanks to the analysis of the data deriving from the questionnaires, which contributed to the drafting of the table of ecosystem services. Despite the positive data on the impact of the activities of the managing body on the reserve, the analysis of the questionnaires reveals problems relating mainly to the relationship with users. Data about awareness of the users as knowledge of the MPA and its rules in carrying out specific activities are given below. Users are asked to express their degree of satisfaction within various aspects of the MPA. Their experience in the reserve is rated as positive by all categories with a total of 76%. In the evaluation of the services with different degrees of satisfaction, most of the respondents declared the services offered to be sufficient, few considered them to be good and a substantial portion was between insufficient or barely sufficient.The 91% of the interviewees state that they are aware to be in a MPA. Among these, 41% of the general users (all users except divers) reported that they were aware of it by referrals, while for divers the greatest incidence occurred by guidebooks with a percentage of 30%. Both categories show high percentages for internet and illustrative material, while the spread of information related to the visit centre of the MPA and diving centres are lacking. Most users claim to know the rules governing the use within the MPA. The only category that deviates from this result is that of bathers, of whom 66% say they are not aware of these rules. Similarly, bathers are the least likely category to go to the MPA visitor centre, with 88% of users who have never been there before. The other categories show the opposite trend. This trend can be easily explained by the need for divers and fishermen to go to the visitor centre for the renewal/issuance of permits to engage in activities and then it rereads a frequency more related to the need than to the personal will. This reflects the need to implement advertising at local level and for activities directly or indirectly related to the reserve. In order to improve these aspects, communication should be more effective, for example by updating the website. In particular, it would be appropriate to modify the latter by inserting the choice of the language of consultation to facilitate foreign users, implement the section on the activities offered with information such as hours and costs and finally add more photographic material. As far as direct contact with users, since the location of the office, which is not exactly central, it would be necessary to have a structure (including a mobile one) near an area that is easier for tourists to reach, such as the harbor. This structure should serve as an info point with distribution of paper material and promotion, point of collection for guided tours and point of sale of gadgets with the ultimate goal of recruiting as many users as possible and bring additional economic revenue. Divers have been identified as the users who generate the most impact on the reserve. In addition, in this case, better choices in the management of these activities and a greater collaboration with the managing body could bring benefits. On the one hand, more control would be needed with regard to the number of daily users of the service and it could be predicted, at least during the periods of greatest attendance, limitations in the number of trips and users transported per dive site. Interesting results emerge from the analysis of data on stay within the MPA. 65% of non-resident users (excluding divers) say a stay time ranging from 1 to 3 hours, only 6% say to stay for the whole day. Similarly, among the divers, 63% of them only dwell on the time necessary for diving and only 7% spend the whole day in the MPA. The trend highlighted by this analysis reflects a negative perspective for local businesses that, given the limited stay time of users, cannot increase their activity by offering their services to tourists.Information on the adequacy of the costs incurred in carrying out the activities is not significant as 79% of respondents preferred not to respond. However, 18% said the cost was adequate. With regard to the willingness to pay for an entrance ticket to the reserve, respondents are divided exactly in half: 49% yes, 50% no and 1% not specified. The trend, on the other hand, shows a greater incidence for the answer no (60%) when asked if you are willing to pay more than the costs already incurred.Even if users show they are not willing to pay a higher price for the activities, a possible solution to overcome the problem of excessive effort, derived from some activities (such as divers), is to increase their costs. This would make it possible to achieve "quality" tourism compared to "quantity" tourism: only those users who are genuinely motivated to visit the reserve would adapt to the new price and, by increasing prices, MPA would obtain the same revenue with a lower turnout and consequently less load on the environment. Economic value of the environmental flows, obtained by Emergy-to-money ratio (EMR) procedure has given the total emergy-euros value of renewable inputs(4.16E+05 em€/yr). The em€ value of rain chemical potential (2.84E+05 em€ y^{-1}) is the higher input to the system, followed by geothermal heat (1.23E+05 em€ y^{-1}). This was the first time that this kind of analysis was conducted in MPA, so there are no data with which to compare the values obtained. In this regard, it is interesting to highlight how further studies could be useful to better understand trends among years. Last step of emergy analysis is the assessment of outputs. Transformity value of each output has been calculated by the ratio between the total emergy contribution of all inputs in output's formation and the energy flux of the product. The lowest transformity value (7.26E-05 sej/J) has been recordered for primary producers (phyto-benthic biomass, *Posidonia oceanica*, and phytoplankton). Then, progressively increasing, primary consumers (zoo-benthic biomass and zooplankton) with an amount of 1.64E-04 sej/J and secondary consumers (fish) corresponding to 2.31E+06 sej/J.

The findings confirm the trend among the reserve the food web: autotrophs transfer their solar-derived energy to the heterotrophs. The heterotrophs' transformities are greater because of their low energy with respect to the solar energy that has been used for it. Organisms receiving feedback from other organisms further down the food chain are reinforced by a small energy flow of high quality, that is, more concentrated and therefore more capable of doing work. After the emergy analisys, Natural Capital and Energy flow of the reserve have been performed starting from the assessment of the trophic web. For this purpose, biocenoses of interest have been clustered into five groups to facilitate investigations: *Posidonia oceanica* meadow (HP), Biocenosis of infralittoral photophilic algae (RIPC), Semi-photophilic biocenosis of infralittoralrock in sheltered waters (RIHC), Precoralligenous biocenosis (PC), Coralligenous biocenosis (C) and benthic autotrophic and heterotrophic groups have been analysed in terms of biomass per unit surface.The results follow a predictable trend according to the biophysical and environmental conditions of these biocenoses. Biomasses highlight the net dominance of autotrophic organisms in photophilous environment (biocenosis of infralittoral photophilic algae and *Posidonia oceanica* meadow) that became less evident in the more sciaphilous one (semi-photophilic biocenosis of infralittoral rock in sheltered waters, precoralligenousbiocenosis and coralligenousbiocenosis) where animal component increases. This is due to the change of environmental conditions that make animal component more competitive on a trophic approach. Primary production and primary biomass required for the heterotrophic stocks' formation have been obtained from biomass values. Finally, the annual total primary production and the annual total primary production supporting the consumption of heterotrophs have been calculated to assess the capacity of the reserve to support its internal consumption. All the biocenoses considered appears to be in a deficit condition: this means that the primary production is not able to sustain the internal consumption and supporting areas are needed to satisfy the requirements. C and RIHC are the biocenoses that present the highest deficit respectively. PC, HP and RIPC followwithlowestvalues. As a consequence, a balance realized at MPA level shows a deficit condition (total amount of -8.83E+04 gC m^{-2}) that highlights the necessity for the reserve to import resources, in terms of primary production, from the outside. The results obtained are conceivable taking into account the small surface of the system examined. Despite the recorded deficit conditions, the presence of surrounding surplus areas allow the marine protected area to ensure its livelihood with a continuous supply of resources. The deficit condition suggest that should be considered a reshaping of MPA limits. Then the natural capital of MPA expressed in emergy and monetary units for each biocenosis has been calculated.The emergy supporting autotrophic component presents its higher values for photophilousbiocenosis RIPC while the higher values of emergy supporting heterotrophic component are recordered for RIPC (4.47E+16 sej). High values achieved for both autotrophic and heterotrophic components of RIPC may be related to the larger extension of the area compared to the others biocenoses. Although their small area, HP and C show high total emergy value that highlight the importance of the two biocenoses in ecological system of the MPA. The use of emergy density (total emergy concentrated per unit of area) indicator allows us to make comparison between biocenoses, despite their different extension in MPA. The highest levels of emergy density have been recordered for *Posidonia*meadow and Coralligenous, which share more than one order of magnitude of difference with the emergy values of RIPC, RIHC and PC, confirming the key role of these biocenoses in marine ecosystem functioning. They represent environments able to maintain high levels of biodiversity and a large amount of key species. Therefore, the two biocenoses should be involved in conservation policies where the main objectives is to preserve biodiversity. In this regard, it is interesting to evaluate the distribution, in terms of percent coverage, of the two biocenoses in the zones of the MPA with different degrees of protection. Both of them seem to follow almost the same trend: are mainly concentrated in the zone with the higher degree of protection (A zone), less in general reserve area (B zone) and finally the value increases slightly, compared to the latter, in the area of partial reserve (C zone). The statements confirm the efficacy of zonation in safeguarding biocenoses of particular interest with regard to the A zone, but highlight that the distribution of the two remaining zones should be attend. Indeed, C zone presents higher value of distribution for both biocenoses (Coralligenous and *P. oceanica*) compared to B zone in which the protective measures are more restrictive.The safeguard of these biocenoses could be improved by an enlargement or reshaping of B zone, and consequently C zone, in order to ensure them more severe protection. It agrees with the general idea to expandreserve surface and to assume as real MPA areas those adjacent areas of surplus. Coralligenous and *P. oceanica* meadows are not only “hotspots” of biodiversity, but they also represent socio-economic stakes. They produce goods and services for several sectors. Activities such as small-scale fishing and scuba diving highly depend on them. That is why, an integrate system of ecological protection and sustainable human activities is an important trade-off between human actions (job, food, tourism and economy) and good ecological status of environment. Marine goods and services does not have direct market value, for this reason, conventional economic evaluation could fail. On the contrary, a monetary evaluation of natural capital and environmental flows, converting biophysical value in monetary units, can ensure a good starting point. The (non-market) monetary value has been accounted for the five biocenosis. The highest monetary value per unit area is recordered for RIPC, about 41% of the total value of MPA. HP and C follow,respectivelywith 18% and 17% of the whole value. Finally, RIHC and PC show the lowest value corresponding to 16% and 8% of the overall monetary value. These results corroborate overall the high value of photophilous environment and for HP and C biocenoses, despite their extension in MPA. The same statement emerge on the observation of emergy percentage contribution and interesting remark can be achieved by the comparison of this parameter with percentage distribution of the five biocenoses. RIPC maintains the same trend with high value of coverage (28%) together with high level of emergy contribution (41%). On the contrary, the important emergy contribution of HP (18%) and C (17%) is not related to their extension, equal to 14% for both. Despite the great surface coverage of 23%, RIHC is similar to the smaller biocenoses (HP and C) in terms of emergy percentage contribution (16%). Finally, the lowest contributes is that of PC (8%)although the large area occupied (21%). The environmental flows present higher values for C with 8.47E+14 sej. Following, in descending order, RIHC (5.21E+14 sej), PC (4.73E+14 sej) and HP

(4.16E+14 sej). The lowest value is recordered for RIPC (3.26E+14). These results reflect the differences among the biocenoses considered in terms of autotrophic and heterotrophic biomass amount. The statement is evident comparing Natural Capital and Environmental flows assessment where HP and RIHC show high capital value but lowest environmental flows. On the contrary, C reveals high value for both natural capital and environmental flows. This is because of the dominance of primary producers in RIHC and PC (photophilous biocenoses) stocks rather than consumers. In fact, in a system the more heterotrophic components there are, the more resources are needed to maintain them. In particular, Coralligenousbiocenosis presents a great amount of heterotrophic biomass generated by primary producers. Moreover, it shows the highest value of deficit; resources for the primary production are also imported from other biocenoses of MPA. In addition, monetary values of environmental flows, expressed as em€ m^{-2}, show the highest rate for Coralligenousbiocenosis. The lowest values are recordered for photophilousbiocenosis: HP and RIPC. Among them, HP presents the high value (as for emergy flow) confirming its fundamental role as tanks of primary production supporting the whole food chain and regardless its extension on MPA. The high values recordered for Coralligenous biocenosis reflect the great costs sustained by biosphere, in terms of environmental flows, to generate and maintain the considerable structural complexity of the coralligenous bioconstruction: this biocenosis is considered as the second benthic ecosystem in the Mediterranean with regard to biodiversity. Despite limitations set out in the methodologies adopted, this analysis contributes to drawing a more precise picture of environmental and anthropogenic flows and their economic value in marine protected area "*Isole Ciclopi*".The environmental accounting, among the different technique of environmental analysis appears to be a complete procedure in integrate ecological and economic components with the main objective to preserve biodiversity. The development of a unique protocol adopted by all marine reserve (drawing a network) may due to a common environmental planning for the coastal zone that involves the development and implementation of new targeted conservation policies.

Appendix

Appendix A. Biocenotic map of MPA "Isole Ciclopi"



Appendix B. Main formula used for Natural inputs

Local Renewable Sources (R)

1. SOLAR RADIATION

Solar radiation = (*I*)(*A*)(absorbed percentage)

Handbook of Emergy evaluation (3) Brown M.T., Bardi E., p. 59

I = average solar radiation (W/m^2)

A = surface area (m^2)

Absorbed percentage = 70%*

Average Solar radiation of Catania 164Kwh/m2/y 1Kwh = 3600000 J 5.90E+08 $j/m^2/y$

Area 6.23E+06 m^2

Absorbed percentage 0.7

Source: INAF - Catania Astrophysical Observatory

Evaluation = 5.90E+08 $j/m^2/y$ x 6.23E+06 m^2 x 0.7 = 2.57299E+15 j/y

* Earth's average albedo is about 0.3, about 30 percent of incoming solar radiation is reflected back into space and 70 percent is absorbed.

2. RAIN

2.1 Rain, chemical potential energy = *A* x *p* x *d* x *ΔG*

Environmental accounting, H.T. Odum, 1996

A = surface area (m^2)

p = yearly precipitation (mm/y)

d = water density 1.00E+06 g/m^3

ΔG = Gibbs free energy

Area=	6.23E+06 m^2	
Yearly precipitation =	290.4 mm/y	0.2904 m/y
Water density =	1.00E+06 g/m^3	

ΔG (*Environmental Accounting*, H.T. Odum, p. 42) = 4.94 j/g

Source: INAF - Catania Astrophysical Observatory

Evaluation = 6.23E+06 m^2 x 0.2904 m/y x 1.00E+06 g/m^3 x 4.94 j/g = 8.93740848E+12 J/y

2.2 Rain, kinetic energy = *A* x *R* x *average elevation gradient* x *g*

Handbook of emergy evaluation (3) Brown M.T., Bardi E., p. 39

A = surface area (m^2)

R = rainfall

Elevation gradient

g = gravity

Area= 6.23E+06 m^2

Rainfall = 290.4 mm/y 0.2904 m/y

Elevation gradient 5.00E+00 m

Water density = 1000 Kg/m^3

Gravity = 9.8 m/s^2

Evaluation = 6.23E+06 m^2 x 0.2904 m/y x 5.00E+00 m x 1000 Kg/m^3 x 9.8 m/s^2 = 8.8650408E+10 Kg m^2/s^2 (J)

3. WIND

Wind, kinetic energy= ***r x c(vg)^3 A***

Handbook of emergy evaluation (3) Brown M.T., Bardi E., p. 39

r = air density Kg/m^3

c = drag coefficient

vg = geostrophic wind (10/6 ***v***)

v = average annual wind velocity m/s

A = surface area m^2

Air density = 1.3 Kg/m^3

Drag coefficient (Odum, 1996) = 1.00E-03

Average annual wind velocity = 2.42 m/s

Time = 4.84E+05 s/y

Area= 6.23E+06 m^2

Source: INAF - Catania Astrophysical Observatory

Evaluation = 1.3 Kg/m^3 x 1.00E-03 $(2.42\ m/s)^3$ x 4.84E+05 s/y x 6.23E+06 m^2 = 5.555496247E+10 J/y

4. GEOTHERMAL HEAT

Geothermal heat = A x (earth heat energy on area) x conversion factor

Emergy synthesis 5, Brown M. T. et al., p. 366

A = surface area m^2

Area= 6.23E+06 m^2

Earth heat energy on area = 0.05 W/m^2

Conversion factor = 3.15E+07 s/y

Source: Webgis National Geothermal Database - Institute of Geosciences and Earth Resources (IGG) of CNR

Evaluation = 6.23E+06 m^2 x 0.05 W/m^2 x 3.15E+07 s/yr = 9.81225E+12 J/yr

5. TIDE

Tide = (Area) x (average annual tidal height)^{2}x d x (1/2 x number of tides in a year) x g

Handbook of emergy evaluation (3) Brown M.T., Bardi E., p. 26

A = surface area m^2

Average annual tidal height

d = water density 1,00E+06 g/m^3

Number of tides in a year

g = gravity

Area = 6.23E+06 m^2

Average annual tidal height 9.37E-02 m

Water density = 1000 Kg/m^3

Number of tides in a year = 706**

Gravity = 9.8 m/s^2

Source: The National Tidegauge Network - ISPRA (http://www.mareografico.it)

Evaluation = 6.23E+06 m^2 x $(9.37E\text{-}02\ m)^2$ x 1000 Kg/m^3 x706 x 9.8 m/s^2 = 3.784408464E+11 J/y

**tides occur every 12 h 27 m (so twice a day), from this consideration we can deduce the number of events in a year.

5. RUNOFF and URBAN WASTE

Runoff, chemical potential =(Volume m^3/y)(4.82 J/g)(1E+06 g/m^3)

Handbook of Emergy Evaluation (Folio 1) Brandt-Williams, 2000.

Volume runoff (current study)= 5.16E+02 m^3/y

Evaluation = (5.16E+02 m^3/y)(4.82 J/g)(1E+06g/m^3)= 2.49E+09

Appendix C. Main formula used for Economic inputs

Imports Non-Renewable Resources (F)

6. FISHING BOATS (BOAT MATERIALS)

Boat materials =M x Transformity

Handbook of Emergy evaluation (3) Brown M.T., Bardi E., p. 11

M (g) **=** Amount of a specific material in all fishing boats of MPA

Fishing boats (whole)	
Materials	g
Wood	1.25E+08
Steel	3.00E+06
Fiberglass	1.50E+07
Metal	5.20E+06
Paint	1.20E+05

Fishing boats	
Fishing practice	**N° of boats**
Harpoon and gaff	5
Trammel nets, entangling nets and trotline	5
Mixed practice	11

Source: based on interview data

7. GOODS AND SERVICES (FISHING SECTOR)

7.1 Human labour(fishing) = (pers-hours)(2500 Kcal/day)(4186 Joule/Kcal)

Emergy Synthesis 5: Hunter A.R.C. et al., 2009.

MPA boats:

- N° 11 fishing boats of 10-12 metres each with 10 crew members (110 men)
- N° 10 fishing boats of 5-6 metres each with 5 crew members (50 men)

Men = 160

Source: based on interview data

Fishing activity (Assumed 12 month/y; 18 days/month; 8 hrs/day; 1 person)

Pers-work hours/y = 1728

Amount work-hours/y = 160 x 1728 = 276480 hours/y

2500Kcal/day = 2500/24 = 1.04E+02 Kcal/hours

Evaluation = 276480 hours/y x (1.04E+02 Kcal/hours) x (4186 J/Kcal) = 1.203639091E+011 J/y

7.2 Fuel (fishing sector) = Volume used (l)(Kcal/l)(J/Kcal)

Handbook of Emergy evaluation (3) Brown M.T., Bardi E., p. 45

Volume used 16800 l/y

Kcal/l 7956.7

J/Kcal 4186

Source: based on interview data

Evaluation = 16800 l/y x 7956.7 Kcal x 4186 J/Kcal = 5.595533362E+11 J/y

7.3 Capital costs (fishing sector) = Capital cost/life time

Handbook of Emergy evaluation (3) Brown M.T., Bardi E., p. 50

Capital cost (price of market of a new fishing boat)= 1200000 €

Life time (y)= 15

Source: based on interview data

Evaluation = 1200000 €/15 y = 8.00E+04 €/y

7.4 Taxinsurance(fishing sector)=T x Transformity

Handbook of Emergy evaluation (3) Brown M.T., Bardi E., p. 26

T = annual taxes paid for fishing boats = 3521 €/y

Source: MPA staff, personal communication

7.5 Maintenance costs (fishing sector)=Mc x Transformity

Handbook of Emergy evaluation (3) Brown M.T., Bardi E., p. 64

Mc = yearly maintenance costsfor fishing boats = 3460 €/y

Source: based on interview data

8. Marine Protected Area (MPA) BOATS (BOAT MATERIALS)

Boat materials =M x Transformity

Handbook of Emergy evaluation (3) Brown M.T., Bardi E., p. 11

M (g) **=** Amount of a specific material in all boats of MPA (boats used for technical activity and/or to recreational purpose by the staff of MPA)

MPA boats (whole)	
Materials	Amount (g)
Rubber	2.00E+05
Plastics, plexiglass	2.00E+05
Fiberglass	4.10E+06
Steel	1.51E+06
Metal	1.74E+06
Iron	5.00E+05
Wood	3.00E+05
Lead	1.00E+06
Paint	6.00E+03

Source: MPA staff, personal communication

Fishing boats	
Activity	**N° of boats**
Glass-bottom boat	1
Raft	1
Boat for the removal of marine litter	1
Traditional wooden boat "La Provvidenza"	1

9. GOODS AND SERVICES (MPA BOAT)

9.1 Fuel (annual energy) = Volume used(l)(Kcal/l)(J/Kcal)

Handbook of Emergy evaluation (3) Brown M.T., Bardi E., p. 45

Volume used 4100 €/y

Kcal/l 7956.7

J/Kcal 4186

Source: MPA staff, personal communication

Evaluation = 4100 €/y x 7956,7 Kcal/l x 4186 J/Kcal = 1.365576594E+11 J/yr

9.2 Capital costs (MPA boats) = Capital cost/life time

Handbook of Emergy evaluation (3) Brown M.T., Bardi E., p. 50

Capital cost (price of market of a new boat) = 340000 €

Life time (y) = 15

Source: MPA staff, personal communication

Evaluation = 340000 €/15 yr = 22666.66667€/yr

9.3 Maintenance costs (MPA boats) =Mc x Transformity

Handbook of Emergy evaluation (3) Brown M.T., Bardi E., p. 64

Mc = yearly maintenance costsfor boats = 8000 €/y

Source: MPA staff, personal communication

9.4 Taxinsurance(MPA boats)=T x Transformity

Handbook of Emergy evaluation (3) Brown M.T., Bardi E., p. 26

T = annual taxes paid for fishing boats = 612 €/y

Source: MPA staff, personal communication

9.5 Human labor (for boats maintenance)= (pers-hours)(2500 Kcal/day)(4186 Joule/cal)

Emergy Synthesis 5 Hunter A. R.C. et al., 2009.

Men = one only

Source: MPA staff, personal communication

Activity (Assumed 14 days/y; 6 hrs/day; 1 person)

Amount work-hours/y = 84 hours/y

2500Kcal/day = 2500/24 =1.04E+02 Kcal/hours

Evaluation = 84 hours/y x (1.04E+02 Kcal/hours) x (4186 J/Kcal) = 36568896 J/y

10. GOODS AND SERVICES (MPA)

10.1 Tourists (energy expenditure) = (People/y)(average stay)(Kcal/hr)(4186 J/Kcal)

Emergy Synthesis 5 Campbell E., 2009.

People/y =	2964
Average stay (hrs) =	3

Source: based on interview data

2500Kcal/day = 2500/24 =1,04E+02 Kcal/hours

Evaluation = 2964 people/y x 3 hrs x 1,04E+02 Kcal/hours x 4186 J/Kcal = 3,87E+09J/y

10.2 Human labor (staff at visitors' centre and touristic services)= (pers-hours)(2500 Kcal/day)(4186 Joule/cal)

Emergy Synthesis 5 Hunter A. R.C. et al., 2009.

Men = 5

Source: MPA staff, personal communication

MPA staff activity (including off work and sick leave) = assumed 12 months/year; 18 days/month; 1 person

Amount work-hours/prs/y = 1296 x 5 = 6480 hours/y

2500Kcal/day = 2500/24 =1,04E+02 Kcal/hours

Evaluation = 6480 hours/y x (1,04E+02 Kcal/hours) x (4186 J/Kcal) = 2821029120 J/y

10.3 Divers (energy expenditure) = (People/yr)(average stay)(average of dive/yr)(Kcal/hr)(4186 J/Kcal)

Emergy Synthesis 5 Campbell E., 2009.

Divers (people/y) =	675
Average stay(hrs) =	5
Average of dive/y	20

Source: based on interview data

2500Kcal/day = 2500/24 =1.04E+02 Kcal/hours

Evaluation = 675 people/y x 5 hrs x 20 dive/y x 1,04E+02 Kcal/hours x 4186 J/Kcal = 2.938572E+10 J/y

10.4 Human labor (Diving centre staff)= (pers-hours)(2500 Kcal/day)(4186 Joule/cal)

Emergy Synthesis 5 Hunter A. R.C. et al., 2009.

Diving of MPA = 2

Men/diving (average of men, considering permanent and seasonal staff) = 3

Source: based on interview data

Diving centre staff activity = assumed 9 months/year; from March to June assumed only Saturday and Sunday (8 days/month, 5 hrs/day, 1 person); from July to September 26 days/month, 5 hrs/day, 1 person;October and November assumed only Saturday and Sunday (8 days/month, 5 hrs/day, 1 person).

Amount work-hours/y = (120 hrs+590 hrs+80 hrs) x 3 = 2370 hours/y

2500Kcal/day = 2500/24 =1.04E+02 Kcal/hours

Evaluation = 2370 hours/y x (1.04E+02 Kcal/hours) x (4186 J/Kcal) = 1031765280 J/y

11. INFRASTRUCTURE (BUOYS)

Infrastructure materials =M x Transformity

Handbook of Emergy evaluation (3) M.T. Brown, E. Bardi, p. 11

M (g) **=** Amount of a specific material in all infrastructure of MPA (buoys)

MPA infrastructure	
Infrastructure features	**N° of units**
Elastic beacons and zone A buoy	5
Docking buoy	5
Signaling driftwood (diving point)	8

MPA buoys (whole)	
Materials	**g**
Plastic	8.81E+06
Iron	5.38E+04
Cement	1.20E+07

Source: MPA staff, personal communication

12. GOODS AND SERVICES (MPA INFRASTRUCTURES)

12.1 Human labour (for MPA infrastructures maintenance)= (pers-hours)(2500 Kcal/day)(4186 Joule/cal)

Emergy Synthesis 5 Hunter A. R.C. et al., 2009.

Men = one only

Source: MPA staff, personal communication

Activity (Assumed 17 days/y; 6 hrs/day; 1 person)

Amount work-hours/y = 102 hours/y

2500Kcal/day = 2500/24 =1.04E+02 Kcal/hours

Evaluation = 102 hours/y x (1.04E+02 Kcal/hours) x (4186 J/Kcal) = 44405088 J/y

12.2 Maintenance costs (MPA infrastrucutures) =Mc x Transformity

Handbook of Emergy evaluation (3) M.T. Brown, E. Bardi, p. 64

Mc = yearly maintenance costsfor boats = 5000 €/y

Source: MPA staff, personal communication

12.3 Capital costs (MPA infrastrucutures) = Capital cost/life time

Handbook of Emergy evaluation (3) M.T. Brown, E. Bardi, p. 50

Capital cost (price of market of a new boat) =	132565 €
Life time (y) =	10

Source: MPA staff, personal communication

Evaluation = 132565 €/10 y = 13256.5€/y

Appendix D. List of transformity and references

Items	Transformity	References
Solar radiation	1.00E+00 sej/J	[1]
Rain (chemical potential)	3.05E+04 sej/J	[1]
Rain (kinetic energy)	1.45E+05 sej/J	[1]
Wind	2.45E+03 sej/J	[1]
Geothermal heat	1.20E+04 sej/J	[2]
Tide	2.36E+04 sej/J	[3]
Runoff and Urban waste (chemical potential)	6.31E+04 sej/j	[4]
Wood	2.40E+09 sej/g	[5]
Steel*	6.97E+09 sej/g	[6]
Fiberglass*	7.87E+09 sej/g	[6]
Metal*	1.78E+09 sej/g	[7]
Paint*	2.55E+10 sej/g	[6]
Human labor (fishing sector)	4.45E+06 sej/J	[8]
Fuel	5.30E+04 sej/J	[9]
Capital cost	2.75E+12 sej/€	[4]
Tax	3.04E+12 sej/€	[10]
Maintenance costs*	1.40E+12 sej/€	[11]
Rubber*	7.22E+09 sej/g	[7]
	5.85E+09 sej/g	[6]

Plastic, plexiglass*		
Iron*	2.05E+09 sej/g	[6]
Human labor*	7.38E+06 sej/J	[13]
Tourists	1.50E+07 sej/J	[14]
Divers	1.50E+07 sej/J	[14]
Cement	1.97E+09 sej/J	[12]
Carbon	1.02E+08 sej/g	[15]
Nitrogen	7.40E+09 sej/g	[7]
Phosphorous	2.86E+10 sej/g	[7]

Odum H. T., 2000 Folio 1	[1]
Pulselli et al., 2009	[2]
Handbook of emergy evaluatio (3) M.T. Brown, E. Bardi, 2001	[3]
Brandt-Williams, 2000	[4]
Brown M.T., Buranakarn V., 2003	[5]
Buranakarn, 1998	[6]
Odum, H.T., 1996	[7]
Amy E Hunter et al., 2009	[8]
Vassallo P., Bastianoni S., Beiso I., Ridolfi R., Fabiano M., 2007	[9]
Russo G.F., Ascione M., Franzese P.P., 2004	[10]
Tiezzi et al.,2002	[11]
Brown, 2003	[12]
Ulgiati et al. 1994	[13]
Campbell E.,2009	[14]

Campbell et al.,2014 [15]

Appendix E. Phyto-benthic and zoo-benthic biomass

Phyto-benthic biomass							
Biocenosis	Dry weight (g)	Ash free Dry weight (g)	g/m2	Biocenosis extent (with percentage increase)	Whole biocenosis (g)	Joule	gC/m2
RIPC	405,26	213,97728	3,42E+03	4,20E+13	1,44E+17	2,41E+21	1,54E+03
HP	248	130,944	2,10E+03	2,03E+11	4,25E+14	7,11E+18	9,43E+02
RIHC	91,82	48,48096	7,76E+02	3,48E+13	2,70E+16	4,52E+20	3,49E+02
PC	52	27,456	4,39E+02	3,44E+12	1,51E+15	2,53E+19	1,98E+02
C	110	58,08	9,29E+02	2,17E+11	2,02E+14	3,38E+18	4,18E+02

Phyto-benthic biomass							
Biocenosis	Dry weight (g)	Ash free Dry weight (g)	g/m2	Biocenosis extent (with percentage increase)	Whole biocenosis (g)	Joule	gC/m^2
RIPC	405,26	213,97728	3,42E+03	4,20E+13	1,44E+17	2,41E+21	1,54E+03
HP	248	130,944	2,10E+03	2,03E+11	4,25E+14	7,11E+18	9,43E+02
RIHC	91,82	48,48096	7,76E+02	3,48E+13	2,70E+16	4,52E+20	3,49E+02
PC	52	27,456	4,39E+02	3,44E+12	1,51E+15	2,53E+19	1,98E+02
C	110	58,08	9,29E+02	2,17E+11	2,02E+14	3,38E+18	4,18E+02

* Ash free dry weight for zoo-benthic component has been thereafter calculated for each taxon

Appendix F. Benthic biomass value (gC/m2) for each biocenosis and taxon

Taxon	RIPC (gC/m2)	HP (gC/m2)	RIHC (gC/m2)	PC (gC/m2)	C (gC/m2)	B Tot	Trophic level (Tl)
Algae	1,54E+03		3,49E+02	1,98E+02	4,18E+02	2,506E+03	1
Posidonia		9,43E+02					1
Phytoplankton	1,47E-03	1,47E-03	1,47E-03	1,47E-03	1,47E-03		1
Mollusca	5,09E+01	5,63E+01	4,69E+01	1,33E+01	6,34E+01		2,1
Bryozoa	5,88E+00	2,33E+01	7,34E+00	4,87E+01	9,25E+01		2,16
Anellida	4,77E+01	6,63E+01	8,46E+01	9,87E+01	2,02E+02		2,05
Crustacea	1,11E+01	3,20E+01	2,57E+01	3,80E-01	2,54E+01		2,7
Sipunculida	1,77E+01	4,95E+01	2,31E+01	4,07E+00	9,35E+00		2,16
Echinodermata	1,42E+01	1,40E+01	1,23E+01	3,41E-02	2,56E+01		2,16
Porifera	1,80E+01	5,70E+01	5,36E+01	3,87E+00	6,78E+00		2,16
Fishes	4,50E-01	5,95E-01	3,37E-01	6,11E-01	7,45E-01		3,5

Appendix F.P/B and Q/B ratios

Functional group	Value	Sources and References
1. Phytoplankton (spp.)		
P/B	161.72	Primary production from via satellite data (http://emis.jrc.ec.europa.eu/#). Conversion factor from (Pauly et al., 1998)
2. Benthic macrophytes (spp.)		
P/B	1.08	Banaru et al. (2013)
3. Seagrass (*Posidonia oceanica* (blade and sheath))		
P/B	2.35	Pergent et al. (1997)
4. Microphytobenthos (spp.)		
P/B	4.2	Banaru et al. (2013)
5. Micro- and mesozooplankton (spp.)		
Q/B	120.82	Pinnegar (2000). Data corrected following Opitz (1996)
6. Macrozooplankton (*Meganyctiphanes norvegica*, euphausids, pteropods, fish larvae and eggs)		
Q/B	49.82	Baamstedt and Karlson (1998)
7. Gelatinous plankton (cubozoa, hydrozoa, scyphozoa, tunicata)		
Q/B	49.38	Malej (1989). Data corrected following Opitz (1996)
8. Worms (nematods and annelids)		
Q/B	20.15	From the empirical equation of Cammen (1979)
9. Suprabenthos (mysids, isopods, amphipods, cumaceans and copepods)		

Q/B	52.12	Cartes and Maynou (2001)
15. Bivalves-gastropods (spp.)		
Q/B	4.09	Banaru et al. (2013)

16. Benthic invertebrates (Echinoderms, cnidarians, sponges, etc.)

Q/B	2.75	Albouy et al. (2010) and (Hattab et al., 2013). Data corrected following Opitz (1996)

17. Demersal fishes small (continental shelf) (*Aphia minuta, Blennius ocellaris, Callionymus maculatus, C. risso, Carapus acus, Chelidonichthys cuculus, C. obscurus, Coris julis, Diplecogaster bimaculata, Diplodus spp., Gaidropsarus biscayensis, Gobius spp., Lepidotrigla cavillone, L. dieuzeidei, Lesueurigobius friesii, L. suerii, Ophidion barbatum, Pomatoschistus minutus, P. marmoratus, Serranus cabrilla, S. hepatus, Trachinus draco, Trigloporus lastoviza*)

B	0.07	Lleonart (2000) and Sardá (1990)
P/B	1.63	Z=F+M; M= empirical equation from Pauly (1980). L∞ and K from Campillo (1992), Tserpes (1996), Labropoulou et al. (1998) and www.fishbase.org

Q/B	7.6	From the empirical equation of Pauly et al. (1990). L∞ and W∞ from Merella et al. (1997), Morey et al. (2003) and www.fishbase.org

18. Demersal fishes large (continental shelf) (*Cepola macrophthalma, C. rubescens, Chelidonichthys lucerna, Dactylopterus volitans, Dentex dentex, Dicentrarchus labrax, Echelus myrus, Eutrigla gurnardus, Gnathophis mystax, Liza ramada, Ophichthus rufus, Ophisurus serpens, Pagellus spp., Pagrus pagrus, Peristedion cataphractum, Phycis blennoides, P. phycis, Sparus aurata, Spondyliosoma cantharus, Scorpaena spp., Syngnathus acus, Trigla spp., Umbrina canariensis, U. ronchus, Uranoscopus scaber, Zeus faber*)

Q/B	5.95	From the empirical equation of Pauly et al. (1990). L∞ and W∞ from Campillo (1992), Merella et al. (1997), Stergiou and Moutopoulos (2002) and www.fishbase.org

19. Bentopelagic fishes (*Anthias anthias, Argentina sphyraena, Capros aper, Gadella maraldi, Gadiculus argenteus, Glossanodon leioglossus, Eutelichthys leptochirus, Hoplostethus mediterraneus, Ichthyococcus ovatus, Macrorhamphosus scolopax, Spicara spp.*)

Q/B	8.58	From the empirical equation of Pauly et al. (1990). L∞ and W∞ from Stergiou and Politou (1995), Merella et al. (1997), Morey et al. (2003) and www.fishbase.org

20. Mesopelagic fishes (*Arctozenus risso, Argyropelecus hemigymnus, Benthosema glaciale, Boops boops, Centrolophus niger, Ceratoscopelus maderensis, Chauliodus sloani, Chlorophthalmus agassizi, Cyclothone braueri, Hygophum benoiti, H. hygomii, Lampanyctus spp., Lobianchia dofleini, Maurolicus muelleri, Melanostigma atlanticum, Myctophum punctatum, Notoscopelus elongatus, Stomias boa, Symbolophorus veranyi, Vinciguerria attenuata, V. poweriae*)

Q/B	7.13	From the empirical equation of Pauly et al. (1990). L∞ and W∞ from Merella et al. (1997), Haimovici and Canziani (2000), Morey et al. (2003) and www.fishbase.org

Appendix H. Natural Capital of autotrophs and heterotrophs for each biocenoses

Note		Item	Units (g, J, €)	Amount autotrophic	Amount heterotrophic	Reference	Emergy/Unit (sej/unit)	Solar Emergy autotrophic (sej)	Solar Emergy heterotrophic (sej)
RIPC									
NATURAL INPUTS									
Local Renewable Resources (R)									
	1	**Solar radiation**	J	2.61E+14	2.88E+14	[1]	1.00E+00	2.61E+14	2.88E+14
	2	**Rain**							
	a	Chemical potential	J	9.08E+11	1.00E+12	[1]	3.05E+04	2.77E+16	3.05E+16
	b	Kinetic energy	J	9.00E+09	9.92E+09	[1]	1.45E+05	1.31E+15	1.44E+15
	3	**Wind**	J	5.64E+09	6.21E+09	[1]	2.45E+03	1.38E+13	1.52E+13
	4	**Geothermal heat**	J	9.97E+11	1.10E+12	[2]	1.20E+04	1.20E+16	1.32E+16
	5	**Tide**	J	3.85E+10	4.24E+10	[3]	2.36E+04	9.08E+14	1.00E+15
	6	**Runoff**	J	2.53E+08	2.79E+08	[4]	6.31E+04	1.60E+13	1.76E+13
	7	**Carbon**	g	2.41E+03	2.65E+03	[15]	1.02E+08	2.46E+11	2.70E+11
	8	**Nitrogen**	g	4.11E+02	4.53E+02	[7]	7.40E+09	3.04E+12	3.35E+12
	9	**Phosphorous**	g	5.87E+01	6.47E+01	[7]	2.86E+10	1.68E+12	1.85E+12
TOTAL LOCAL RENEWABLE RESOURCES, R (2a,4,5,6,8)								**4.06E+16**	**4.47E+16**

Note	Item	Units (g, J, €)	Amount autotrophic (Unit/year)	Amount heterotrophic (Unit/year)	Reference	Emergy/Unit (sej/unit)	Solar Emergy autotrophic (sej/yr)	Solar Emergy heterotrophic (sej/yr)
HP								
NATURAL INPUTS								
Local Renewable Resources (R)								
1	**Solar radiation**	J	5.39E+13	1.90E+14	[1]	1.00E+00	5.39E+13	1.90E+14
2	**Rain**							
a	Chemical potential	J	1.87E+11	6.59E+11	[1]	3.05E+04	5.70E+15	2.01E+16
b	Kinetic energy	J	1.86E+09	6.53E+09	[1]	1.45E+05	2.70E+14	9.47E+14
3	**Wind**	J	1.16E+09	4.09E+09	[1]	2.45E+03	2.84E+12	1.00E+13
4	**Geothermal heat**	J	2.06E+11	7.24E+11	[2]	1.20E+04	2.47E+15	8.69E+15
5	**Tide**	J	7.93E+09	2.79E+10	[3]	2.36E+04	1.87E+14	6.59E+14
6	**Runoff**	J	5.22E+07	1.83E+08	[4]	6.31E+04	3.29E+12	1.16E+13
7	**Carbon**	g	6.23E+02	2.65E+03	[15]	1.02E+08	6.35E+10	2.70E+11
8	**Nitrogen**	g	1.06E+02	3.74E+02	[7]	7.40E+09	7.84E+11	2.77E+12
9	**Phosphorous**	g	1.51E+01	5.34E+02	[7]	2.86E+10	4.32E+11	1.53E+13
TOTAL LOCAL RENEWABLE RESOURCES, R (2a,4,5,6,8)							**8.37E+15**	**2.95E+16**

Note	Item	Units (g, J, €)	Amount autotrophic (Unit/year)	Amount heterotrophic (Unit/year)	Reference	Emergy/Unit (sej/unit)	Solar Emergy autotrophic (sej/yr)	Solar Emergy heterotrophic (sej/yr)
RIHC								
NATURAL INPUTS								
Local Renewable Resources (R)								
1	**Solar radiation**	J	2.42E+13	1.88E+14	[1]	1.00E+00	2.42E+13	1.88E+14
2	**Rain**							
a	Chemical potential	J	8.40E+10	6.54E+11	[1]	3.05E+04	2.56E+15	2.00E+16
b	Kinetic energy	J	8.33E+08	6.48E+09	[1]	1.45E+05	1.21E+14	9.40E+14
3	**Wind**	J	5.22E+08	4.06E+09	[1]	2.45E+03	1.28E+12	9.95E+12
4	**Geothermal heat**	J	9.22E+10	7.18E+11	[2]	1.20E+04	1.11E+15	8.62E+15
5	**Tide**	J	3.57E+09	2.77E+10	[3]	2.36E+04	8.42E+13	6.55E+14
6	**Runoff**	J	2.34E+07	1.82E+08	[4]	6.31E+04	1.48E+12	1.15E+13
7	**Carbon**	g	6.60E+01	5.13E+02	[15]	1.02E+08	6.73E+09	5.23E+10
8	**Nitrogen**	g	1.30E+01	8.77E+02	[7]	7.40E+09	9.62E+10	6.49E+12
9	**Phosphorous**	g	1.61E+00	1.25E+01	[7]	2.86E+10	4.60E+10	3.58E+11
TOTAL LOCAL RENEWABLE RESOURCES, R (2a,4,5,6,8)							**3.75E+15**	**2.92E+16**

Note	Item	Units (g, J, €)	Amount autotrophic (Unit/year)	Amount heterotrophic (Unit/year)	Reference	Emergy/Unit (sej/unit)	Solar Emergy autotrophic (sej/yr)	Solar Emergy heterotrophic (sej/yr)
PC								
NATURAL INPUTS								
Local Renewable Resources (R)								
1	**Solar radiation**	J	1.35E+13	1.03E+14	[1]	1.00E+00	1,35E+13	1,03E+14
2	**Rain**							
a	Chemical potential	J	4.69E+10	3.58E+11	[1]	3.05E+04	1.43E+15	1.09E+16
b	Kinetic energy	J	4.65E+08	3.55E+09	[1]	1.45E+05	6.74E+13	5.15E+14
3	**Wind**	J	2.92E+08	2.22E+09	[1]	2.45E+03	7.15E+11	5.44E+12
4	**Geothermal heat**	J	5.15E+10	3.94E+11	[2]	1.20E+04	6.18E+14	4.73E+15
5	**Tide**	J	1.99E+09	1.52E+10	[3]	2.36E+04	4.70E+13	3.58E+14
6	**Runoff**	J	1.31E+07	9.96E+07	[4]	6.31E+04	8.25E+11	6.29E+12
7	**Carbon**	g	2.33E+01	1.77E+02	[15]	1.02E+08	2.38E+09	1.81E+10
8	**Nitrogen**	g	4.51E+00	3.03E+01	[7]	7.40E+09	3.34E+10	2.24E+11
9	**Phosphorous**	g	2.59E+00	4.32E+00	[7]	2.86E+10	7.41E+10	1.24E+11
TOTAL LOCAL RENEWABLE RESOURCES, R (2a,4,5,6,8)							**2.10E+15**	**1.60E+16**

Note	Item	Units (g, J, €)	Amount autotrophic (Unit/year)	Amount heterotrophic (Unit/year)	Reference	Emergy/Unit (sej/unit)	Solar Emergy autotrophic (sej/yr)	Solar Emergy heterotrophic (sej/yr)
C								
NATURAL INPUTS								
Local Renewable Resources (R)								
1	**Solar radiation**	J	1.96E+13	1.95E+14	[1]	1.00E+00	1.96E+13	1.95E+14
2	**Rain**							
a	Chemical potential	J	6.80E+10	6.78E+11	[1]	3.05E+04	2.07E+15	2.07E+16
b	Kinetic energy	J	6.74E+08	6.73E+09	[1]	1.45E+05	9.77E+13	9.76E+14
3	**Wind**	J	4.22E+08	4.22E+09	[1]	2.45E+03	1.03E+12	1.03E+13
4	**Geothermal heat**	J	7.46E+10	7.45E+11	[2]	1.20E+04	8.95E+14	8.94E+15
5	**Tide**	J	2.88E+09	2.88E+10	[3]	2.36E+04	6.80E+13	6.80E+14
6	**Runoff**	J	1.89E+07	1.89E+08	[4]	6.31E+04	1.20E+12	1.19E+13
7	**Carbon**	g	1.06E+02	1.06E+03	[15]	1.02E+08	1.08E+10	1.08E+11
8	**Nitrogen**	g	1.81E+01	1.81E+02	[7]	7.40E+09	1.34E+11	1.34E+12
9	**Phosphorous**	g	2.59E+00	2.59E+01	[7]	2.86E+10	7.41E+10	7.41E+11
TOTAL LOCAL RENEWABLE RESOURCES, R (2a,4,5,6,8)							**3.04E+15**	**3.03E+16**

Appendix I. Questionnaires

<u>Dati generali</u>

Età ….

Sesso M ☐ F ☐

Nazionalità ….

Luogo di residenza ….

Titolo di studio ….

Posizione professionale ….

Tipologia di visitatore:

Assiduo (almeno una o più volte a settimana) ☐ Sporadico (Più volte in un mese) ☐

Occasionale (da poche ad una volta l'anno) ☐ Prima visita ☐

<u>Se non residente</u>

Tempo di permanenza nell'AMP

da 1 a tre ore ☐ intera giornata ☐ una settimana ☐ un mese ☐ altro ☐ (specificare)

<u>Consapevolezza</u>

E' a conoscenza di essere in una Area Marina Protetta? Si ☐ No ☐

Se si grazie a quale mezzo?

Materiale cartaceo illustrativo ☐ Centro visite ☐ Guide turistiche ☐
Mass media ☐ Internet ☐

E' a conoscenza delle norme che regolano le varie attività all'interno di questa AMP?

Si ☐ No ☐

Prima di accedere ai servizi si è recato al centro visite o ha avuto modo di interagire con il personale dell'AMP? Si ☐ No ☐

Secondo la sua opinione è veramente necessario imporre delle limitazioni nell'utilizzo di questo tratto di mare e di costa? Si ☐ No ☐

Secondo la sua opinione l'istituzione di questa AMP è stata utile al fine di tutelare gli aspetti naturalistici e paesaggistici? Si ☐ No ☐

Grado di soddisfazione

Come giudica la sua esperienza nell'AMP? Positiva ☐ Negativa ☐

Come valuta i servizi offerti dall'AMP? Insufficienti ☐ Appena sufficienti ☐ Sufficienti ☐ Buoni ☐ Ottimi ☐

Come giudica il lavoro svolto dall'ente gestore?(Rispetto delle regole, assistenza, informazione etc…) Positivo ☐ Negativo ☐

Utilizzo delle risorse/attività di fruizione

Ha avuto modo di usufruire di qualche servizio dell'AMP? Si ☐ No ☐

Quali delle seguenti attività ha praticato?

☐ Visita sul battello on il fondo trasparente

☐ Visita guidata Isola Lachea

☐ Attività di snorkeling con accompagnatore

☐ Attività di snorkeling senza accompagnatore

☐ Immersioni con accompagnamento di diving (Se si, specificare quante volte in un anno) ….

☐ Immersioni senza accompagnamento di diving (Se si, specificare quante volte in un anno) ….

☐ Pescaturismo

☐ Pesca da natante (Se si, specificare quante volte in un anno) ….

☐ Pesca da riva (Se si, specificare quante volte in un anno) ….

☐ Balneazione libera

☐ Balneazione presso Isola Lachea (Specificare se ha usufruito dei barcaioli) si no

☐ Balneazione presso strutture (lidi)

Secondo la sua opinione le norme e i divieti imposti sono sufficienti a tutelare le risorse? Si ☐ No ☐

Se venisse dimostrato che le attività praticate provocano danni all'ambiente marino sarebbe favorevole all'applicazione di vincoli più restrittivi? Si ☐ No ☐

Se bagnanti:

Quanti giorni l'anno nell'AMP? Assiduo (almeno una o più volte a settimana) ☐

Sporadico (Più volte in un mese) ☐ Occasionale (da poche ad una volta l'anno) ☐
Prima visita ☐

Preferisce le acque dell'AMP per la balneazione o le zone che non ricadono all'interno della riserva?

AMP ☐ Altro ☐

La presenza di bagnati in una zona di riserva può avere impatti sull'ambiente marino?

Si ☐ No ☐

Se si, di che genere? …

Possiede un'imbarcazione propria che utilizza all'interno dell'AMP? Si ☐ No☐

Se si:

Conosce le norme che regolano le attività dei diportisti nelle riserva? Si ☐ No ☐

Quanti giorni l'anno utilizza la sua imbarcazione entro i confini dell'AMP?

Assiduo (almeno una o più volte a settimana) ☐ Sporadico (Più volte in un mese) ☐

Occasionale (da poche ad una volta l'anno) ☐ Prima visita ☐

Come valuta la presenza dei campi boa? Positiva ☐ Negativa ☐

Secondo lei la loro presenza ha utilità per la tutela dell'ambiente marino? Si ☐ No☐

Come giudica numericamente i campi boa? Insufficienti ☐ Sufficienti ☐

Da incrementare ☐

Preferisce le acque dell'AMP per il diporto o le zone che non ricadono all'interno della riserva?

AMP☐ Altro ☐

Se subacquei:

Conosce le norme che regolano le attività dei subacquei nelle riserva? Si ☐ No ☐

Preferisce le acque dell'AMP per le immersioni o le zone che non ricadono all'interno della riserva?

AMP☐ Altro ☐

Quali attrezzature utilizza?(macchina fotografica, videocamera etc…) …

Secondo lei esistono specie a rischio estinzione nella riserva? Si ☐ No ☐

Secondo lei la presenza della riserva ha consentito un incremento di biodiversità?

Si ☐ No ☐

Se pratica pesca sportiva:

Conosce le norme che regolano le attività di pesca nelle riserva? Si ☐ No☐

Preferisce le acque dell'AMP per le attività di pesca o le zone che non ricadono all'interno della riserva?

AMP☐ Altro ☐

Che tipo di pesca pratica (specificare anche se riva o natante)? ...

Qualiattrezzatureutilizza? …

Le attrezzature utilizzate provengono: Attività locali ☐ Attività non locali ☐ Costruite dal fruitore ☐

Quali specie sono oggetto di cattura? …

Secondo lei, tra le specie oggetto di cattura, esistono specie a rischio estinzione nella riserva? Si ☐ No☐

Riscontra delle differenze tra la pesca entro i confini dell'AMP e all'esterno della riserva? Si ☐ No ☐

Secondo lei la presenza della riserva ha consentito un incremento di biodiversità?

Si ☐ No ☐

Preferisce consumare un pranzo: A sacco☐ Presso gli esercizi commerciali della zona☐

Disponibilità a pagare

Sarebbe disposto a pagare un biglietto per accedere all'area marina protetta?Si ☐ No ☐

Se si, quale importo reputa adeguato? …

Quali sono stati i costi sostenuti per raggiungere l'AMP? (Spostamento auto/treno/bus etc) …

Quali sono stati i costi sostenuti per praticare attività all'interno dell'AMP?(specificare attività) …

Secondo lei l'importo richiesto per le attività è adeguato?Si ☐ No ☐

Sarebbe disposto a pagare di più? Si ☐ No☐

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"Un tempo i Malavoglia erano stati numerosi come i sassi della strada vecchia di Trezza; ce n'erano persino ad Ognina, e ad Aci Castello, tutti buona e brava gente di mare, proprio all'opposto di quel che sembrava dal nomignolo, come dev'essere. Veramente nel libro della parrocchia, si chiamavano Toscano, ma questo non voleva dir nulla, poiché da che il mondo era mondo, all'Ognina, a Trezza e ad Aci Castello, li avevano sempre conosciuti per Malavoglia, di padre in figlio, che avevano sempre avuto delle barche sull'acqua, e delle tegole al sole."

I Malavoglia

Giovanni Verga