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An Eco-GAME Meta-Evaluation of Existing Methods for the Appreciation of Ecosystem Services

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Abstract: The isolation of science disciplines and the weak integration between science, policy and society represent main challenges for sustainable human development. If, on the one hand, the specialization of science has produced higher levels of knowledge, on the other hand, the whole picture of the complex interactions between systems has suffered. Economic and natural sciences are, on matters of sustainable development, strongly divergent, and the interface informing decision-making is weak. This downplays uncertainty and creates room for entrenched political positions, compromising evidence-based decision-making and putting the urgent need to achieve the Sustainable Development Goals (SDGs) of Agenda 2030 at risk. This article presents the heterodox Eco-GAME framework for interconnecting science through trans-disciplinary social-learning and meta-evaluation of scientific knowledge in pursuit of SDGs. The framework is tested and refined in the BONUS MARES project by systematic literature analysis, participatory workshops, and semi-structured interviews, in relation to the specific habitats of Baltic Sea mussel reefs, seagrass beds and macroalgae ecosystem services produced and methods applied. The results, acknowledging the urgency of interfacing science, policy and society, validate the Eco-GAME as a framework for this purpose and present a multi-dimensional system of indicators as a further development.

Keywords: quality evaluation of scientific information; science integration; evidence-based decision-making; sustainable development; ecosystem services; meta-evaluation

1. Introduction

Evans et al. argues that “environmental problems are everyone’s fault but nobody’s problem” by following the metaphor of Voltaire stating that: no snowflake in an avalanche ever feels responsible” [1] (p. 1). Sustainability issues involve social, human and environmental phenomena and are invariably caused by the intervention of human and social agents with the natural environment, and by the inability of human societies to get along with the natural laws. According to Lipschutz et al. [2] (p. 4), “rather than seeing environmental change as solely a biogeophysical phenomenon [...] we should also think of it as a social phenomenon.”

The dependence of humans on nature and the environmental assets it produces (e.g., clean water or nutrient cycling) is not something new. The same idea of assets produced has just been relabeled by emergent literature in order to gain attention. Mooney and Ehrlich [3] used first the term ‘environmental services’ [4] to identify, for instance, fisheries, insect pollination, pest control or climate regulation. On the basis of earlier literature focusing on the societal value of nature’s functions, the concept of ‘ecosystem services’ (ESS) was introduced in the late 1970s and 1980s [5,6]. The initial rationale was mainly pedagogic, and mostly adopted by natural scientists to demonstrate the importance of biodiversity for human well-being, thereby inducing and promoting nature conservation [7]. However,

later, Costanza et al. [8], when presenting in figures the monetary valuation of global natural capital, set a milestone that produced high impact in both science and policy making and, at the same time, both criticism and an increase of interest [7]. The term ‘ecosystem services’ became increasingly popular with the publication of the Millennium Ecosystem Assessment (MA), which proposed a conceptual framework that clearly linked ecosystem services to human well-being [9].

The same idea was, however, interpreted by different authors in different ways. Daily et al. [10] has defined ecosystem services as “the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life.” According to Daily et al. [10], these conditions are required to maintain biodiversity, which is core to the production of all goods humans produce and consume, and upon which the economy is built. Ecosystem services also include functions supporting life, such as recycling and renewal, as well as many intangible aesthetic and cultural benefits. These transform natural assets (free in nature) into things that people value.

The ecosystem service approach has, therefore, been used to attempt for valuing natural assets and, in this way, regulate their use. However, the different methods—economic and non-economic, monetary and non-monetary, deliver different results, also in relation to the purpose of their use.

This article tests the already published Eco-GAME framework [11] for the participatory meta-evaluation of methods used in the appreciation of Baltic Sea ecosystem services, related to mussel reefs, seagrass beds and macroalgae habitats. In particular, the Eco-GAME is applied to cover the existing methods that can describe and appreciate natural resources, ecosystems, functions, and services provided for meeting human needs, and especially referred to the realization of Agenda 2030 [12].

This article promotes the actual use of the Eco-GAME framework in real life and plans for further development for processes of decision-making, considering both use and non-use values, aiming at aligning the needs of present and future generations with the maintenance of natural resource stocks.

Literature on Agent-Based Modeling and Simulation (ABMS) refers to attempts to describing an overall phenomenon by mean of a model on simulation of actions and interactions of the multiagent system [13]. Even if, for this specific event, some similarities could be noticed, the overall idea of the Eco-GAME is to be applied in real life, among real actors in specific but real matters, as, for example, the cases proposed. The SimLab was used as a practical method to perform social learning among the participants (see Section 2), on the basis of the Eco-GAME structure. However, this is just an exercise of social learning that tests the framework within a research project. The aim of the Eco-GAME is to be used extensively, not for simulation but for assessing all existing and real scientific information. In fact, it has been first tested for a systematic literature analysis including all publications relevant for the specific purpose. Certainly, the outcomes of the Eco-GAME could be used as an input for developing an ABMS model.

This article is structured in seven sections. Following this introduction (Section 1), Section 2 describes the research methods applied to test and validate the Eco-GAME framework. Section 3 presents the challenge of sustainable development and the ecosystem-based approach by a historical perspective. Section 4 introduces the conceptual ideas of household management [10] and governance for sustainability [14]. In the light of the conceptual framework in Section 4, Section 5 introduces the Eco-GAME approach [11], based on the earlier GAME (Governance Assessment Matrix Exercise) [14,15] and on the Five Capitals Model of Sustainability proposed by the Forum for the Future [16]. Section 6 then presents the application and testing of the Eco-GAME meta-evaluation in pursuit of SDGs to the BONUS MARES (Multi-Method Assessment for Resilient Ecosystem Services and Human-Nature System Integration. BONUS MARES has been funded from BONUS (Art. 185), funded by the EU) project, in order to test a process of social learning about non-economic and economic methods for assessing knowledge related to the use of resources in the Baltic Sea. This accompanies a recent systematic literature analysis [17] and continues to consider the responses from interviews with researchers on the MARES project. It presents the participatory exercises performed for the project expert meeting held on 3 December 2019, and the workshop and Simulation Laboratory held on

12–14 February 2020. Finally, Section 7 draws conclusions about the use of the Eco-GAME and introduces future developments for the approach. These include a plan for integrating the Eco-GAME into the Sustainability Compass [11], to be implemented in the MAREA project (from MARine Ecosystem Accounting to integrated governance for sustainable planning of marine and coastal areas) which is already funded by the Interreg Central Baltic program.

All sections are complemented by the insights of the interviews with the participant experts, according to their specific relevance to the emerging arguments.

2. Research Methods

In order to avoid misunderstandings, it is important to distinguish the methods applied in this research for testing and validating the Eco-GAME framework, from the ecosystem services valuation methods object of investigation, which will be treated in the following sections.

This article, in order to test the Eco-GAME framework, is based on a mixed approach of analysis, which includes the following research methods:

- General outlook of relevant literature on sustainable development and evaluation (or valuation) of ecosystem services
- Application of the Eco-GAME to the systematic literature analysis performed during the BONUS MARES project and under process of publication [17] (see Section 6.1)
- Individual semi-structured interviews to BONUS MARES researchers for the interpretation of results of the systematic literature analysis (see Section 6.2)
- Individual semi-structured interviews to BONUS MARES participating experts (referred in the text)
- BONUS MARES expert meeting among economists and ecologists (3 December 2019) (see Section 6.3)
- BONUS MARES participatory workshop and Simulation Laboratory (13–14 February 2020) (see Section 6.4)

BONUS MARES has involved experienced experts, selected from the fields of social sciences, economics and ecology from different research institutions Europe-wide (see Annex I) in individual interviews and participatory events. Ensuring a good participation of experts not directly involved in the project is always challenging. Nevertheless, the level of motivation and participation has been excellent. This assured the coverage of the capitals considered for the Eco-GAME framework. The interviews to participant experts allowed triangulating their inputs with the consulted literature, the results of the participatory events and those of the systematic literature analysis. The experts have also suggested some scientific literature references.

3. The Challenge of Sustainable Development and the Appreciation of Natural Resources: A Historical Perspective

According to one expert interviewed, the rise of scientific rationality (especially 500 years ago) [18], which led to an increase of the level of education among the society at large, also led humans to lose their capability to live according to the natural world. In addition, the economic rationality, and nowadays, a strong belief in economic growth (since the last 200 years), killed the natural instinct to live according to natural laws. The same sources report how humans are, in fact, a very sensitive species, and originally, very vulnerable in nature. The development of human brain and intellect, and the adoption of different lifestyles and very successful intelligent engineering accompanied a progressive detachment from nature. Sadly, the more humans use rational intelligence, the less they listen to nature. However, a healthy future and prosperous society requires nature as the ultimate bottom line; forgetting that humans are part of nature is a risk.

In relation to the growth of rationality, the classical economic perspective does not take into account whether ecosystem services (ESS) are derived from an ecological system, since the focus is

merely on societal or consumer choice, and not on what the system optimally can deliver, which means meeting human needs while maintaining the ecological functions in present and future times. This is because people are, since millennia (starting 12,000 years ago) [18], more and more decoupled from what nature can deliver, and that both the importance of ‘human needs’, detached from more objective, basic and non-negotiable human needs, as well as the level of resources and services extracted from the natural environment, are determined through the political process, by means of decision-makers (since the last 200 years) [18].

As reported by an interviewed expert, an example of this are fisheries. Till 100 years ago, fishing was considered in the same way as hunting and gathering. About 100 years ago, policy and research organizations on fish and fisheries, such as the International Committee for the Exploration of the Sea (ICES) were established, with an emphasis on increasing the economic efficiency of fish catches by investing in more advanced and larger fishing techniques. Fishing did, however, remain largely unregulated. Until 20 years ago, this was done without taking the production capacity by ecosystems into account, fishing more than the Maximum Sustainable Yield, which led to overfishing of, e.g., herring and cod (fishing down the food chain) [19]. Although the EU and the ICES already provided advice on fishing quota, based on the carrying capacity of the ecosystem, it was only at the start of the 21st century that fisheries’ working groups for setting ecological principles were established. Thus, only after many years of top-down policies, a bottom-up and nature-inclusive approach was adopted, to generate models based on the carrying capacity of the ecosystem and the optimum yield.

Nevertheless, as with fisheries, other ecosystem services retain a strong top-down control based on economic principles. Regulatory policies are based on market prices, so that ecological elements that do not have a price (e.g., plankton) are not taken into account. A similar enigma exists for the Natural Capital Accounting (NCA) approaches, which make use of various monetary and non-monetary methods to calculate the total stocks and flows of natural resources and services in a given ecosystem or region.

The Ecosystem Service Approach: Monetary and Non-Monetary Methods

The ecosystem service (ESS) approach strived to communicate the importance and value of environmental assets, in order to better regulate the use of resources or to mitigate environmental impacts. However, the economic approach always refers to costs and benefits for humans and the society from an anthropocentric and short-term perspective [20], which is top-down. This means that it requires, for valuing ESS, to know beforehand, the purpose, and spatial (or administrative) relevance of decision-making, and the related societal and political aims. One difficulty with economic models has been the incorporation of externalities into economic accounts, often referring to environmental resources or impacts produced, and generating costs or benefits that affects a third party who did not choose to incur on them [21]. In other words, externalities are produced when the price/cost of production or consumption of a product or service cannot reflect the true costs or benefits generated for the society as a whole [22], failing to reach the Pareto optimality.

Some authors have considered ecosystem functions as separated from final services, and defined them as “the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly” [23,24]. Ecosystem functions have been also distinguished in different categories:

- Regulation functions, which is the capacity of ecosystems to regulate essential ecological processes for supporting life
- Habitat functions, which are the refuge and reproduction habitats to wild plants and animals contributing to biodiversity
- Production functions, such as photosynthesis and other kinds of energy conversion
- Information functions, which is an essential ‘reference function’, to remind humans they belong to nature, contributing to human health

According to interviewed experts, monetary methods are mostly based on the demand for goods and services (what humans would pay for it). This makes them the easiest methods to use, and therefore, the most frequently applied. However, the ease of use has a price because it oversimplifies the system and fails to represent all dimensions involved, eventually leading to the over-exploitation of the (eco)system. In fact, monetary methods consider the underlying ecosystem with producing them just as a source for their delivering, whose production capacity is not accounted, even when they would be on the verge of collapse. When goods and services would have become rarer, and therefore, more sought by consumers, they would even get higher monetary value and would become more expensive, due to supply and demand mechanisms.

Higher financial values of ecosystem goods and services would not guarantee their conservation, as market mechanisms may even lead to their complete depletion. This point was held by more than one participating expert interviewed. One of them made the example of tourism: A high-value sea location, based, for instance, on the high preference for clean water and wildlife, may increase its use for the tourist industry, and generate increment in pollutants. This would mean that the strong preference (and high value) is not effective for pursuing nature conservation.

Non-monetary methods can be used to counterbalance the gaps of monetary methods, as they can provide a measure for the natural capital and its carrying capacity for the delivery of goods and services. The use of multiple measures, reflecting the complexity of the system at hand, results in being more adequate for human-nature systems' integration, in which human society can enjoy the benefits of ecosystems without destroying them.

According to some interviewed experts, among non-monetary methods, ecology-based approaches need to carry out environmental monitoring programs for measuring the natural capital and its carrying capacity. This means that they are often more time-consuming and therefore, more costly and less commonly used. However, as the experts admit, these are more reliable than non-monetary sociology-based approaches, which are not only very complex and time-consuming (they need surveys and questionnaires), but also less reliable than the ecology-based because they attempt to measure often very subjective and abstract perceptions, such as, for instance, the beauty of a landscape that are very difficult to value. The uncertainty of this value results very high from many perspectives, as it may change according to a very great number of factors which are hardly determinable, such as, for instance, space, time, cultural background, societal influences, individual interests or even mood of the respondents [11].

As experts refer, assigning values to nature by preference-based approaches is difficult because people do not have often enough knowledge to recognize the value of nature, even when important for meeting human needs or societal aims. For example, as people normally do not like very much the smell of a swamp, preference-based methods will determine low monetary and social values. From a less subjective perspective and the knowledge coming from ecological science, this approach forgets to consider that the swamp, although smelly, may also provide fresh water, as well as deliver a function of nursery for fish. In this case, the monetary (financial/economic capital) or societal value (social capital) may not reflect these important functions. This example confirms the vision that valuation methods often contribute to contingent policies and decision-making regardless of the real and more objective importance of ecosystems and habitats. The more costly and time-consuming biological methods will highlight this being important for both human needs and societal aims (if fish and fresh water are policy objectives).

Considerable variability and inaccuracy in the outcomes of different valuation methods has been noticed in relevant literature [25]. This is also dependent upon the political purpose for which they are developed and makes the translation of physical knowledge into economic in a way that is generally verified through space, time and contingent choices/cultures challenging. Moreover, different methods would be required to value a single ecosystem service, yet the majority of studies use just a single method [25]. According to some views, the valuation of final services and benefits is not sufficient, as many ecosystem values are not included. When valuing ecosystem services, it would be important

to understand the environmental functions that are producing them, as well as the interactions between services produced [25].

According to Kosenius et al. [20], in economic valuation, ecosystems' values are given from an anthropocentric perspective. "Ecosystem services are material or immaterial benefits that produce well-being for the society—either in economic or non-economic terms" [16]. As the authors continue, the intrinsic value of nature, independent of humans, is not part of the economic analysis, as it contains ethical and philosophical insights.

The economic valuation is easy to be used because it expresses the value in one monetary measure [20]. For this reason, there has been some success of policy initiatives, especially regarding the effectiveness of the term 'ecosystem services' for communication purposes; however, some authors raise concerns on the negative effects of such commodification of nature. Peterson et al. [26] report about the possible risks of decoupling of ecosystem functions from the service, as many people may acknowledge the economic value of a given ecosystem service but, at the same time, not being aware about the human dependence on ecosystems. The extensive use of the ecosystem service concept also gives a perception of the ecosystem functions as exchange values that could be eventually sold out without considering all ethical and practical aspects [7]. As these valuations are anthropocentric and based on preferences of societal aims, they might easily miss not only environmental values, but also human aspects related to health, security, and well-being, for which a price cannot be given and which are not on the market (but on which ESS are built).

There is a gap between ecological and economic methods, which view ESS from different perspectives, the first from a biophysical perspective of systems' functioning, and the second from a societal perspective, represented by the purpose of decision-makers. According to La Notte et al. [27], because of the utilitarian nature of the concept of ecosystem services, research and policy tend to highlight the benefits for end-users rather than the importance of underpinning ecosystem functions. The authors continue that ecosystem services are not the benefits, they are, instead, the sources and material vehicles for enjoying these benefits, often expressed as biomass. On the other hand, ecosystem functions are ecological processes that have to be maintained in order to ensure a sustainable flow of service. Therefore, functions should be assessed by a more holistic and bio-centric approach [27]. Therefore, in order to adequately estimate the multifaceted aspects of ecosystem services and functions, biological, economic and societal approaches could be combined and integrated. In order to assure the continuous provision of vital ecosystem services and sustainable use of natural resources, more attention should also be given to long-term ecosystem integrity and resilience against human-driven (possibly disturbing) activities [28,29].

From a perspective of the use of valuation methods by decision-makers, according to two interviewed experts, the dependency of valuation on societal purposes is a common concern of natural scientists, when decision-makers use them with manipulative intentions, far from the scientific approach, and choose the 'best method' to serve an already desired result. As experts claim, even in the absence of malicious behavior, whenever decision-makers are content to find evidence that suits their own needs, they will not be inclined to search for more knowledge that may eventually jeopardize their ultimate objectives, although data would be uncertain, incorrect or not sufficient.

For this, a much stronger collaboration among economists and ecologists and a methodological approach to raise awareness about the importance of ecosystems and ESS produced is needed. This can propose integration and combinations of methods (and sciences) in order to represent all the contributing factors and reflect systems' complexity. In line with this conceptual idea, and on the basis of the literature above-described, ecosystem services can be defined as natural ecosystems' assets and processes—either economic or non-economic—that are direct or indirect sources of well-being and satisfaction of material or immaterial human needs for present and future generations.

In order to solve the dilemma of externalities, a view of household management, which is an optimal and efficient allocation of resources for meeting human needs, in consideration of resources

which are scarce, is required. In Jackson's words [30] this is the concept of bounded capabilities. This will be treated in more detail in the next section.

4. Background at the Roots of the Eco-GAME: Governance for Sustainable Development for the Baltic Sea

In relation to the challenge of sustainable development as presented above, this section proposes an approach of joint integrated governance between science, policy and society, by means of the repositioning of economics as 'household management' as hereafter described. This approach represents the conceptual background supporting the Eco-GAME framework.

The Baltic Sea is a highly complex and interconnected ecological system, characterized by high vulnerability and critical relevance for both humans and the environment. From a geo-political perspective, the sea knows no borders and many impacts are produced from cumulative effects, including cross-border, regional impacts. These impacts exceed the scope of action and responsibility of single administrative areas and involve a multiplicity of uncoordinated decision-makers, stakeholders and social structures. In fact, results of the recently ended Pan Baltic SCOPE project [31] clearly demonstrated that although different directives advocate the use of ecosystem-based management, there are few existing approaches for a joint practical application. The project shows how human activities, intensifying and diversifying the use of sea space, produce mostly negative impacts on the environment, which can be effectively alleviated only by using harmonized cross-border approaches at the pan Baltic scale.

In this light, decision-making is urgent for assuring the sustainable use of resources as well as for maintaining the regulating services needed for the survival of ecological systems, often earlier disregarded, in an especially critical and interconnected environment.

However, decision-makers at national level cannot promote their action beyond their own borders and cannot be accountable alone for the state of the Baltic Sea. Moreover, different countries rely on very different methodological basis for implementing their management and assessing environmental impacts. Therefore, it is truly challenging to compare different plans, as well as to calculate cumulative environmental impacts of joint human activities in the Baltic Sea. Indeed, the main obstacle is the poor understanding of the linkages between, and thereby, the governance of ecosystems, ecosystem functions and ecosystem services for human beings to enjoy. Therefore, a more harmonized maritime planning is needed to assess and govern regional cumulative impacts on various dimensions: natural, human, social and economic.

The Need for Governance for Sustainability and a Holonic Vision of Economics

As highlighted in the previous section, the monetary and non-monetary methods used for appreciating (eco)systems which are complex, often fail in representing their multi-dimensionality. This is particularly relevant also for the case of the Baltic sea. A harm produced in one region can easily propagate in complex, intricate, non-linear and unpredictable cascading effects onto other areas and even generate irreversible (ecosystem recovery is impossible) or unrecoverable (ecosystem recovery is possible but too costly for any institution) impacts, of which none is able to take responsibility [32]. The reference to complexity identifies a context that is "holistic (i.e., the whole cannot be understood by the mere accumulation of its parts), emergent (i.e., high level patterns derive from simpler rules at lower levels), and chaotic (i.e., non-linear behavior sensitive to initial conditions)" [33].

In complicated systems, even multiple and potentially 'right' solutions, the cause-effect relationships are mostly not known [34], however, we still remain in the domain of the 'unknown knowns' (we know that we do not know). Instead, a 'complex system' is composed of heterogeneous and interacting parts, systems or subsystems, operating at various levels [34]. Importantly, complex systems are characterized by 'unknown unknowns' that means we do not know that we do not know, a condition often being mistakenly interpreted among the domain of the known [35–37].

While scientific specialization has effectively supported an increasing understanding of very specific issues, it has also often led to the decoupling of systems and a failure to represent the whole picture of complex systems and the interactions between different, yet interconnected parts. This isolation between different scientific fields limits knowledge integration and may generate a lack of ‘hard’ scientific evidence as well as a higher uncertainty, leaving room for ‘softer’ political judgement [38].

The weak integration of economic and environmental sciences and their objectives into a holistic vision of sustainable development [39] reveals a need for improved and more adequate participatory governance for sustainability, through models that facilitate science integration and communication in support of evidence-based decision-making. According to complex systems thinking, governance for sustainability strives to understand the inter-relationships among identifiable parts (e.g., social, economic and ecological), rather than just the parts themselves [40]. A general principle of wisdom is the use of methods of analysis and systems’ representations that are adequate to reflect systems’ actual complexity and multifaceted nature [41,42] providing a “repertoire of responses which is (at least) as nuanced as the problems you face.” In other words, the evaluation models that are adopted should adequately reflect the multi-dimensionality at hand [43], because “every good regulator of a system must be a model of that system” [42].

As earlier research, conducted for the European Commission, argued, governance represents a form of management, which can reflect this complexity, and is defined as “a conceptual construct dealing with societal sensitive and complex issues that can be translated in a decision-oriented process, inclusive of all concerned private and public stakeholders. The outcome of the process is based on participative deliberation, the informing of options, and commitment to the implementation of the joint deliverances” [32] (p. 8). Governance supports strategic decision-making through the implementation of the principle of accountability and the “joint and integrated management of affairs that cannot be handled by single stakeholders because of their multi-impact effect and because of the complexity of relations between them” [32] (p. 8).

Effective governance would therefore generate social learning through flexible, self-learning adaptive structures that reflect systems’ complexity and related changes [44]. Complexity can be addressed by engaging processes [45] that support systemic and reflexive thinking, and adaptation to reflect changes. Bierman [46] advocates an “earth system governance [. . .] adaptive to changing circumstances, participatory through involving civil society at all levels, accountable and legitimate as part of new democratic governance beyond the nation state, and at the same time fair for all participants.” Sajeve [14] (p. 80) developed the same concept to identify a notion of governance for sustainability: “Governance for sustainability would identify a concept of joint and integrated social structure designed for the pursuit of a harmonic human sustainable development, involving the endurance of human systems (basic needs) within the boundaries of environmental systems (ecological functions), through human agency—i.e., joint deliberation about sustainability criteria and action that is adequate for their pursuit.”

This concept of governance for sustainability has referred to Sen’s capability approach [47] within environmental boundaries [30] (p. 35) represented by the availability of resources and posits a vision of economics that goes back to its root meaning of οἰκονομία (oikonomia), which describes a concept of “household management” [48,49]. This is the holistic and systemic understanding of human-nature interaction and integration striving for “the effective allocation of resources for meeting human (as householder) needs” [11].

The repositioning of economics as household management provides a theoretical support to address the current conflict between human (economic) development and ecological capital (or natural capital) and pursue their systemic integration. This is based on the idea of “carrying capacity” [50–52], which is the external limit within which human development can take place. The notion of ‘household management’ posits a way of thinking when interfacing natural and social sciences (see Figure 1) [11].

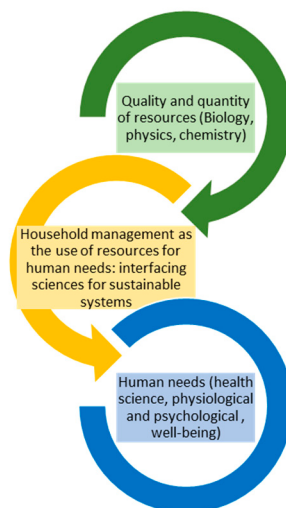


Figure 1. The role of economics for assuring natural and human systems' equilibrium [10].

The reference to an original interpretation of economics as household management incorporates whole systems thinking (e.g., Panarchy) [53] and more heterodox approaches to economics [54–56], and promotes a view of ‘holonic economics’, which refers to the systematic collection of evidence concerning coupled human-ecological systems. Household management focuses on both the general equilibrium of interacting systems and pursues human basic needs, by an approach, which is consistent with the availability of resources and other sustainability aims [11], such as, for instance, the Sustainable Development Goals (SDGs) of Agenda 2030.

A holonic vision of household management would increase understanding and the sharing of knowledge on the basis of emerging evidence aligned with Flyvbjerg’s phronetic research planning approach [57]. Phronesis, from the Greek language ‘φρόνησις’, is the knowledge and practical wisdom that can address choices under incomplete, dynamic and uncertain information, in contraposition with the Homo economicus models in which rational economic agents possess complete knowledge as the basis for efficient action.

As La Notte et al. [27] argue, assessing ecosystem services from a bio-centred or holistic approach, focus on biophysical structures and functions as a whole, whereas observations from a reductionist or human-centred approach just look at the short-term human end. In the exploratory interviews, one expert argued that this does not necessarily coincide with more objective long-term benefits and well-being (human capital) [16] but refers to the (subjective) purpose for decision-makers (social capital) [16], often referred to short-term objectives (the period in office). An interviewed expert argued the economics is about understanding the optimum scenario of needs met within the constraints (resources), in line with the vision of household management as earlier described. This optimization is normally embedded in market mechanisms; however, in the case of environmental resources, the mechanism is biased as these are not possible to be accounted by monetary methods (see the discussion in the next section). Preference-based methods, as they are anthropocentric, can be applied to evaluate values for people, and not life values (environment and human needs).

The idea of social learning refers to multi-disciplinary cognition and learning developed from the individual to the collective level and applied to interacting groups and organizations [58]. Social learning, resulting from the sharing of diversified knowledge among groups of individuals, reveals and integrates diversified and even contrasting viewpoints [59]. It builds shared and informed visions, as well as the understanding and acknowledgement of the diverging perspectives. Social learning supports the transformation of individuals into communities of practice, sharing common goals [60], with the aim to undertake collective action [61,62]. Fostering adaptive capacity social learning is a key element of success for dealing with socio-ecological complexity and high

uncertainty, which characterizes, for instance, natural resources management, water management and or environmental risk assessment [58].

In particular, social learning assumes strategic importance for understanding effective participatory management of complex socio-ecological systems [63]. It plays a major role in adaptive management [64], whenever the interactions within a group can affect individual knowledge and understanding or, vice versa, individual learning affects and informs collective knowledge and the related actions [65].

5. The Eco-GAME Meta-Evaluation and the Five Capitals Model of Sustainability of Methods in Pursuit of Agenda 2030

This approach of ‘holonic economics’ as described in the previous section, considers firstly non-negotiable boundaries and needs for systems’ functioning, for maintaining those conditions that are critical to the functioning of the biosphere and its subsystems [66] and attempts to mitigate the strong debate among different fields of science, as well as within each of them, to realize a more integrated approach that would reduce uncertainty of scientific knowledge and support evidence-based decision-making. As it will be discussed in the following sections, the question is how well economic (monetary and non-monetary) methods and non-economic evaluations are able to represent and deliver scientific knowledge to the society, for purposes of individual and collective decision-making.

In order to initiate a process of social learning and to implement an integrated sustainability evaluation, the earliest studies [14,15] underpinning the initial GAME (Governance Assessment Matrix Exercise) framework referred to the Five Capitals Model for sustainable development and aimed at identifying some main general criteria for systems’ sustainability [14,15,48,67]. In contraposition with the more traditional vision of compromise of the three pillars representing social, environmental and economic dimensions, the Five Capitals Model (Figure 2) represents the economy as embedded within a larger world ecological system [56]—the natural capital—and includes also human, social and manufactured capitals in an integrated framework that rejects compromises. Indeed, Porritt et al. [54] considers the Earth’s ecological system as the only (and probably only partially) closed system and the ultimate limit or real ‘bottom line’ for all growth, and therefore, the starting point for any further economic analysis.

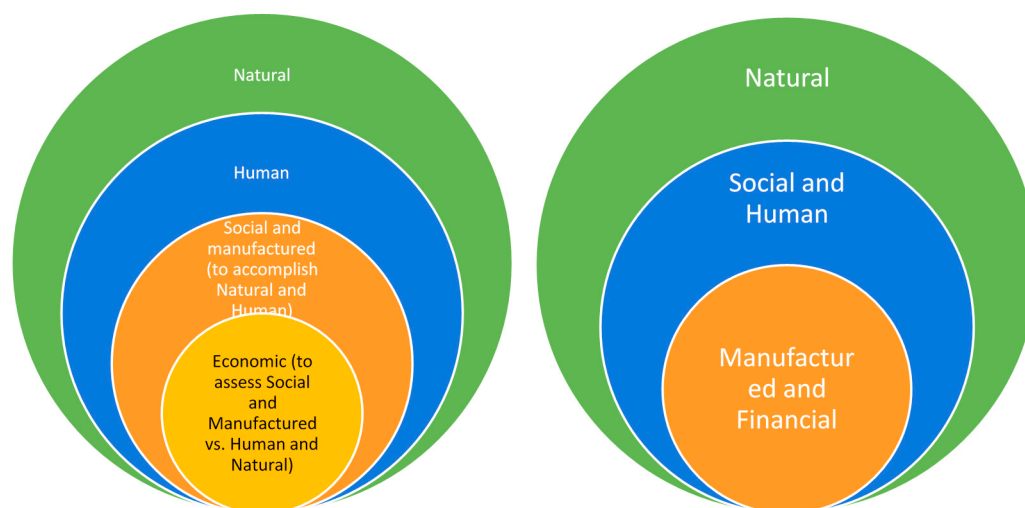


Figure 2. The development of the Five Capitals Model of Sustainability [16].

This also reflects the conception of the European Green Deal [68] and aims to make EU a fair and prosperous society based on a resource-efficient and competitive economy, decoupled from the use of resources and free from greenhouse gases, by 2050. As the European Commission continues, the Green Deal “aims to protect, conserve and enhance the EU’s natural capital, and protect the health and well-being of citizens from environment-related risks and impacts.” The aim of the Green Deal of

decoupling economic growth from the natural capital would mean that the financial capital would not be increased by decreasing the natural capital, and therefore, would be more able to represent it. This aim reflects the notion of financial capital promoted by the Five Capitals Model of Sustainability of the Forum for the Future [16]. The Green Deal [68] also promotes a just and inclusive transition, that would put people, local communities and workers first (the human capital), and pay attention to the regions, industries and workers who will face the greatest challenges. Active public participation is also considered very important for a joint governance at all administrative levels (social capital).

5.1. *The Development of the Eco-GAME Based on the Five Capitals Model of Sustainability*

The original scheme of the Forum for the Future [16] and its further elaboration at the basis of the Eco-GAME [11] (see Section 5.2) has been further developed as represented in Figure 2. The natural capital describes the full range of ecological and biological substratum, including biodiversity, resources and sink, i.e., the most significant system upon which everything else is dependent. Nested within the ecological system, there is the human capital, which pertains to human basic needs of health, security and well-being needs, human and civil rights, well-being, as well as knowledge and cognitive capabilities.

The social capital, which is composed by collective institutions, systems and networks, is a human-made system which is responsible for the accomplishment of human needs and the maintaining of the natural capital. The social capital, placed by the Five Capitals Model at the same level of the human, is moved below it (Figure 2). The reason for this resides in the acknowledgement of the primacy of basic needs. In fact, often societal aims pretend to interpret human aims, however, as claimed in Section 4 [11], individual or collective choices are very often not based on measured facts, but just on preferences and perceptions, which are unaware of the possible consequences.

However, the false belief to know may lead to forget the higher natural complexity of which humans probably can understand just very little. Often, populations need to believe in a politician or scientist that has all the wisdom, while this is very unlikely to happen and the knowledge about all interactions may remain just a hope. The illusion of certain knowledge can be a huge risk, as it reduces precaution, and harm becomes clear only when it is too late. For Aristotle, political and practical wisdom, *phronesis* or *prudence*, describe the common goal of politics to achieve happiness or well-being (*eudaimonia*) for society. This means, for the political man, acting according to reason (wisdom) and moral virtue, such as courage, temperance, justice, self-discipline, moderation, gentleness, modesty, humility, generosity, friendliness, truthfulness, humor and honesty. The lack of complete knowledge and the presence of high uncertainty is not a reason for interpreting knowledge according to each individual's desires or interests. It is, instead, a reason to act more carefully, according to practical wisdom (the right means) and moral virtue (the right mark).

A common translation of Plato's reporting about Socrates searching for the 'wise man' refers that "although I do not suppose that either of us knows anything really beautiful and good, I am better off than he is—for he knows nothing, and thinks that he knows. I neither know nor think that I know" [69]. Socrates searched for a wiser man than himself among politicians, poets, and craftsmen. Politicians claimed their own wisdom without having knowledge, whereas poets touched people's hearts by beautiful words without really knowing their meaning. Craftsmen owned great knowledge in very specific yet very narrow fields.

Indeed, the development of human intellect has successfully produced very specialized skills (the craftsman's ability) and generated more comfortable lifestyles. However, the reference to wisdom and the moral virtue of meeting primarily human basic needs limits and informs the 'political purpose'. Therefore, wisdom means, based on knowledge, being able to interconnect, listen to nature and to what we humans really need for our lives, regardless of societal or individual choices that would pretend to be perfectly rational, yet often driving away from the 'truth' we search for. Food security, health, security, education and human rights are first and, in turn, the conditions that allow these to be produced—clean air, sun, freedom, peace, absence of stress, and healthy food. The combination of wisdom and moral virtue involves that science informs the political man by the intellectual virtue of

the scientific evidence but cannot replace the moral virtue. However, the principles of moral virtue of the policy-maker prevent non-accounted and individual interest-driven choices from reverting the evidence of the common good. The earlier mentioned vision of economics as household management can provide for the intellectual virtue of wisdom that integrates ecosystems, the functions they produce, and the needs they contribute to meet.

The manufactured capital constitutes actually the physical infrastructure in support of human needs and social arrangements needed to meet them—those material assets supporting the production process—e.g., machines and buildings. Embedded in the society, economics represents a human-made system that regulates human relations. This is the financial capital, as the Forum for the Future describes it, referred to as currency, bonds and corporate stocks and shares. This latter does not have real value in itself but is a metric that represents natural, human, social or manufactured capital.

The level of uncertainty of financial capital in measuring the other capitals can be seen as the degree of detachment of anthropocentric evaluations and the real world [11]. As the authors hold, the greater the share of financial (economic) capital that represents manufactured and social capitals, the lower the level of well-being that it is able to capture in human and natural capitals, in terms of “bounded capabilities” [30], and a clear under-representation of the great part of the natural and human capitals. This is an example of a society in which infrastructure is very well-developed, with societal choices also accomplished; for instance, the aim to become a major producer in a strategic sector, or to have a main role in space activities or in scientific achievements; however, the majority of the population suffers of malnutrition or is unemployed and the natural environment is very much polluted or the biodiversity greatly reduced. In such a situation, the financial capital is high, however it does not reflect human well-being and resilient production from the natural capital.

5.2. The Eco-GAME Matrix for the Integrated Meta-Evaluation of Scientific Information

The developed idea of the Five Capitals Model of Sustainability has been employed for the construction of an updated framework for the meta-evaluation of metrics and indicators, and thereby, of the knowledge these generate. This is the Eco-GAME [11] (see Table 1), a framework that assigns attributes to metrics/indicators, to describe their technical ability to discover and deliver knowledge, and ultimately, to their capability to represent the Sustainable Development Goals (SDGs, see Figure 3) of Agenda 2030 [12], based on earlier experiences such as pedigree matrices for the assessment of quality of scientific information for policy [38,67].



Figure 3. The SDGs of Agenda 2030.

Table 1. Eco-GAME framework for the appraisal of metrics relevance for SDGs (slightly modified from [11]).

Eco-GAME Levels of Science Relevance for SDGs-Based Decision-Making		
Level of Knowledge Relevance		Example
Human-nature system integration: Analysis effectiveness for policy purposes according to SDGs	The analysis produces metrics to practically and effectively assess performances related to UN Sustainable Development Goals (SDGs)	The analysis can effectively provide metrics regarding local employment, gender equality, health, well-being or environmental health deriving from fisheries' activities, directly referred to SDGs
Dynamic multi-dimensional interaction	The analysis assesses systemic impacts of ecosystem services across economic, human, social and natural dimensions	The analysis can assess the revenue generated by fish markets and the improvements in population health, security or well-being (measurable impact)
Forecasting	The analysis forecasts future systemic impacts of ecosystem services	The analysis can forecast the state of health of the ecosystem in terms of fish population and/or the generated well-being (e.g., increased employment) in the long run
Dynamic uni-dimensional interaction	The analysis assesses interactions between parts of the ecosystem/service within one dimension	The analysis can assess the revenue generated in the fish market
Static quantitative	The analysis assesses quantitative aspects of ecosystem services	The analysis can tell us quantity of fish or give fish a value, for instance, through price
Static qualitative	The analysis provides qualitative assessment of ecosystem services	The analysis is suitable to discover the species of fish or provides uncountable valuations (high or low value)
Discovering knowledge	The analysis allows to discover knowledge	A method reveals the presence of fish
Not applicable	The methodology is unsuitable to the purpose	A method is not suitable for telling us whether there are fish or not in the sea

In fact, Agenda 2030 is a very representative framework in pursuit of human needs within environmental boundaries. It includes 17 SDGs and 169 targets, to be considered as indivisible. It is a “plan of action for people, planet and prosperity. It also seeks to strengthen universal peace in larger freedom [. . .] to realize the human rights of all and to achieve gender equality and the empowerment of all women and girls [. . .] and to free the human race from the tyranny of poverty and want and to heal and secure our planet [. . .] so that no one will be left behind” [12].

The Eco-GAME approach responds to the two aspects of multi-dimensionality and indivisibility, as it aggregates performances that refer to four dimensions: natural, human, social and economic, and rather than searching for a compromise, assesses each method's adequacy for purpose, or promotes a combination of different methods to reach SDGs. On the basis of the multifaceted nature of the Agenda 2030, the Eco-GAME meta-evaluation does not belong to any pre-established orthodox approach, such as the neo-classical economics or other specific school, but is based on the idea of trans-disciplinary science integration.

In fact, the whole conceptual framework takes advantage of a variety of scientific literature, such as post-normal science [38], and systems theory [41], governance and sustainable human development [16,47,68] and a heterodox approach to economics, which relies on the original conception of household management [11]. This premise helps understanding the use of the terminology in this article. Usually, the ecosystem service approach would use the term ‘valuation of ecosystem services’, for the reason that a value, often monetary, is attached to it. However, the Eco-GAME refers not only to more traditional economic valuation methods, but also to non-economic knowledge. The sharing of this integrated knowledge and emerging evidence promotes the practical wisdom that can address choices under incomplete, dynamic and uncertain information, in contraposition with the conception of Homo economicus where rational economic agents possess complete knowledge for efficient action.

The systemic understanding is, according to von Bertalanffy [70] “more than the sum of its parts.” Science integration assumes great importance in consideration of the irreducibility of integrated and complex systems [71] (p. 13), because, as Morgan states [72], in these systems “the behavior of the parts depends more on how the parts are connected rather than on the nature of the parts.” Experts report how the relations between the parts are the product of their intrinsic nature, not singularly considered but in relation with each other. This understanding requires both the expertise associated with disciplinary specialisms, and the ability of those specialist practitioners to work across disciplines (trans-disciplinarity) with the participation of policy and society.

The conceptual idea of the Eco-GAME is represented in Figure 4, where the capitals and the related aims and scientific fields that can be applied are further specified. The principles of The Natural Step [73] for a sustainable society can be applied as precautionary principles in presence of high uncertainty: “Nature is not subject to systematically increasing (1) concentrations of substances extracted from the earth’s crust, (2) concentrations of substances produced by society, or (3) degradation by physical means; and, in that society, (4) human needs are met worldwide.”

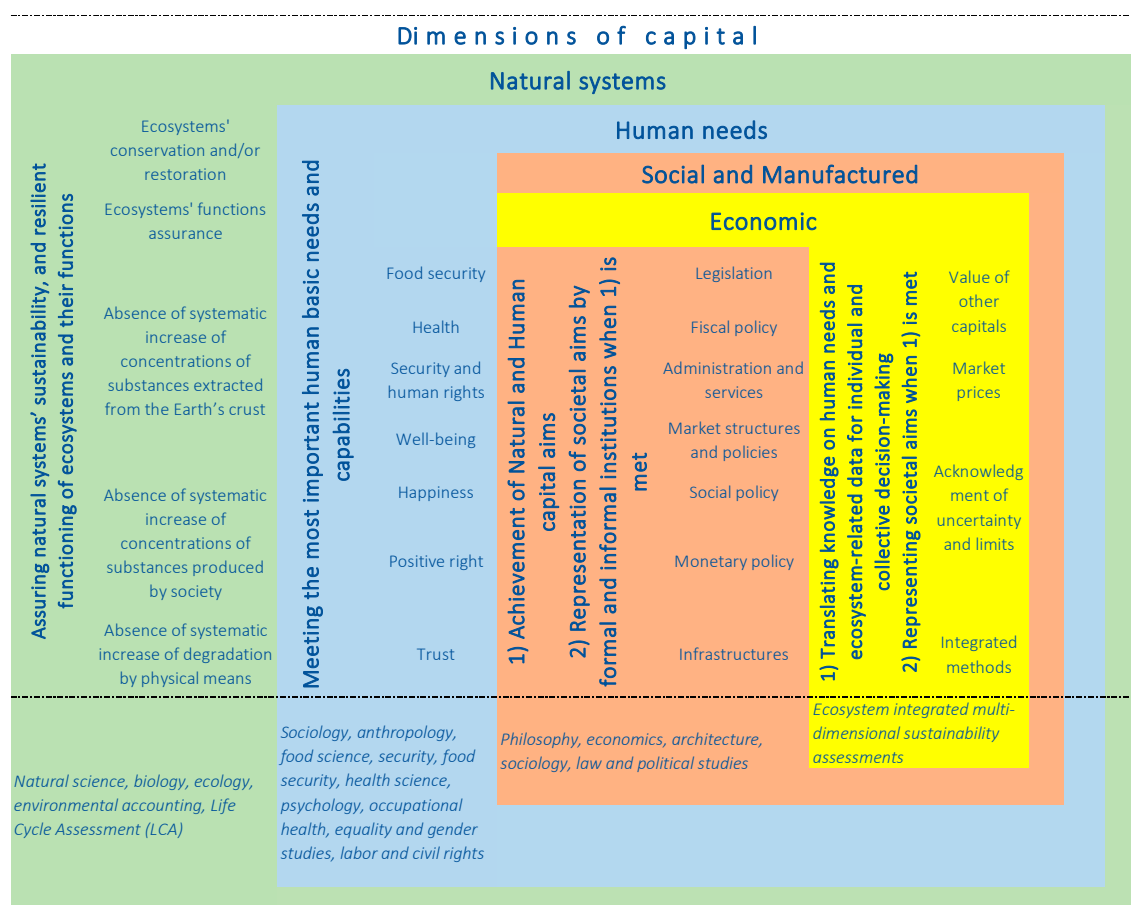


Figure 4. The development of the structure of the Five Capitals Model [14–16,48,67,73].

Moreover, the Eco-GAME supports choices of decision-makers as well as individual citizens in pursuit of SDGs or any other goal of social communities, for their well-being and sustainable development. This facilitates the agreement around the common good and the decrease of social conflict, which is a result of non-supported and subjective interests. The Eco-GAME forms an interface between science, policy and society, and thereby facilitates the processes of co-creation of knowledge for a more informed and evidence-based decision-making. It provides several functions for different actors of the society.

6. The Application of the Eco-GAME in the BONUS MARES Project and the Bottom-Up Approach

The Eco-GAME has been employed in the BONUS MARES project (Figure 5), (Multi-Method Assessment for Resilient Ecosystem Services and Human-Nature System Integration. <https://sisu.ut.ee/mares/> BONUS MARES has been funded from BONUS (Art. 185), funded by the EU), in order to “perform a meta-evaluation for the observation and monitoring of ecosystem services of the Baltic Sea region and an analysis of the strength of science-policy interaction. This expresses the capacity of existing methods to synthesise and transfer this knowledge from the research community to practice, for ensuring evidence-based decision-making” as mentioned in the project “Description of Work” (DoW).



Figure 5. The BONUS MARES (Multi-Method Assessment for Resilient Ecosystem Services and Human-Nature System Integration) project.

To pursue this objective, the Eco-GAME breaks the isolation between science communities and develops a more holistic and integrated approach for the integrated appreciation of the benefits which ecosystems provide to humans (ecosystem services). This means coming out from their own isolated laboratories, and cooperating and integrating their own results with other disciplines. For science funding, this means building scientific aims common to more disciplines, from different perspectives.

The Eco-GAME promotes an idea of governance for sustainability, through the holistic and systemic understanding of the interactions between nature and human beings. It is applied to all economic and non-economic ‘methods for appreciating ecosystem services’ and the knowledge these deliver in pursuit of integrated and indivisible SDGs, aiming to contribute to a better holistic understanding of marine ecological systems and their interactions and interdependencies with human systems. The integrated and multi-disciplinary approach aimed to assess how the selected habitats from a biological perspective produced ecosystem services.

As reported in Section 2, the Eco-GAME meta-evaluation was tested by means of a number of methods: It was first applied to a systematic literature analysis of existing knowledge on the benefits the Baltic Sea provides—the so-called ecosystem services—related to the specific habitats of mussel reefs, seagrass beds and macroalgae [17]. In a following phase, it was applied in two participatory events (an expert meeting held in Helsinki on 3 December 2019 and a participatory workshop and Simulation Laboratory held in Suomenlinna on 13–14 February 2020), described in detail in the next Sections 6.3 and 6.4, have highlighted this need to address scientific integration in pursuit of a holistic understanding. The greatest contributions came from the challenges that were put across by specialized sciences, and the building of a common integrated understanding, breaking the boundaries between different sciences. More specifically, the two participatory events have tested the Eco-GAME to appraise the qualitative characteristics of different methods and hypothesize possible combinations/integration of these to represent systems’ complexity and multi-dimensionality.

Table 2 describes the implementation of the Eco-GAME assessment through the scoring of the attributes. In order to increase the weight of higher performances, the Eco-GAME final performance is calculated by a function, Σx^2 , that increases the distance between higher scores.

Table 2. Legend of attributes for the different dimensions.

Eco-GAME Levels of Knowledge Relevance for SDGs-Based Decision-Making						
Level of Knowledge Relevance	Domain				Score	
	Natural Functions	Human Needs and Well-Being	Societal Aims	Economic Aspects	x_i	x_i^2
Human-nature system integration: effectiveness for SDGs	The analysis produces metrics that represents ecosystem functions related to SDGs	The analysis produces metrics that represents human well-being related to SDGs	The analysis produces metrics that represents societal aims related to SDGs	The analysis produces metrics that represents economic aims within SDGs	7	49
	☐	☐	☐	☐		
Dynamic multi-dimensional interaction	The analysis assesses systemic impacts of ecosystem services across economic, human, social and/or natural dimensions				6	36
	☐	☐	☐	☐		
Forecasting	The analysis forecasts future systemic impacts of ecosystems and their functions	The analysis forecasts future systemic impacts on human well-being	The analysis forecasts future systemic impacts on social aims and structures	The analysis forecasts future systemic economic impacts	5	25
	☐	☐	☐	☐		
Dynamic uni-dimensional interaction	The analysis assesses interactions within ecosystems and their functions	The analysis assesses interactions within aspects of human well-being	The analysis assesses social interactions, e.g., societal aims	The analysis assesses economic interactions	4	16
	☐	☐	☐	☐		
Static quantitative	The analysis produces quantitative assessments of ecosystems and their functions	The analysis produces quantitative assessment of human well-being	The analysis produces quantitative assessment of societal aims	The analysis produces economic quantitative assessments	3	9
	☐	☐	☐	☐		
Static qualitative	The analysis produces qualitative assessments of ecosystems and their functions	The analysis produces qualitative assessments of human needs and well-being	The analysis produces qualitative assessments of societal aims	The analysis produces economic qualitative assessments	2	4
	☐	☐	☐	☒		
Discovering knowledge	The analysis allows to discover knowledge concerning ecosystems and their functions	The analysis allows to discover knowledge concerning human well-being	The analysis allows to discover knowledge concerning societal aims	The analysis allows to discover economic relevant knowledge	1	1
	☐	☐	☐	☐		
Not applicable	The methodology is unsuitable to the purpose				0	0
	☐	☐	☐	☐		

For example, a given pair method-ESS achieves performances for the values 1, 2, 4 and 5. The meta-evaluation will be $\Sigma x^2 = 1 + 4 + 16 + 25 = 46$, and a related normalized performance calculated as $46/140 \times 100 = 32.8$, given that the maximum Eco-GAME value would be 140 ($1 + 4 + 9 + 16 + 25 + 36 + 49$).

The meta-evaluation is calculated as the sum of squared values related to the attributes obtained, singularly considered, when the score is verified by $V(x) = 1$ and not verified for $V(x) = 0$, as represented below:

$$Eco - GAME = eg = \sum_{x=0}^7 x^2 V(x) \quad (1)$$

6.1. The Systematic Literature Review and the BONUS MARES Bottom-Up Approach

The search string used for the systematic literature analysis has been designed to capture existing knowledge on habitats under study, i.e., mussel reefs, macroalgae and seagrass beds; ecosystem services generated by these habitats and the valuation methods used [17]. The application of the Eco-GAME framework to the systematic bottom-up literature analysis has revealed the existence of a good quantitative knowledge about the generation of ecosystem services related to the chosen habitats and ecosystems.

On the contrary, the same selected literature considered in the systematic literature analysis contained little insight about how this service translates into socio-economic benefits, how it affects human well-being and how it could be managed sustainably. This means that, while the knowledge of these single parts, individually considered, resulted into massive evidence, there is quite limited knowledge that looks at the whole, and incorporates all component parts of the system, habitat, ecosystem functions, final services and their valuation. The search found only seven ecosystem service valuation articles on food production (excluding food for organisms) and highlighted that this was due to the inclusion criteria, which required that at least one of the chosen habitats had to be included in the search string used for the literature review.

Indeed, the systematic literature analysis demonstrated a lack of integration among ecological and economic sciences (see Figure 6). This was confirmed by two of the interviewed researchers: The bottom-up literature analysis and the related search string was designed with the specific purpose to identify integrated knowledge that linked the selected habitats to the ecosystem services provided and to their final valuation. In spite of the high quantitative knowledge about habitats and the ecosystem services these provide, almost no insight existed about how socio-economic benefits were valued. This does not mean that knowledge on the economic valuation of the Baltic Sea ecosystem services is absent, but that it is not linked to habitats and ecosystem functions. While economic specialized knowledge about methods for valuating these benefits exists for specific human purposes, the Eco-GAME demonstrated that these values are not linked to the natural capital that produced them. This may cause natural capital (often a complex interaction of different ecosystems) to become quickly depleted (and the benefits lost), because it is not appreciated as being the source that produces the benefits.

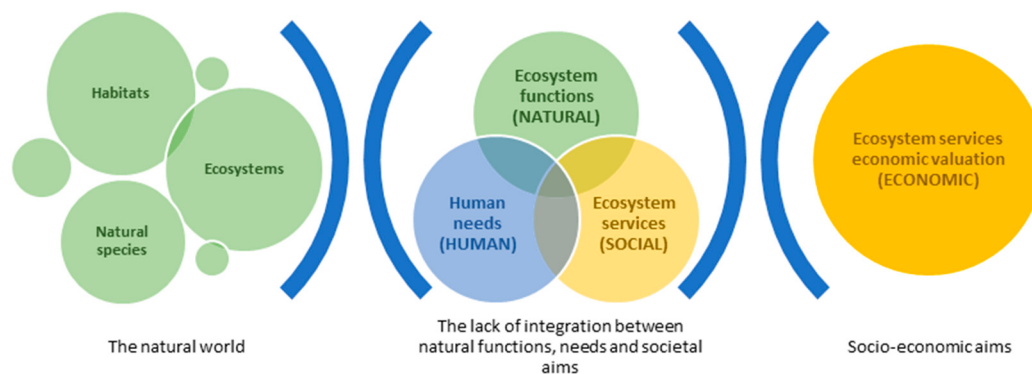


Figure 6. The lack of science and policy integration.

This outcome was corroborated during the discussion in both participatory exercises (expert meeting and SimLab), in which the reason for this was made explicit. The isolated approach

by different sciences is not a simple lack of communication or willingness to cooperate, but depends upon deeper cultural, scientific and philosophical perspectives. While the focus of ecological research is on ecosystems and related processes and is bottom-up, the studies on economic valuation methods focus especially on societal and political choices and purposes, thereby limiting their scope to the final ecosystem services produced. The economic valuation of ecosystem service focuses on services at an aggregated level and does not typically account for the ecosystem(s) producing the service.

Many economists, in both BONUS MARES participatory events, claimed the project should use an ESS classification system that is in line with already established classifications. Certainly, different sciences should attempt for approaching to one another: In fact, the “Supporting” and “Regulating” notions, closer to already existing classifications replaced the earlier terminology of “Regulation and maintenance” [17] (see Table 3). However, as a general consideration, the heterodox bottom-up approach, starting from the habitats and ecosystem services they produce, and aiming to inform society about the existing interrelations, not always can follow the very specialized concepts of the established science. The aim of science integration can be hardly accomplished without breaking, at times, specialist science’s orthodoxy.

Table 3. Expert meeting first phase results: Ecosystem services for mussel beds and specification of natural (N), human (H), social (S) and economic (E) dimensions.

	Ecosystem Service	Type of Service
1	Benthic pelagic coupling and shifting in primary production	Provisioning, Supporting and Regulating (N)
2	Disservices for industrial assets	Provisioning (E, S)
3	Use as fertilizer (terrestrial)	Provisioning, Supporting and Regulating (E, H, S)
4	Seeding mussel farming	Provisioning (E, H, S)
6	Fish spawning grounds	Supporting and Regulating (N, E)
7	Biodiversity conservation	Supporting and Regulating (N, S)
8	Stops over for birds’ migration	Cultural, Regulation and Maintenance (N, H)
9	Attractive fishing grounds	Provisioning, Cultural (E, S, H)
10	Keystone species for conservation of the whole system	Supporting and Regulating (N)
11	Genetic diversity	Supporting and Regulating (N)
12	Feeding habitat for fish and birds	Provisioning, Regulation and Maintenance (E, S)
13	Food for birds	Provisioning (S)
14	Research	Cultural (H)
15	Recreational, diving, cultural, ecotourism, underwater landscape and scenery	Cultural (S)
16	Natural heritage	Supporting and Regulating, Cultural (N, S)
17	Animals for economic use	Provisioning (E, S)
18	Food for humans	Provisioning (E, H, S)

The Eco-GAME (and BONUS MARES) was based on a bottom-up approach, not to be ‘on the side of ecologists’, but because the project was planned around three selected habitats in the Baltic Sea (mussel reefs, seagrass beds and macroalgae). These were considered as important for the coastal systems of the Baltic as natural filters between the Baltic Sea and its watershed, which are threatened by multiple pressures, putting at risk the future provision of ecosystem goods and services, as well as other key ecosystem functions. Science integration and communication to decision-makers about important ecological functions that support human needs, and the possible economic optimization in their use, requires implicitly linking habitats and the related ecosystem functions to human needs. This is why consideration of the whole chain from habitats to ESS and human benefits is necessary. Therefore, the meta-evaluation of economic and non-economic methods (and of their combinations) aims at assessing their capability to capture and transfer knowledge about different natural, human, social and economic dimensions.

This communication gap between different sciences could be approached, as a proposal, by including knowledge about the importance of ecosystems and human needs for the sake of sustainability into decision-making models. This can be represented by weights, taking factors relating to a systems' resilience into due account, regardless of societal preferences. These latter factors are not always able to meet human needs, especially in more developed societies, when knowledge about human well-being is lacking (even unknown unknowns) and the precautionary principle is not adequately applied.

6.2. The Interpretation of the Systematic Literature Analysis

To complement the results of the systematic review and provide an in-depth interpretation of its key findings, the six researchers responsible for the systematic literature analysis were interviewed. The interviews followed a semi-structured format, where predetermined, open-ended questions were asked in a flexible manner, allowing for a discussion. The main discussion points covered the following areas: (i) key results from the Eco-GAME meta-evaluation, (ii) the methods used in the reviewed literature and integration of different methods, (iii) current status of science-policy interaction and (iv) feedback for Eco-GAME framework.

All the interviewed researchers thought that the key finding of the systematic literature review was the main knowledge gap between the value dimensions. There is a fairly good ecological understanding on the selected, specific habitats and related services, and the use of different species, e.g., as bioindicators of pollution. On the contrary, the literature extracted by the search string contained very little research done on the economic, social or human values these ecosystems and the identified services bring to human beings. One of the interviewed researchers pointed out that although the economic considerations of specific ecosystems and the services they provide have been rarely studied so far, this is likely to change in the coming years. Nowadays, more research is concentrating, for example, on bladderwrack and other macroalgae, from which different commercial products such as cosmetics can be derived. In addition, the Maritime Spatial Planning (MSP) process was identified as an example of the recent development, which increasingly puts emphasis on the human and social benefits that ecosystems produce. MSP puts the environment in the central role; thus, all actions along different dimensions should be integrated together with the impacts produced on nature.

Most researchers performing the systematic literature analysis recognized the need of integration of different methods and sciences, in order to link the knowledge on species and habitats to the valuation of the economic, human and social benefits they provide. One interviewee commented that economic valuation using ecosystem attributes or nature-based values, instead of monetary ones, would be more appropriate. None of the articles included in the systematic literature review reached the highest level of being able to support the achievement of UN Sustainable Development Goals. As two of the interviewed researchers pointed out, peer-reviewed scientific literature, which was analyzed in this study, is not typically targeted at policy-makers; instead, grey literature is more commonly used. Therefore, for the purpose of studying science-policy interactions, it would be advisable to extend the analysis to these other forms of literature. In summary, the interviews revealed that bringing scientific knowledge to the decision-makers requires active and continuous dialogue, which is nowadays more and more common among researchers.

6.3. The Expert Meeting (3 December 2019)

The results of the earlier activities have been presented for further analysis on occasion of the first expert meeting, held on 3 December 2019 and composed mainly by expert economists and ecologists sitting on the two sides of a long table.

The meeting aimed to realise a multi-disciplinary and focused approach to match ecosystem service types with monetary and non-monetary valuation methods, and a discussion on how they can be used together to advance the level of knowledge on the benefits that ecosystem services provide in the Baltic Sea region. The expert meeting (results in Table 4, participants in Appendix A) was

composed of two phases. A first phase aimed to synthetically map ecosystem services (ESS) that a given habitat in the Baltic Sea can provide and the interactions between them, on the basis of the results of the systematic literature review already performed.

As a result of the first phase of discussion for selected ecosystem services, specific ESS associated to mussel beds are taken as an example to go forward with the second phase about the appropriate valuation method(s) by the Eco-GAME framework with regard to natural (N), human (H), social (S) and economic (E) dimensions. Recreational aspects and the production of food for fish (production of nutrition sources for feeding fish), for which data is available at local/regional/national/sub-national level, were chosen.

6.3.1. The First Phase: Non-Economic Valuation

In the first phase, the initial systematic literature review and the attached Eco-GAME meta-evaluation was presented describing existing knowledge and the linkages within and between ecological and socio-economic systems on how ecological processes translate into ecosystems' services and how these can be valued to represent all dimensions involved. On the basis of suggested inputs about existing blind spots and possible responses (Table 5), a discussion was initiated among economists and ecologists.

Taking mussel beds as an initial example for the participatory exercise, experts were asked to suggest additional inputs about ecosystem services not considered in the literature analysis, and to indicate the level of knowledge on the proposed ESS according to the Eco-GAME matrix (Table 3) and the dimensions concerned (natural, human, social, economic).

6.3.2. The Second Phase: Economic Valuation

As revealed in the participatory event, experts had varying views on whether the valuation of ecosystem services should include (also) ecosystems. While ecologists highlight the importance of linking ecology (habitats/ecosystems) and economic valuations, for economists measuring the value of habitats singularly considered, it is not relevant (not necessary) for their own field of studies.

Economists challenged the need of valuing nature, arguing that the purpose of the valuation process is to make the ecosystem services more visible in the bigger picture, so that their value is better acknowledged in decision-making (social capital). Even when the share of value related to the contribution of a specific habitat (e.g., mussel bed) onto a specific service (e.g., water clarity) would be taken into account, it would be, in any case, difficult to calculate. Economists considered it not really possible, nor relevant for their purposes, to just value specific habitats or ecosystem functions, as they mainly focused on the final services delivered for specific purposes and specific services. The focus is on human choices and decision-making purpose in relation to final services, and in order to meet the societal aims of decision-makers (social capital). This means that the purpose of the valuation determines the valuation process and the selection of the method(s). Indeed, the literature on ecosystem services' valuation methods refers just to final ecosystem services, not to whole habitats, nor to the interactions within and between them. This is one reason why while performing the earlier systematic literature analysis, the targeted habitats are so poorly represented in the economic studies and the link with ecosystem services is missing.

Intermediate services and ecosystem functions are not relevant for economic valuation and thereby, these elements are left unassessed, considering both intermediate and final services would not be consistent in economics. This means that in the absence of a societal aim that gives value to a given ESS, environmental resources will not be assessed even indirectly, thereby limiting their scope in the mitigation of environmental impacts.

Table 4. The Eco-GAME results of the expert meeting (3 December 2019).

Eco-GAME Levels of Science Relevance for SDGs in Support of Decision-Making														Recreation	Food for Fish	
Level of Knowledge Relevance		Example	Score Xi	xi ²	Travel-C Method	Contingent Behavior	Statistics on Indirectly Linked Sectors	Habitats + Flander	Fuzzy Cognitive Modeling	NMV Studies on Importance	Stated Preference	Value Added/Use of Money	Bio-Economic Models	Production Function (Information?)	Market Price	Statistics (Number of Visits)
Human-nature system integration: analysis effectiveness for policy purposes according to SDGs	The analysis produces metrics to practically and effectively assess performances related to UN Sustainable Development Goals (SDGs)	The analysis can effectively provide metrics of local employment, gender equality, health, well-being or environmental health deriving from fisheries activities, directly referred to SDGs	7	49							49 (which of the SDGs?)					
Dynamic multi-dimensional interaction	The analysis assesses systemic impacts of ecosystem services across economic, human, social and natural dimensions (please, check the dimensions concerned)	The analysis can assess the revenue generated by fish markets and the improvements in population health, security or well-being (measurable impact).	6	36					36							
Forecasting	The analysis forecasts future systemic impacts of ecosystem services	The analysis can forecast the state of health of the ecosystem in terms of fish population and/or the generated well-being (e.g., increased employment) in the long run	5	25		25		25			25					
Dynamic uni-dimensional interaction	The analysis assesses interactions between parts of the ecosystem/service within one dimension	The analysis can assess the revenue generated in the fish market.	4	16				16	16	16		16	16	16	16	
Static quantitative	The analysis assesses quantitative aspects of ecosystem services	The analysis can tell us quantity of fish or give fish a value, for instance through price	3	9	9		9		9	9		9			9	9
Static qualitative	The analysis provides qualitative assessment of ecosystem services	The analysis is suitable to discover the species of fish or provides uncountable valuations (high or low value)	2	4						4						
Discovering knowledge	The analysis allows to discover knowledge	A method reveals the presence of fish	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Not applicable	The methodology is unsuitable to the purpose	A method is not suitable for telling us whether there are fishes or not in the sea	0	0												
Total assessment					10	26	10	42	62	30	26	26	17	17	26	10
Normalized values				140	7.1429	18.57143	7.14286	30	44.2857	21.4286	18.57143	18.571	12.143	12.14286	18.6	7.1429

Table 5. Blind spots, limited consistency and possible responses in the Baltic marine ecosystem services [25].

Blind Spots	Possible Responses from Funding Institutions and Research
(1) Interactions of Ecosystem Services (ESS) are often neglected	<i>Plan studies including the assessment of interactions</i>
(2) Different methods are required to value a single ecosystem service, yet the majority of studies use just a single method	<i>Science integration</i>
(3) Holistic studies synthesizing and integrating the results are missing	<i>Joint platforms for holistic evaluations</i>
(4) Conclusions concerning the Baltic Sea as a whole cannot be derived from studies from a single country	<i>Cross-border cooperation and governance</i>
(5) Valuation research seems to concentrate especially in Sweden and Finland	<i>Knowledge transfer from Sweden and Finland to other countries; focus on primary data collections where it was lacking</i>
(6) Many ESS have not been valued at all	<i>Identification of more ESS and suitable methods</i>
(7) Revealed preference methods little applied for lack of data	<i>Centrally organized primary data collection and complementing data</i>
(8) Inaccuracy and lack of validity of benefit transfer methods	<i>Further research and combination with other methods</i>

However, this raises a question: Does economics concern, also, more objectively, determinable human needs (human capital), which not necessarily coincide with social preferences (social capital)? As earlier treated, with reference to the original concept of economics as household management [11], does the approach focused on societal aims as just described and address the meeting of more objective human needs with the available resources? This way, economic valuations remain isolated in the area of societal aim and utility for various economic actors. However, the benefits for humans and people's well-being, even if in regard to humans, cannot always be known with a good level of certainty [11].

Contrary to economists, ecologists claimed that not assessing, for any reasons, important elements of ecosystems, does not mean that effects of various economic activities/decisions on these functions/services are not produced. Considering just a final ecosystem service, and not an ecosystem function, as relevant for producing benefits, might mean missing very important knowledge about many possible benefits. Moreover, as many experts argued, the unavailability of an ESS would reduce to zero the value of the habitat or function, which is key for its production. For instance, recreation (e.g., boating), as it was admitted by an economist, while providing a cultural service and an income can generate, at the same time, environmental pressures on the natural capital, thereby ultimately resulting in a decreased performance. According to these views, habitats and ecosystem values, required for the production of the services, are of the utmost importance and should be included in the valuations, as the production of final services are species- and habitat-specific and thereby, the possible future unavailability of final services would privatize of value, the sources, as well. The absence of valuation of the habitat that provides the final service (e.g., the fish) is considered a gap, because it neglects the cost for its growing (importance of habitat, nursery and breeding grounds). Making a comparison, it would be like pricing a house, just on the basis of the demand, and not taking into account the cost of labor and materials for its construction. The ecologists in the workshops called for means to make ecosystems visible and recognized in society as a source of many services that benefit us.

Again, as experts admitted, it is very challenging, even impossible, to know about all cause and effect relationships. The pressure on natural capital might, in turn, eventually cause health problems, known or partially unknown. The problem is that when valuing final services as detached from functions, all the chains are not included nor well-known. Even when the values of functions were known, the value of a single fish in terms of price would be added by the value of all the functions that produce it, and would become much higher. A valuation involving just one natural habitat,

as disconnected from the others, is not enough, and there is a need for understanding the more holistic picture. Many ecologists agreed that this holistic and systemic approach is often not in evidence within their discipline. Moreover, even when these interrelations were identified and recognized, valuation methods cannot represent them. Holistic studies synthesizing and integrating the results are missing [25]. Considering a whole natural habitat, different methods (e.g., market price of produced services or cost of its recovery) can give very different valuation results. Valuation methods belonging to the Ecosystem Services Approach (ESA) were evaluated as not adequate, or at least hardly usable, for the goals of Agenda 2030, which are not strongly dependent on contingent policy objectives or consumer choices limited to single communities.

Experts agree on the fact that although data on health effects is available, the high specialization in ecology, health or food quality for health, and the lack of interconnections between them, prevents those impacts to be clearly visible. The knowledge on ecosystem functions, human needs and services for societies overlap just for a very tiny area and, for the rest, is developed in a detached and independent way. However, in order to realize processes of decision-making based on evidence and not just on societal or economic aims, it is important to understand from, an ecological perspective, which is the combination of factors/elements of the ecosystem that are needed to generate, for instance, good water quality, which is in turn essential for good human health. The scopes of work are also often different: Ecologists target specific species or habitats while economists/humanists work with more local, national or regional levels. This consequently influences also the applicability of results for further research. It seems that there is much scope to increase connections between fields of research.

The expert meeting revealed that ESS valuation methods can assess ESS when related to anthropocentric societal and political aims, however, they fail to capture the importance of ESS for less-negotiable basic human needs (human capital) in present and future times, and for the continuous functioning of ecosystems. If a decision is based on economic valuations alone (corresponding to societal aims), it cannot be made on the basis of evidence, thereby missing to take into account for these very important, yet not accounted elements. Ecosystem valuation methods attain, therefore, mainly societal and economic aims and do not include complementary evaluations, thereby missing to incorporate environmental and human values, which are respectively intended as values of ecological functions and human (basic) needs (see Figure 4).

For instance, the discussion on biodiversity revealed that there was no adequate method for its valuation, and doubts were raised on whether economics would even be supposed to value biodiversity. Biodiversity could perhaps be measured rather by questionnaires (for example, willingness to pay) or with monetary methods. However, these methods, revealing very low willingness to pay values, would suggest that there is no reason to keep the Marine Protected Areas (MPAs). This raises additional questions: Are individuals or society able to appreciate with satisfactory level of uncertainty, the value they would be ready to pay for these services, when the possible impacts in the natural environment and the relation to human well-being might be mostly unknown? Even if these impacts were known, would individuals and the society have the feeling they can appreciate how much biodiversity contributes to their health, and what this might cost in monetary terms? Instead, would ecological indicators provide a better measure of the level and importance of biodiversity?

In order to provide a more thorough valuation, as discussed in the meeting, the historical biodiversity background could be used as the basis, aiming at balancing human needs, social interests, and ecosystems' continuous functioning. Some questions to address this issue could be: Can we restore the territory? Can we try to incorporate the cost of the restoration into ecological and economic models? As the interactions between species are changing over time, are the models used able to change accordingly?

On the basis of the arguments above, a question can be formulated: Has the initial rationale, as described, of highlighting the importance of biodiversity for human well-being to promote nature conservation (see the Introduction) [6] lost its way?

Indeed, the aim of the Eco-GAME is not to evaluate the ability of valuation methods to pursue specific top-down political objectives, detached from evidence about human well-being and environmental sustainability. The Eco-GAME attempts to evaluate how much human needs and environmental sustainability goals (referred to SDGs) are represented and taken into account by economic and non-economic methods, and this is the reason for BONUS MARES to follow a bottom-up approach. Indeed, the relevance for policy was considered in the expert meeting as a two-way interaction: On the one hand, decision-makers may ask for specific research at support of the pursued policies, on the other hand, science can communicate its results regardless of political enquiries, in order to warn, advise and influence policy-making on important issues it (for instance, on SDGs). This recalls the idea of Aristotelian wisdom as combination of intellectual and moral virtues.

6.3.3. The Examples of Recreational Services and Mussel Beds as Food for Fish

The ecosystem services ‘Recreational services’ (blue scores in Table 4) and ‘Food for fish’ (red scores in Table 4) were selected for the analysis.

Recreational ecosystem services are relatively easy to value economically, for instance, by the travel cost to a fishing site. This can attempt to calculate the change in the value, which is related to water quality and the general environmental status. Again, the link between the habitat and the ESS (water quality as the functional ESS) should be established. This can be done by the travel cost, the assessment of the preferences (what is valued), or the mental health (not much information is available on the marine ecosystems). Other options are the quantity of nutrients mussels take out from the sea or the compensation methods.

On the contrary, the ecosystem service ‘Food for fish’ produced by mussel beds represents a more complex case, which practically describes the different visions of economists and ecologists presented above. When making the hypothesis of depleting part of all mussel beds in pursuit of other purposes, starting from an economic perspective, a price can represent the value of fish for sales purposes (economic capital). However, when considering mussel beds as part of the ecosystem and production factor in fisheries, making a decision about the methods would require setting specific priorities and aims, according to more complex valuations (social capital), for instance, by mean of a decision tree: alternative policy/decision-making situations and options → what is needed → what methods and data are needed. The matter becomes one of political choice (social capital), whether we can live without mussel beds or not has to be made: If we can live without, then the market price of fish is enough, if instead we cannot afford to lose it, the most appropriate method would be the replacement cost.

Market price (economic dimension, financial capital) is the method that would be mostly chosen to value fish stocks, but the habitat and the intermediate services, such as food for fish or feeding grounds, is not included, nor reflected in the price because it is difficult to calculate. This means that the method is not suitable for the purpose of measuring aspects that cannot be translated into societal/economic form. For commercial fish species, more detailed information and statistics are available, which allows to reach higher qualitative level of knowledge and to assign higher scores, in terms of Eco-GAME meta-evaluation. Conversely, for non-commercial species, detailed information is not available, and the meta-evaluation remains at lower levels. Actually, economic non-monetary methods were assessed to achieve different levels, depending on the use and purposes (stated preference: level 6/7; FCM “fuzzy” models: level 5).

However, from the perspective of more objective importance of the natural capital and the functions it accomplishes, even indirectly for the human capital (well-being, health) i.e., irrespective of whether fish were caught to eat, the question is whether the use of different methods would lead to the destruction of the mussel beds or to a more naturally balanced system.

Where the ecosystem function is evaluated biophysically as crucial and important, the replacement cost method calculates the cost for generating elsewhere the same amount of biomass, mussel reefs, and/or biodiversity which was lost in one place, for instance, for building a harbor. Historically, as an expert recalled, the restoration cost allowed, for instance, to restore and conserve habitat, water quality,

the living coastal and marine resources, and the enhancement of recreational opportunities in the case of the Mexican Gulf oil spill. However, the replacement cost can be hard to calculate, and, in some cases, the replacement of biodiversity is not possible, such as with the very common case of Baltic Sea eutrophication, which requires direct investments for more effective actions, not just a reliance on valuation methods that so far have not been effective. As more times advocated, where the calculation of a given cost would be too complex or uncertain, the adoption of the precautionary principle would be required.

The process as described above assumes an anthropocentric perspective. First, the decision about the method, when limited to political orientations, fails to consider the more objective evidence about the importance of the ecosystem function from a biophysical perspective (natural capital). Therefore, integrative knowledge from ecology is needed, to communicate, for instance, that, as one expert reported, “if mussel beds would disappear by 20%, flounders will lose x% of their food.” This integration will communicate to economists and decision-makers that: “We’re thinking of destroying 20% of the habitat. Can we do it?” The communication of the function of habitats for producing food for a given amount of fish stock would be needed, with the assessment of other possible consequences, to prove the importance of the habitat. Moreover, the evaluation of just one habitat is not sufficient, and there is a need for a more holistic picture of interaction among the different habitats within an ecosystem. On top of this, political decisions might impact on human health and well-being, for instance, because the possible pollutant activities in the water may impact on the health of fish, and in turn, on human health as well (uninformed anthropocentrism). The lack of perfect information and optimal choice due to unknown knowns and unknown unknowns [11], means that societal aims and choices do not always produce increased well-being or health. An example was provided by experts on the preference-based approach, performed by a survey in Latvia, Finland and Germany, focusing on the preferred locations for holidays in relation to water quality, complemented by a travel cost method. People’s perceptions are very difficult to link to water quality because they are related to other environmental conditions. Linking mussel beds, water clarity and people’s preferences seemed to be very challenging. These considerations reveal the importance of science-policy interaction, not only to respond to policy and societal aims, but also to inform about the more objective importance of ecological functions and human needs, a point recognized by some economists.

On this basis, as it is important that fish stocks are in good health, ecologists would hope to include in the price also the value of shelter, gas regime and food, which implies taking the carrying capacity and the conditions to realize it into account. Some valuation models can integrate different services that habitats produce and can also optimize the use of different resources, so that ecological factors are considered. Biodiversity values should be also taken into account, but this can be done just by non-economic methods: Biological and ecological models can assess, for instance, how much of any habitat in percentage is needed to support flounders. The question is how to transfer the knowledge about the importance of mussel beds as food for fish and also as support to biodiversity to the policy-makers.

6.4. The MARES Simulation Laboratory (SimLab)

The first expert meeting of Section 5.1 was followed by a participatory workshop held in Suomenlinna, Helsinki, on 13 and 14 of February 2020 with the aim of deepening the discussion related to decision-making and proceeding towards an integrated approach among ecology, economics and society (see Figure 7).

The workshop was attended by some of the participant experts from the expert meeting, supplemented by additional participants, especially from the field of policy advice (see Appendix A). To pursue this aim, a Simulation Laboratory (MARES SimLab) was organized, for initiating a process of social learning and building evidence-based decision-making (see Figures 7 and 8). The MARES SimLab was structured into six groups of four participants, representing the four capitals, i.e., key actors having a role relating to the specific capital as further specified in Table 6.

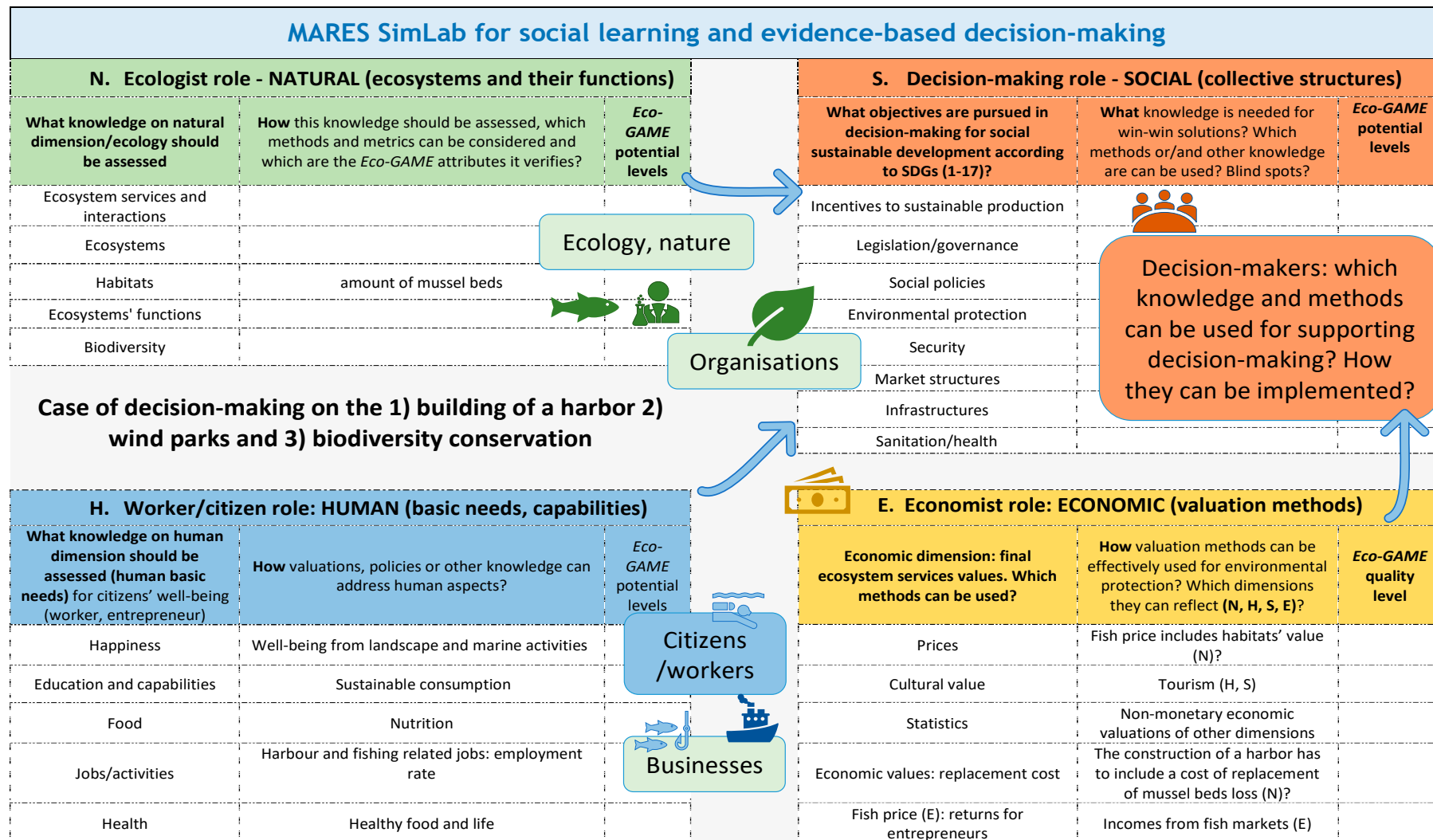


Figure 7. MARES SimLab for social learning and evidence-based decision-making.

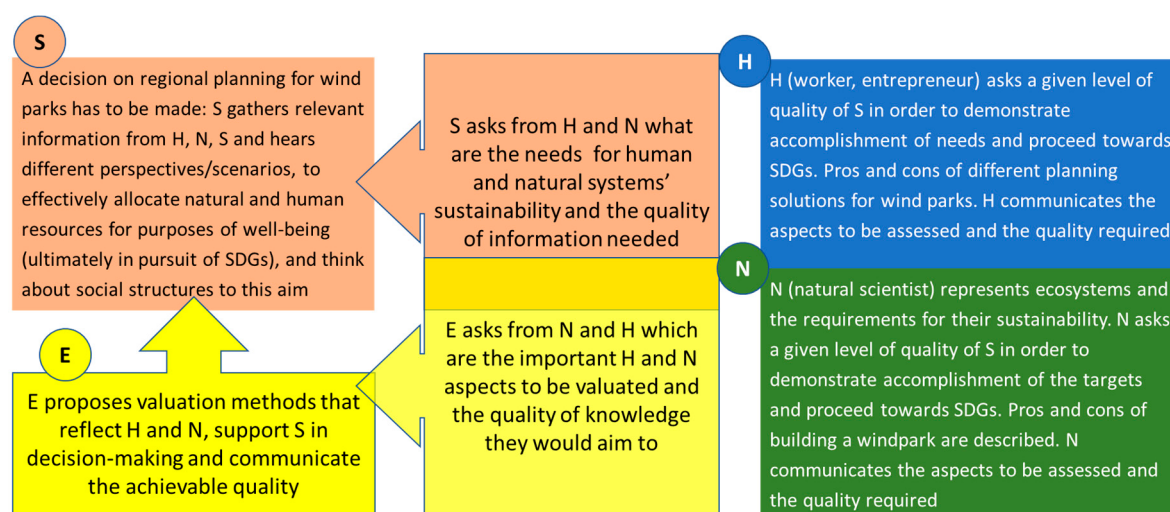


Figure 8. MARES SimLab functioning for the theme of wind parks.

Table 6. The roles of participant experts in the BONUS MARES SimLab.

N. Ecologist Role: This is a natural scientist, representing the needs for natural systems' sustainability, whose main aim is to communicate knowledge about ecosystems and their functions
H. Citizens Role: This is a representative of workers, entrepreneurs or civil society in general, aimed at meeting human needs
S. Decision-Making Role: This is the role of administrators and rulers, representing and interpreting societal aims
E. Economist Role: This is the role of an economist who is specialized in the field of ecosystem valuation, aimed at translating knowledge on human needs and ecosystem-related information for the use of decision-making

The groups were naturally formed on the basis of the expertise of the participants, especially for the roles of ecologists and economists. The other roles were more freely assigned, as citizens and decision-makers in real life may have very different backgrounds. The activity of the groups was focused on three different case studies, two of which were aimed at more concrete decisions, i.e., the building of a harbor and of a wind park, and one on a more complex and general matter, the conservation of biodiversity, chosen as agreed with the participants. The first two cases were chosen as practical examples of real decisions, the third was chosen as it represents a challenge and an opportunity to generate a combination of methods. In fact, in the earlier expert meeting, economists admitted how economic valuation methods could hardly assess biodiversity. An example of the process of interaction within each of the groups is provided in Figure 8. In order to maintain the confidentiality of the contributions by individuals, each group is labeled by letters (a, b, c, d, e, f, g) that do not correspond to the numbers assigned to them at the workshop. One of the groups was removed due to some registered participants having to cancel at the last minute.

6.4.1. The Wind Farms Case

The SimLab for the wind farm, group (f), discussed tourism and recreation as the human dimension and considered that residents would need to be involved in decision-making processes, especially in relation to the possible risks for health or impacts on employment (e.g., fishing). With regard to the natural capital, the experts proposed the following activities and methods needed to increase knowledge, as listed in Table 7.

Table 7. Wind farm activities and methods discussed in group (f).

ACTIVITIES	Education of decision-makers on the importance of ESS and the need of preserving them	ECONOMIC METHODS	Time use /travel-distance for tourism Official statistics (to be reviewed)	POSSIBLE SDGs INVOLVED	Affordable and clean energy
	Assessing flyways occurrence		Hedonic price/revealed preference		Decent work and economic growth
	Assessing habitat/species/biodiversity at the different sites		Stated preference Benefit transfer		Industry, innovation and infrastructure
	Assessing seasonal visitors (e.g. spawning ground for fishes)		Fuzzy cognitive mapping Measure of well-being (different psychological methods)		Sustainable cities and communities
	Identification of possible loss of ecosystems, valuation of their monetary/non-monetary values and determination of possible compensation areas		Replacement costs (e.g., nutrients) Market price (mussels/fish spawny CO ₂ uptake) Bio-economic models Focus group discussions Key informant (interview of single people)		Life below water

The challenge would be to understand which methods can be more adequate to describe and assess the performance in order to achieve them and in which way this can concretely happen. In relation to the sound emissions and the aesthetic impact of the wind parks, the impacts generated on tourism/recreation, residence and property values (social capital), (human capital) local fishing activities and jobs created/lost should be taken into account. As case context, the group described a situation in which the contractor for the wind farm determined four possible locations around Turku's coastal area. Group (a) stressed also that the effects on the environment and issues linked with the characteristic of being a renewable energy should also be considered at local level. For human capital, the creation and loss of jobs should be considered. For social capital, group (f) stated that policy-makers need to know about the ESS produced and the effects of the investment onto various aspects, for instance, on local ecological processes and on the possible loss of services, which can have social and/or economic relevance. For this reason, community involvement is important and the economic methods indicated for this purpose were benefit transfer, stated and revealed preferences and replacement costs. Group (a) stressed energy policy as a driver alongside the need to understand existing regulations. This has to do mainly with the social capital, while for the economic capital, technical issues regarding core financial data (costs, revenues) were considered. The group focused on the societal aspects, regarding political and economic aims, more than on the need to inform about methods that would increase their knowledge about environmental and human needs. Group (c) also identified some issues and possible valuation methods, as listed in Table 8 and graphically represented in Figure 9.

6.4.2. Harbor Construction Case

Group (d) started the discussion about a multifunctional harbor, built for goods, cargo, and passengers (cruise ships). This suggests that some questions about alternative options, and their impacts, should be taken into account. Groups (d) and (e) considered, among human issues, additional workplaces, and among social issues, infrastructure, schools and services to be developed. Both groups also argued that the views of local people should be taken into account through questionnaires and/or surveys. Group (d) suggested combining questionnaires with already existing statistical data, in order to provide more robust and informed results. Group (e) considered economic methods such as replacement cost, travel cost, willingness to pay, cost-benefit analysis and risk-analysis in their discussions.

Table 8. Issues and methods about wind parks (group c) by Eco-GAME meta-evaluation.

Wind Parks: Some Results of the Application of the Eco-GAME				
	What	How	Method	
				Desired Actual
Natural	Elements of Water Framework Directive including fresh water and 3 miles coastline/Marine Strategy Framework Direct (Good Environmental Status Descriptors) Natura 2000	Key habitats (+ iconic charismatic key species): seagrass beds, mussels, plants, seals, birds		39 21
	Impacts of wind farms	Habitat + bird Directive Effect on hard substrata(=new habitat) = stepping stone for invaders		39 21
	Impact on geophysical environment	Effects on turbulence, sedimentation, etc		39 4
	Inexpensive life	CBA		39 1
	Undisturbed living environment	Fuzzy Cognitive Model (FCM)		39 1
Human needs	Maintaining traditions (social coherence)	Fuzzy Cognitive Model (FCM)		65 65
	Well-being	Fuzzy Cognitive Model (FCM)		100 1
	Health	Fuzzy Cognitive Model (FCM)		100 65
	Security	Fuzzy Cognitive Model (FCM)		100 4
	Jobs	Fuzzy Cognitive Model (FCM)		100 4
	Social life	Fuzzy Cognitive Model (FCM)		100 65
	Social life	Fuzzy Cognitive Model (FCM)		100 65
Social: societal aims	Common sense	Information portals needed (FCM, Gaming)		65 21
	Common sense	Communication		65 21
	Sustainable public and private profit (balance society/environment)	CBA/EIA		100 4
Economic: translation of knowledge for societal aims	Value of energy production	Market price/CBA/EIA		65 21
	Value of fisheries	Market price/CBA/EIA		65 21
	Value of food production	Market price/CBA/EIA		65 4
	Value of shipping/traffic	Market price/CBA/EIA		65 21
	Value of traffic infrastructure	Market price/CBA/EIA		65 4
	Value of ports	Market price/CBA/EIA		39 10
	Value of recreation	Travel cost/FCM Contingent valuation		65 4

Group (b) suggested the multi-criteria analysis framework in order to analyze the trade-offs and effects of different scenarios, and the possibilities for impact minimization. The group suggested the use of spatial analysis methods for the selection of most suitable sites (see Tables 9 and 10, and Figure 10).

Natural data is already often available, more for some locations and less for others. A more specific analysis of the pressures, ecological conditions, identification of the ecosystem components and connections between habitats was also suggested by group (b). Environmental impact assessments could be performed for this purpose. From the economic perspective, the change in ecosystem services and related value should be estimated: Cultural services such as recreation could be valued by stated preference methods, while provisioning services such as fish catches could be valued, for instance, by market-based methods. For some services, such as carbon sequestration, there is uncertainty about the possibility to calculate the expected change, and from the perspective of human capital, the effect on local employment and change in local livelihoods should be assessed, and the possible incentives for change hypothesized. Marine Spatial Planning (MSP) includes decision support tools that could be useful for this purpose. Uncertainties need to be considered, as well as the continuous monitoring of the effects after the investment, in order to see if compensation actions have to be implemented. The biggest gap in policy-making is the lack of spatial connection and therefore, governance approaches would be needed.

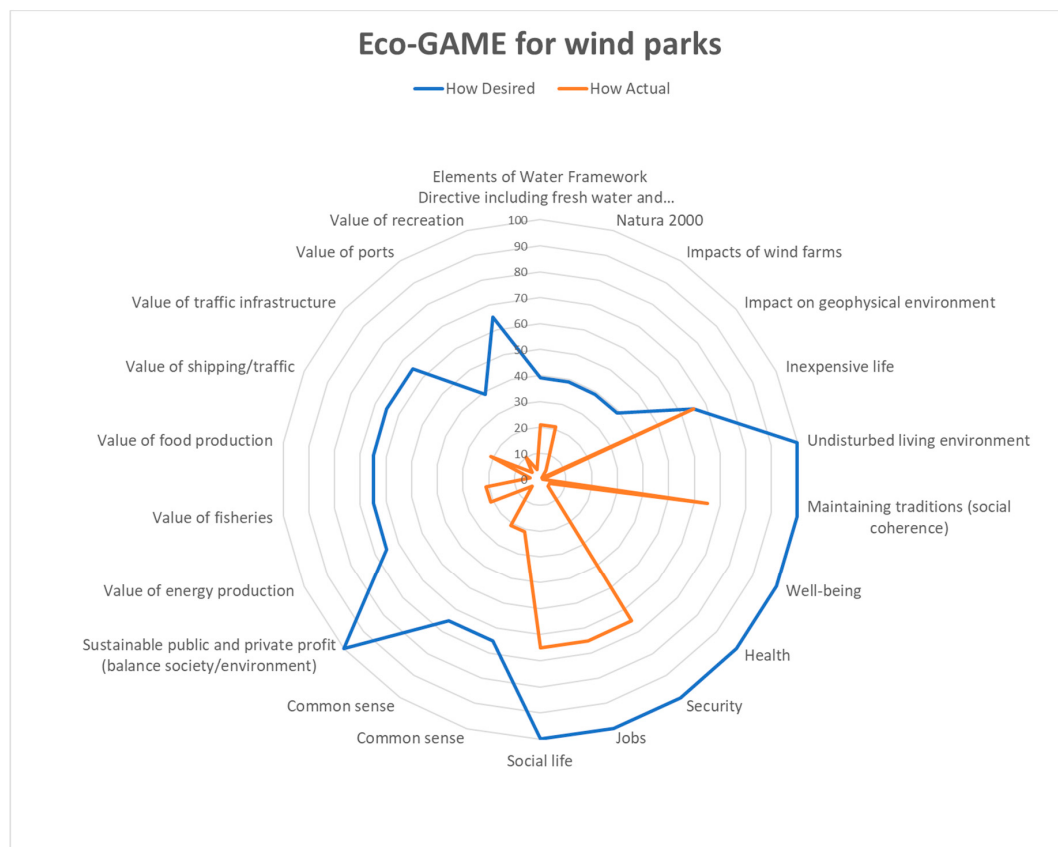


Figure 9. The application of the Eco-GAME meta-evaluation to wind parks: Graphical representation of the performance of different methods (actual, and possibly desired but not implemented). See Table 8.

6.4.3. The Biodiversity Case

With regard to the natural dimension of the biodiversity case, group (c) questioned the status of current knowledge, and argued that this is typically low (scoring 1–2). This could change, because whereas for some species there is not much knowledge at all, for others there is a significant amount available. Group (c) listed different aspects of biodiversity to be measured and possible methods to do so, with actual and desired performances, as indicated in Table 11 and Figure 11.

The group reported that the interactions of different species should be studied more systematically. Group (a) argued along similar lines that ecosystems are dynamic and continuously changing and knowledge on connections of different habitats, the maximum sustainable yield and supply of biomass is needed.

Group (d) stressed the importance of regulatory activities for important matters, for instance, to avoid bottom trawling, which has a significant negative impact on benthic biodiversity. Furthermore, according to the precautionary principle, several environments with high biodiversity should be kept intact, to limit the danger that an accident in one may cause irreversible losses in ecosystem patrimony, and the extinction of species. National monitoring activities could assess the most suitable locations, area of coverage and distribution.

Table 9. Multifunctional harbor (group b).

	What	How	Score
Human	General human well-being	Questionnaire + statistical data on: - Balance between jobs and well-being - Health and safety - Pollution aspects (noise, particles in air)	6–7
	New jobs and links between different new businesses based on the new jobs of harbor	Questionnaire + statistical data on: +more new jobs –more traffic, noise –pollution	
Social	Possible conflicts between locals and new workers from outside the local community Pressure on infrastructure: schools, roads, apartments Changes in local traditional living	Local stakeholders' involvement and comparison of different alternatives: scenario building	5
	Increasing tourism	Questionnaire + statistical data on: +benefits from tourism –more traffic, noise –pollution –higher prices/structural changes in rental services disadvantaging locals - Impacts' predictions of long-term changes by forecasts	
Natural	Water quality: changes in water conductivity, pollution risk, hazardous substances and litter in water Biodiversity and habitats: bird species in the area (breeding and feeding areas) Possible changes in sediments and currents' movement	Environmental Impact Assessment (EIA) or national monitoring Identification of protected species EU Directive Frameworks EIA or national monitoring	5 or higher
	Identification of the most suitable area, including the needed investments and the amortization time	Cost-Benefit Analysis (CBA) (E)	
Economic	Threat/risk analysis (E; N; H; S)	Replacement cost (E; N; H; S)	5–6
		Travel cost method, willingness to pay (difficult; compare different countries/cultures/wealth)	4
	Sustainable tourism	Questionnaires Conjoint analysis	3

Group (c), when considering the economic dimension, reported that the level of knowledge varies for different activities, such as shipping or fishing, highlighting the anthropocentric focus. Group (e) felt that there was little knowledge at all levels and there is a need to educate citizens for a deeper understanding and to raise awareness of biodiversity issues. A wider picture of the whole is needed and group (d) argued the need for knowledge translation, simplification and clarification within policy-making purposes, as policy-makers are often not aware of the nature of the problems and are afraid of making decisions because of the uncertainty of possible impacts. By extension, communication professionals focused on facilitating this knowledge transfer for evidence-based decision-making were felt to be missing. Group (a) discussed finding ways for linking supply and demand for ESS, as well as the necessary legal structures being in place, impact assessments and constraints in terms of time and money. The group considered stakeholder involvement to be key throughout the whole process, as was the need to take uncertainties into account. Group (c) focused more on the importance of

natural capital and related functions, and considered activities of ecosystem restoration for which the replacement cost can be a more suitable method.

Table 10. Issues and methods about the construction of a harbor (group b) by Eco-GAME meta-evaluation.

Building a Harbor: Some Results of the Application of the Eco-GAME			
	What	How Method	Score
Natural	Water quality: changes in water conductivity, pollution risk, hazardous substances and litter in water	Environmental Impact Assessment (EIA) or national monitoring.	39
	Biodiversity and habitats: bird species in the area (breeding and feeding areas)	EU Directive Frameworks	39
	Possible changes in sediments and currents movement	EIA or national monitoring.	39
Human needs	General human well-being: balance between jobs (new jobs and old businesses) and well-being, health and safety, pollution	Questionnaire + statistical data	65
Social: societal aims	Possible conflicts between locals and new workers from outside the local community		39
	Pressure on infrastructure: schools, roads, apartments	Scenario building	39
	Changes in local traditional living		39
	Increasing tourism: benefits and negative impacts (traffic, noise, pollution, higher	Questionnaire + statistical data	39
		Long-term scenario building	39
Economic: translation of knowledge for societal aims		Travel cost method, willingness to pay (difficult compare different countries/cultures/wealth)	21
	Sustainable tourism	Questionnaires	10
		Conjoint analysis	10
	Identification of the most suitable area, including the needed investments and the amortization time	Cost-Benefit Analysis (CBA) (E)	65
	Threat/risk analysis (E; N; H; S)	Replacement cost (E; N; H; S)	39

However, from a more environmental perspective, group (f) focused on the primary importance of the good environmental status, which implies the existence of ecologically diverse systems, and questioned whether services-based biodiversity (functional to service production) per se is what we need. On the issue of biodiversity, existence values (expert-based) are hard to assess. Typically, the way to deal with higher uncertainty is to adopt a precautionary approach. The group questioned whether valuing biological knowledge on biodiversity, in terms of food web analysis and interactions between habitats does have any sense and whether the value should be just put on final products, such as, for instance, tourism and recreation. Group (e) reported willingness to pay, use and non-use values and opportunity cost as possible methods. However, their Eco-GAME levels have been assessed as low.

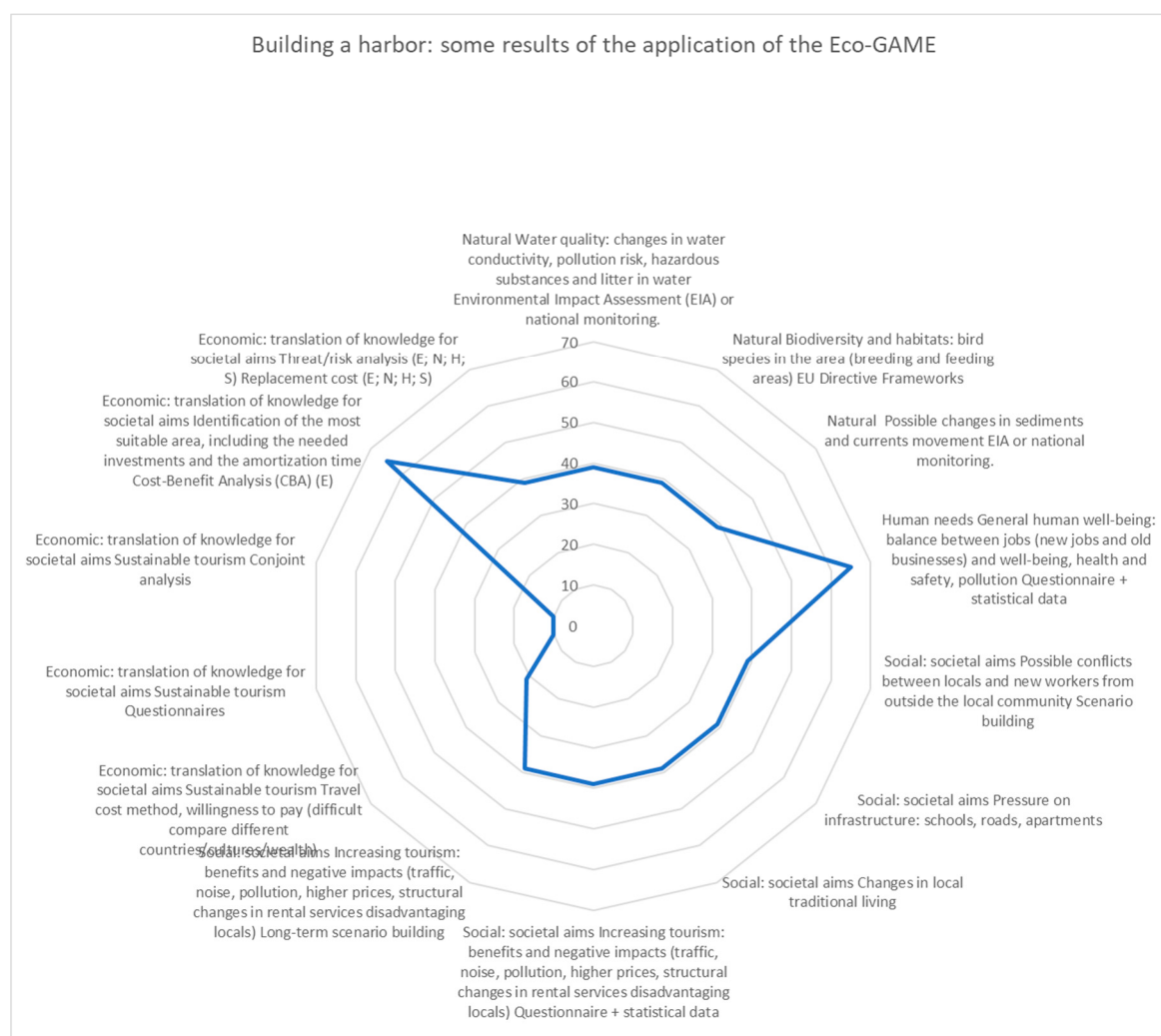


Figure 10. A graphical representation of the Eco-GAME meta-evaluation for the construction of a harbor.

The establishment of Marine Protected Areas (MPAs) was discussed by Group (b) as a way of protecting certain features of biodiversity, existing habitats and species, and actively monitoring data to justify the initial choice (what has to be protected and how) or the possible change of their boundaries. This activity involves the mapping of the green infrastructure (habitat), in terms of ecosystem components, and linking their variability to ecosystem services, aiming to identify hot spots both on natural and benefit levels. The problem is the lack of knowledge about the natural dimension. In any case, the key aspect is to score the ecological importance of providing the services. In this case, the question is whether valuation methods are needed or not. The high-value areas for establishing MPAs can be identified and established when ecological knowledge allows the ranking of biodiversity.

Table 11. Issues and methods about maintaining biodiversity (group c) by Eco-GAME meta-evaluation.

Marine Biodiversity: Some Results of the Application of the Eco-GAME				
What		How		
		Method	Desired	Actual
Natural	MSFD/GES descriptors	Frameworks' harmonization between countries	100	10
	e-DNA	e-DNA	65	10
	Diversity in species groups	Remote sensing (satellite images)	100	39
	Detailed species diversity	Classical sampling	100	65
	Dominant species diversity	Key species and their diversity	100	39
	Habitats diversity	Habitats (UNIS classification)	100	39
Human needs	Fish diversity	Hedonic pricing	100	39
	Other	Hedonic pricing	100	4
	Human health-well being	Salubrity of the environment and impact analysis	100	10
	Charismatic landscape, recreation	Surveys/FCM	100	65
	Cultural environment	Surveys/FCM	100	39
Social: societal aims	Fish diversity (commercial)	Sustainable yield	100	65
	Fish diversity (non-commercial)	Interactions	100	39
	Food sector	Salubrity of the environment	100	10
	Restoration	Replacement cost, biodiversity increase	100	39
	Recreation from habitat diversity	GPS tracking, tax (tourists), statistics (licenses)	100	65
Economic: translation of knowledge for societal aims	Fish diversity	Market/hedonic price	100	10
	Other	Market/hedonic price	100	1
	Recreation from habitat (sailing, diving, swimming)	Travel cost, surveys, statistics, FCM, social mapping (GPS tracking)	100	1

Group (d) argued about the importance of understanding and knowledge transfer of the indirect links between habitats' biodiversity and ecosystem services. For instance, fisheries are economically measurable but not necessarily the connections with the habitat underpinning their production. Understanding the connections and cause-effect relationships between the environment and the services humans enjoy is clearly of major importance. Spreading and transferring the knowledge on these connections between biodiversity and ESS is a major objective from a societal point of view, especially for raising awareness and informing individual and collective/political choices which can end up with regulatory provisions.

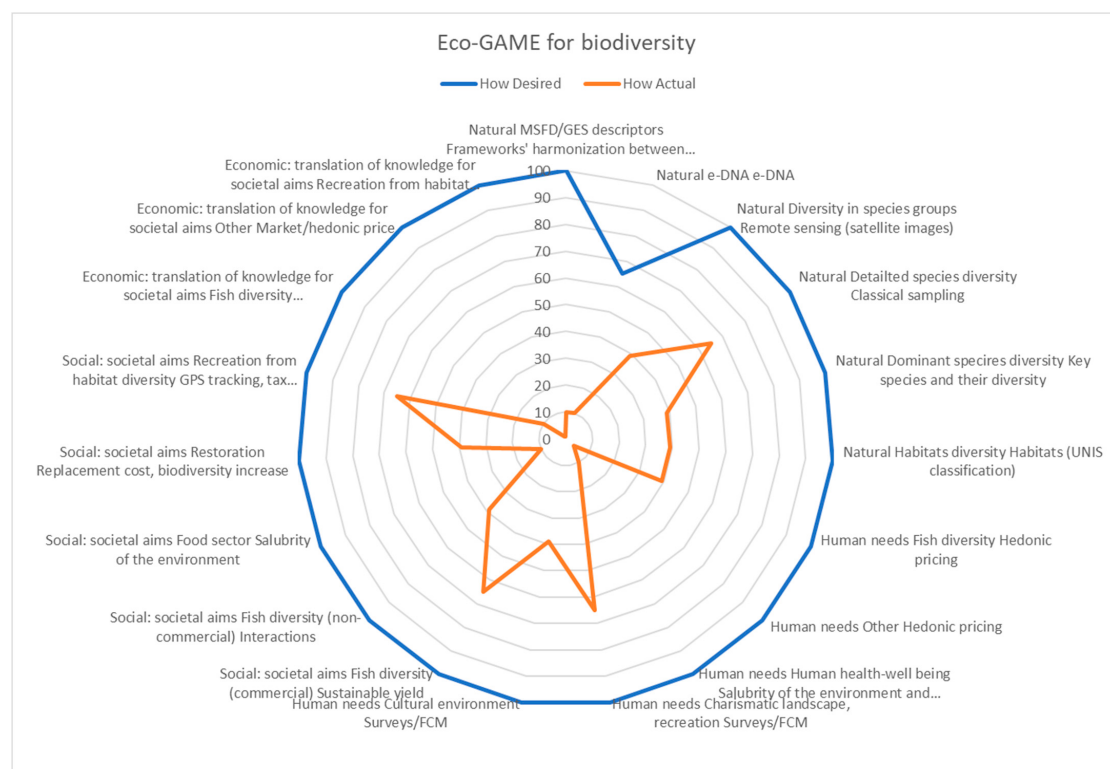


Figure 11. The representation of the Eco-GAME meta-evaluation of valuation methods for marine biodiversity, related to Table 9.

7. Conclusions and Proposal for Further Research

This article presented the application of the Eco-GAME framework for the meta-evaluation of economic and non-economic information on selected habitats in the Baltic Sea, within the BONUS MARES project. The first testing of the Eco-GAME framework to the systematic literature analysis first revealed knowledge gaps in the availability of scientific information related from the ecological and economic perspectives [17]. More in particular, the systematic literature analysis revealed a lack of knowledge linking ecosystems to services and to their valuation, across the whole chain.

This first test was followed by interviews to the researchers involved in the systematic literature analysis and by a first participatory expert meeting, defined by a participant expert as “an adventure between economists and ecologists—both ‘eco’ but in a different setting and fashion. A lot to experience and learn from such an approach.” These investigations revealed that the knowledge gaps arisen in the systematic literature analysis reside in the conceptual philosophy of thinking of ecological and economic approaches, and in the difficulty facing economics, when it attempts to reduce complex ecological-societal interactions by simplified valuation methods which are anthropocentric [20]. While ecologists look at whole systems’ interactions for ecological balance (mainly the natural capital), economists, based on the utilitarian view, look at direct benefits depending on political orientation and on the societal aims, which means ‘what people want to enjoy’ (the social capital). According to the economists involved, the aspects on how environmental functions or indirect services translate into benefits, i.e., their importance for the functioning of the ultimate substrate for life resulting as indirect and hardly measurable, not even relevant for current economic valuations. In fact, some economists interpreted first that the Eco-GAME meta-evaluation was an assessment of how well valuation methods would address decision-makers’ objectives. However, the aim of the Eco-GAME is not related to the sole assessment of the usefulness of methods to meet decision-makers’ political objectives, which reflects the social capital. Even when adopting a participatory approach, the Eco-GAME conceptual idea is

based not on the formulation of mere opinions from an anthropocentric perspective, even if educated and informed, but on the reference to accredited and documented knowledge.

The abovementioned is why the Eco-GAME follows a bottom-up approach and strives for building more objective understanding on how much methods are technically adequate for providing knowledge support to decisional processes, which are based on evidence (both at individual or at policy level), in pursuit of SDGs. Evidence is primarily related to the value of human and natural capitals; so, how well a method can assess human needs and natural ecosystems from a scientific and more robust perspective (health, well-being, environmental sustainability), rather than how well a method can be useful for societal or political aims. The analysis performed showed that the aspect concerning how the natural capital translates into human needs (human capital), remains uncovered as well. This reveals a lack of integration in approaches and cultures, both in different scientific fields and even among similar fields belonging to human and social sciences.

The presented Figure 4 provides a more detailed description of the capitals involved, and the expertise attached to them. In particular, the notion of human capital, according to the Forum for the Future [16], refers to basic needs and capabilities, life-long learning and positive rights, i.e., the opportunities for work and active participation in the social life. The vision of economics refers to the optimization of the use of resources to these aims, as referred also by some members of the expert platform, and to the notion of household management, as referred to in the Introduction.

In the light of these preliminary results, the Eco-GAME framework was embedded in a geo-spatial MARES tool-kit and tested in a participatory process of social learning—the MARES Simulation Laboratory—and finally implemented in the MARES geospatial tool-kit for consultation, as an interface between science and society/policy-making, as well as for interactive participation for science integration. The participatory activities aimed to generate social learning and integration about the opportunities offered by the non-economic evaluation of ecosystem services and by economic (monetary and non-monetary) valuation methods. The Eco-GAME was proposed as a framework to learn and improve the quality of scientific methods to reflect SDGs, through their most suitable integration.

First, the SimLab provided the understanding of the different capitals involved, and of the need of adequate methods that can properly reflect them. In fact, as one expert argued, ESS valuation methods are complementary to other evaluations about the status of ecosystem components and cannot be used alone. In the practical exercise performed by means of the MARES geospatial tool-kit, the participant, by feeding an economic or non-economic method, could pick other methods already present in the lists and justify the combination as able to raise the quality of the knowledge in representing all dimensions involved. In this way, the users of the portal will be informed about linkage between ESS, functions and habitats, and about the best ways to assess them. For instance, as one expert suggested, the Multi-Criteria Decision Analysis (MCDA) method could be complemented by weights that, instead of representing mere political choices, would indicate the more objective importance for human well-being and continuous functioning of ecosystems.

One expert suggested the evaluation of losses in ecosystem services, consequent to a policy action. This suggestion requires understanding about the linkages between ESS and their production factors, i.e., functions and habitats. The expert also admitted, however, that although knowledge increases uncertainties which are huge, human society cannot be aware of all interconnections and has to depend on knowledge (risk-based approached and predictions), which is more or less fragmented. Scientific knowledge is very important for human society, and the sole capital that can be increased endlessly. There is indeed an endless need for further research. However, in the meanwhile, we are unaware of so much knowledge (and we probably will be in the future as well), as the precautionary principle teaches human society to wait and do nothing as the best option, or when, in absence of knowledge, the less possibly harmful option is to be preferred.

The Eco-GAME was evaluated by the expert participants as a flexible, useful and relevant tool for accessing the whole picture about the state of the knowledge, and inform decision-making about the possible options and their performances. In the geo-portal application, the purpose is to gather

and assess the quality of scientific-supported knowledge. Even in this case, we know about the limitations of scientific knowledge in terms of general understanding, cause-effect relationships, as well as discrepancies existing within and between scientific fields. Therefore, the precautionary principle, the option of ‘doing nothing’, or the option to adopt security coefficients, which means maintaining the operations in a safe area which is below the limits of systems’ resilience, in order to meet present and future needs, have been discussed in the SimLab.

These outcomes reflect a definition of economics as human well-being within natural ecosystems, which would not necessarily involve an endless accumulation of material goods, nor a level of activity at the upper limit of systems’ carrying capacity [74]. According to this conception, the dimension of an inner system should be much smaller than the maximum sustainable potential and therefore, in order to maximize well-being and meet human needs, a socio-ecological system growing all the way until the biophysical limits of an ecosystem are reached is not necessary, let alone to exceed them. The authors report that there is a need to recognize the limits to growth because the part of it that exceeds the economy’s optimal scale and the biophysical limits results in the reduction of well-being, as it affects and modifies natural and also social equilibriums, thereby determining unrecoverable damage. In the case of the Baltic Sea, this means setting the limits of resource exploitation, and within these limits, expressing preferences, identifying societal aims and making choices. A subsystem, such as the economic one, should be planned to reach an “about optimal” dimension, which is adequate to avoid disturbances to the larger ecological system and live with that in a balanced relationship. Nevertheless, studies on ecological footprint demonstrate how more than half of national economies, as well as the entire global economy, exceed the limits of sustainability [75]. In this understanding, according to the concept of ecological footprint, living sustainably is “living within the regenerative capacity of the biosphere” [76,77].

The challenge of putting a value on nature suggests the need for integrated social structures that are appropriate to the nature of the goals to be reached: This means that complex collective matters would require collective action and integrated evaluations [14].

7.1. Further Developments for Putting the Eco-GAME into Practice: The MARES Project

In the consideration of the challenges encountered and the valuable participant contributions to the BONUS MARES project, future developments go in a direction of science integration of the different capital dimensions (see earlier Figure 4). An initial proposal for the determination of the economic value could be formulated as described in Figure 12. This is a more thorough decision support that can be provided through an economic optimization, based on the balance between natural resources and human well-being, in order to ensure the sustainability of both systems. This requires the adoption of multi-methods that are able to include biological and human knowledge. In the context of the established Sustainable Development Goals (SDGs) of Agenda 2030 and in line with the goals of the European Green Deal, the Eco-GAME and its geospatial representation through the final MARES tool-kit, support scientists and decision-makers in searching for combination or integration of methods that would improve knowledge and give more adequate and thorough support to decision-making.

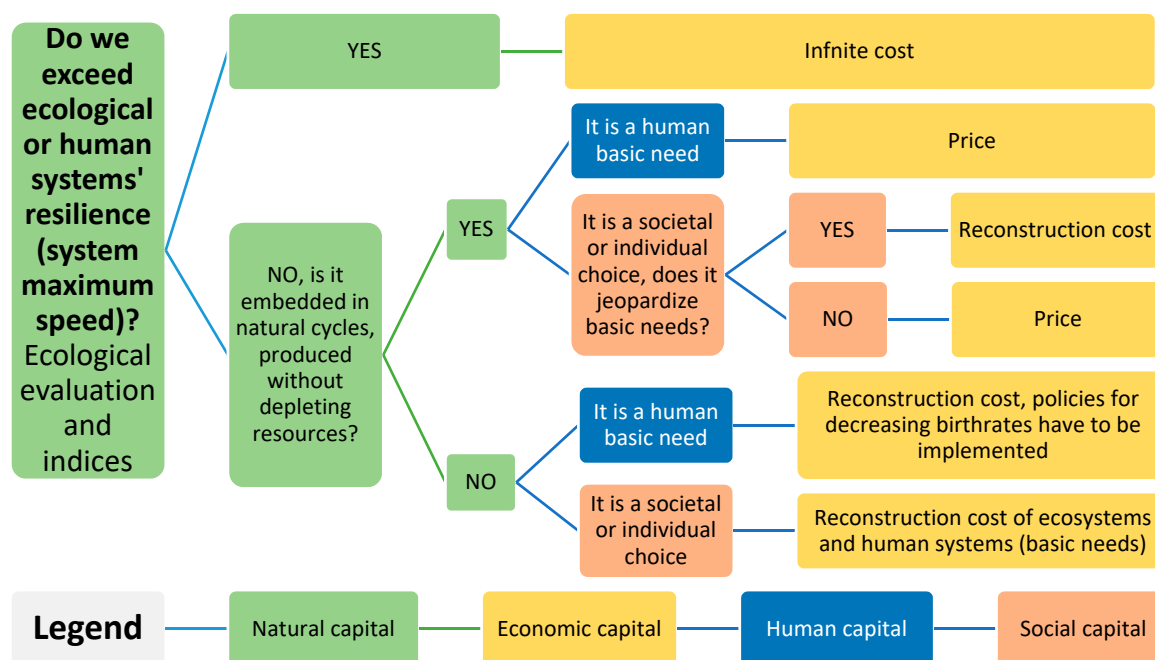


Figure 12. The determination of prices more adequate for reflecting resilience in human-nature integrated systems by an Eco2 model.

Figures 12–14 specifically link ecological indices to human well-being and economic valuations. The framework is based on some main assumptions:

- A market price can be assigned when markets are based on the actual availability of resources. This is possible when the Baltic Sea can produce fish in a continuous way.
- When, on the other hand, some activity would jeopardize the ability of the Baltic Sea to produce fish, a reconstruction cost for the lost habitats needed for growing them should be included in the price.
- Where the resilience of the Baltic Sea is exceeded, this would mean irreversible changes, translating into an exponential cost, tending to become infinite. This is justified by the integration into the model of ecological boundaries, which cannot be exceeded.

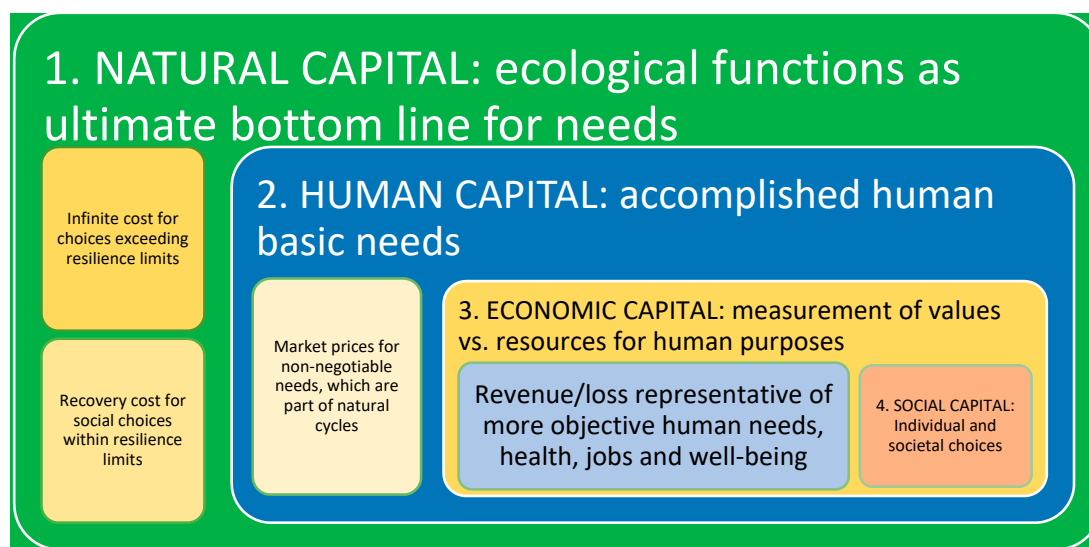


Figure 13. The bottom-up approach informing decision-making about 3. Monetary valuation, representative of 2. Human needs, within the limits of 1. Sustainable use of resources.

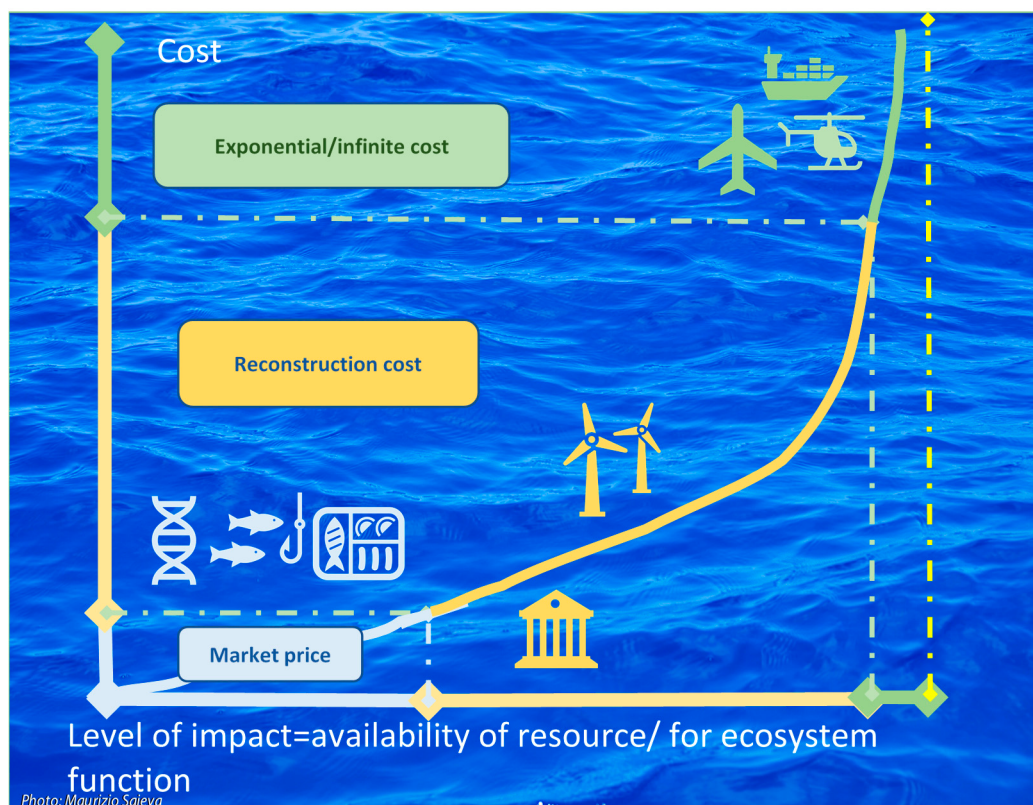


Figure 14. An economic model for human-nature scientific integration, based on household management.

The bottom-up approach (Figure 14), which aims at evidence-based decision-making, prevails on the top-down approach, which aims at responding to decision-makers, individual and societal aims. This is based on the rejection of an assumption of perfect information of economic actors, and the need to acknowledge known knowns and unknown unknowns.

The participatory events demonstrated that the choice of the valuation method for ecosystem services influences the outcomes. For instance, market prices that result from the isolated approach of equilibrium between supply and demand, were indicated as reliable methods when the ecological perspective of maintaining the habitats that produce the services is not concerned. The need of assessing habitats and ecosystem functions requires a method based on the reconstruction cost.

Whenever the societal aims would be reached but the basic human needs would not and/or the SDGs would not be represented, this would mean that the societal structures and choices are not really based on evidence, and would reflect more individual or collective isolated political aims, partially unaware of the potential impacts. The more reliable and thorough knowledge is delivered across the capitals and the SDGs, the more it is useful to inform decision-making in pursuit of integrated systems' sustainability. To take an example, the method of market price could be chosen because it is effective for limiting the use of resources, for instance, the access to a coastal area (social capital). However, the realization of facilities and tourist advertising may increase its economic value, related to the market demand, and increase its use to a point that the ecosystem would be eventually depleted. In this case, the price for the use of the site does not represent its value from the perspective of natural functions (natural capital) nor from the perspective of the human health and well-being (human capital) it delivers, regardless of the individual preferences for recreational use (social capital).

Integrated approaches to science are needed. However, it would be hard, probably impossible, to know all interactions within and between ecosystems, nor their role for human health and most important human needs. Many aspects remain unknown or uncertain and there is no way to avoid

this. The virtue of the precautionary principle would suggest that reaching maximum efficiency is an utopia, and acting on the border of systems' limits is unnecessary, let alone exceeding them.

7.2. The Proposal for an Integration of the Eco-GAME into a Larger Multi-Dimensional Evaluation

Earlier research proposed a model of multi-dimensional accounts and indicators—the Sustainability Compass [11,48,49]—representing thematic areas and their aggregated performance in pursuit of SDGs, in order to provide direction to sustainable individual agency and collective decision-making in daily life (see Table 12 and Figure 15).

Table 12. Sustainability Compass user manual [11,48,49].

Sustainability Compass User Guide			
Actor	Business	Consumer or Expert	Decision-Maker
1. Construction of the Sustainability Compass per sector: Which metrics of criteria can we use to evaluate the proposed themes? Which other themes can we propose?			
Innovation design	Think about how to design an innovation so that it can improve the indicators related to the themes proposed. Think whether the evaluation of the sustainability of the innovation would require new themes or indicators. If this is the case, please send a proposal		
Adoption, commercialization and support	Design the competitive strategy for the adoption and commercialization of the innovation through the themes and indicators proposed. Propose new themes or indicators if not present	Suggest models for markets, governance or public services that can promote more sustainable innovations, according to the themes and indicators. Propose new themes or indicators	Design market models, governance or public services to promote and support more sustainable innovations, according to the themes and indicators. Propose new themes or indicators
Cooperation	Propose and design cooperation models in support of more sustainable activities		
2. Self-evaluation: Measure your performance level according to themes and indicators of your sector. If some of them do not concern your activity, you can leave them blank by an adequate justification.			

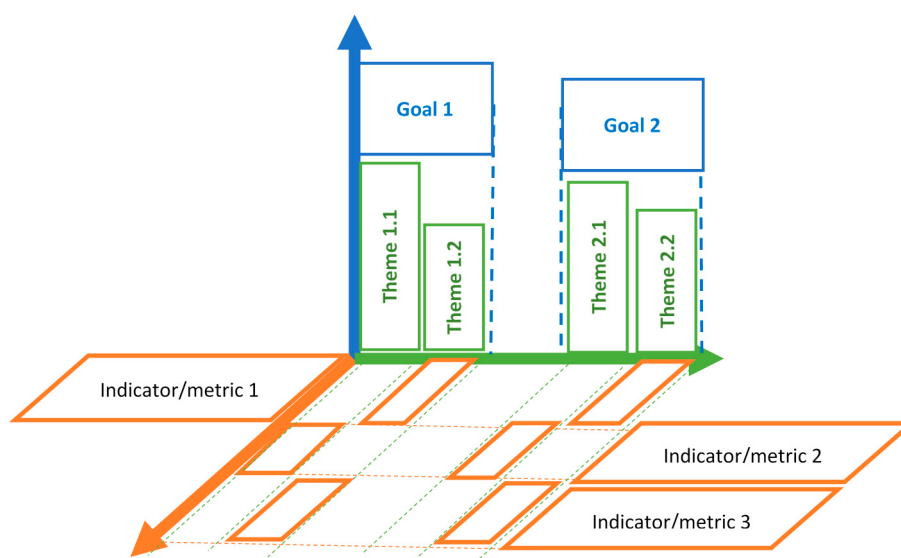


Figure 15. The structure of the Sustainability Compass, composed by goals, themes and practical indicators.

The Eco-GAME was already proposed in earlier publications [11] to complement the Sustainability Compass with a meta-evaluation for the determination of the weights w (see the formula below), expressing the relevance of each indicator for the achievement of SDGs.

$$\text{Sustainability Compass Index SCI} = \min x_i \frac{\sum_{i=1}^n w_i x_i}{\sum_{i=1}^n w_i} \quad (2)$$

The proposal for calculating the weight w is planned as the coefficient of variability of the single meta-evaluations e.g., (see Section 6), which is the ratio between the standard deviation and the average of the meta-evaluations, e.g., done on the same observation, composed by the object of analysis and the indicator or the method used for its assessment.

$$w_{(n, h, s, e)} = \frac{\sqrt{\frac{\sum_{i=1}^n (eg_i - \mu(eg))^2}{n}}}{\mu(eg)} \quad (3)$$

This proposal paves the way for an integrated Economic-Ecological model (Eco²) of multi-dimensional and systemic evaluation of the SDGs in support of governance for sustainability. This has already been proposed for a newly funded MAREA project, which strives to go “From MARine Ecosystem Accounting to integrated governance for sustainable planning of marine and coastal areas”.

The project, involving Finnish, Estonian and Latvian research and governance organizations, aims at supporting more sustainable planning in the two transnational pilot areas of Finland-Estonia in the Gulf of Finland and of Estonia-Latvia in the Gulf of Riga. Realistic high-resolution maps of ecosystem services in the pilot areas will aim specifically to avoidance of irreversible environmental impacts. These maps will benefit from the work carried out in BONUS MARES.

MARES will develop an innovative approach to integrate ecosystem structure and functioning with the benefits produced, including the regulating of services that sustain life. In particular, the project will advance the assessment methodology and take the cumulative impacts of human activities on the environment into account, by expanding the ecosystem accounting approach in the Baltic Sea environment and embedding it into a geospatial decision-support platform.

The Eco² will attempt to combine different metrics that could identify actions and the necessary performance levels in pursuit of Agenda 2030 and deepen understanding of the sustainable use of common/joint natural resources in the Baltic Sea area. This will facilitate the re-acquisition of a natural instinct to understand how human actions can be planned and performed according as embedded into natural cycles, which is the ultimate bottom line and basic capital to maintain and preserve. In the same way, the approach will facilitate understanding the most important human basic needs to be accomplished for well-being. This means building a culture that is composed by both ‘intellectual and moral virtues’ that are the way towards wisdom.

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Appendix A

Table A1. List of the participants in the expert meeting of the 3rd of December 2019.

	First Name	Last Name	Country	Organization	Type of Organization
1	Heini	Ahtiainen	Finland	HELCOM	Other
2	Juris	Aigars	Latvia	Latvian Institute of Aquatic Ecology	Research
3	Robert	Aps	Estonia	University of Tartu, Estonian Marine Institute	Research
4	Christine	Bertram	Germany	Kiel Institute for the World Economy	Research
5	Riccardo Giuseppe	Boschetto	Italy	ISPRA	Public/Governmental
6	Christiaan	Hummel	The Netherlands	Royal Netherlands Institute for Sea Research	Research
7	Herman	Hummel	The Netherlands	Royal Netherlands Institute for Sea Research	Research
8	Eduard	Interwies	Germany	InterSus—Sustainability Services	Other
9	Susanna	Jernberg	Finland	Finnish Environment Institute	Public/Governmental
10	Marina	Orlova	Russia	Federal budgetary scientific organization “Saint-Petersburg Research Center of the Russian Academy of Science” (SPBRC RAS)	Research
11	Anneliis	Peterson	Estonia	Estonian Marine Institute	Research
13	Paul	Tuda	Germany	Leibniz Centre for Tropical Marine Research (ZMT)	Research
14	Vassiliki	Vassilopoul	Greece	Hellenic Centre Marine Research	Research
16	Adam	Wozniczka	Poland	National Marine Fisheries Research Institute	Research
17	Maurizio	Sajeva	Finland	Pellervo Economic Research PTT	Research
18	Paula	Horne	Finland	Pellervo Economic Research PTT	Research
20	Mats	Godenhjelm	Finland	Pellervo Economic Research PTT	Research
21	Marjo	Maidell	Finland	Pellervo Economic Research PTT	Research
22	Wouter	Blankestijn	Sweden	Swedish University of Agricultural Sciences (SLU), Division of Environmental Communication	Research
23	Stina	Powell	Sweden	Swedish University of Agricultural Sciences (SLU), Division of Environmental Communication	Research
24	Tin-Yu	Lai	Finland	University of Helsinki	Research

Table A2. BONUS MARES—Participatory workshop, Suomenlinna, 13 and 14 February 2020, list of participants.

First Name	Last Name	Country	Organization	Expertise
Georgios	Angelakis	Greece	CHIEAM-MAICH	Business and management (E5)
Robert	Aps	Estonia	University of Tartu, Estonian Marine Institute	Baltic Sea (N2)
Wouter	Blankestijn	Sweden	Swedish University of Agricultural Sciences (SLU)	Environmental communication
Mats	Godenhielm	Finland	Pellervo Economic Research	Economics (E3)
Melanie	Heckwolf	Germany	GEOMAR	Marine biology (N3)
Hansen	Henning Sten	Denmark	Aalborg University	Ecosystem Services (H5)
Christiaan	Hummel	The Netherlands	Royal Netherlands Institute for Sea Research	Ecosystem services (H3)
Herman	Hummel	The Netherlands	Royal Netherlands Institute for Sea Research	Marine biology (N1)
Eduard	Interwies	Germany	InterSus—Sustainability Services	Ecosystem services valuation (E2)
Mark	Lemon	UK	De Montfort University	Systems' integration (S2)
Fiona	Nevzati	Estonia	Estonian University of Life Sciences	Ecosystem services (H1)
Kaisa	Karttunen	Finland	e2	Policy communication (S3)
Kristin	Kuhn	Germany	Leibniz University Hannover	Ecosystem services (H7)
Tanel	Ilmjärv	Estonia	Vetik OU	Business and management (E7)
Jonne	Kotta	Estonia	Estonian Marine Institute	Marine biology (S1)
Marjo	Maidell	Finland	Pellervo Economic Research	Economics (E6)
Kimmo	Mäkilä	Finland	Pellervo Economic Research	Science communication (S7)
Anneliis	Peterson	Estonia	Estonian Marine Institute	Marine biology (N5)
Stina	Powell	Sweden	Swedish University of Agricultural Sciences (SLU)	Environmental communication
Thorsten	Reusch	Germany	GEOMAR	Marine biology (S6)
Anda	Ruskule	Latvia	Baltic Environmental Forum	Ecosystem services (H6)
Maurizio	Sajeva	Finland	Pellervo Economic Research	Sustainability evaluation (H2)
Anni	Savikurki	Finland	e2	Policy communication (S4)
Lise	Schroeder	Denmark	Aalborg University	Baltic Sea (N7)
Meelis	Sirendi	Finland	BONUS EEIG	Baltic sea (S5)
Vassiliki	Vassilopoulou	Greece	Hellenic Centre Marine Research	Marine biology (N4)
Adam	Wozniczka	Poland	National Marine Fisheries Research Institute	Marine biology (N6)

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