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Perspectives and Scenarios for Coastal Fisheries in a Social-Ecological Context: An Ecosystem Service Assessment Approach in the German Baltic Sea

Miriam von Thenen [1,*], Nina Effelsberg [1], Lars Weber [1] and Gerald Schernewski [1,2]

[1] Coastal & Marine Management Group, Leibniz Institute for Baltic Sea Research Warnemünde, Seestrasse 15, D-18119 Rostock, Germany; gerald.schernewski@io-warnemuende.de (G.S.)
[2] Marine Research Institute, Klaipeda University, Universiteto Ave. 17, LT-92294 Klaipeda, Lithuania
* Correspondence: miriam.thenen@io-warnemuende.de; Tel.: +49-381-5197158

Abstract: Worldwide, fisheries have experienced change over time. An excess of exploitation for providing food has led to overfishing and the depletion of fish stocks. However, fishing communities are also part of the cultural heritage and contribute to the attractiveness of coastal areas to tourists. Our aim is to identify if ecosystem service assessments (ESA) can reflect the condition of fisheries and their economic and social aspects. We developed a tailored, expert-based ESA and applied it to two case studies in the eastern German Baltic Sea under different fishery management scenarios. The results show that reducing fishing pressure, actively restoring habitats, and improving their ecological status increase the provision of most ecosystem services. We discuss and conclude that ESAs allow for a holistic view on fisheries that goes beyond the economic importance of fisheries and shows both the interdependence between fisheries and healthy marine ecosystems, and their relevance for coastal communities. Such a holistic view is necessary for a sustainable approach to fisheries management. Our approach is easily transferable to other regions, and can be used to structure discussion on fisheries management scenarios, as well as to track and visualize societal changes.

Keywords: small-scale fishery; cultural heritage; coastal management; Greifswald Bay; social—ecological system; marine protected areas; good ecological status

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1. Introduction

Fishing, as an anthropogenic activity, dates back to ancestral hominins and early modern humans [1]. It evolved from subsistence to barter and then to trade. Fish as a trade commodity, and the first signs of extensive fishing activities, were already present in the Mediterranean during the Iron Age [1]. In northern Europe, the herring fishery formed the backbone of the wealth of the Hanseatic League of trading cities in the Middle Ages, characterized by the extensive commercialization of herring [1,2]. In the Baltic Sea, herring shoals were so abundant that, according to written records, they could even be caught by hand [2,3].

With the industrialization and development of modern fishing techniques and preservation methods, extensive fisheries increased rapidly, producing surplus fish as a commodity for the market and resulting in overfishing and the depletion of fish stocks from the 1950s onwards; e.g., the North Sea herring fish stocks were almost driven to extinction by the 1960s [1]. Early examples of fishery regulations exist [1], but modern international fisheries laws and regulations only came into existence after the agreement on the United Nations Convention on the Law of the Sea (UNCLOS) in 1982, which defined that fish stocks should be maintained or restored to produce a maximum sustainable yield [4]. In Europe, a new generation of the Common Fishery Policy (CFP) was established just a year later, including management measures such as total allowable catches and quotas [5].

In the 20th century, there was a shift in how fisheries were perceived, from a divine task to feed humankind with limitless resources towards fisheries as the source of the overexploitation of fish stocks and destruction of marine habitats, while fishery management was increasingly targeted at protecting marine ecosystems [6]. The management of marine living resources has become an environmental issue and a subset of environmental politics [6] with controversial debates, as perceptions on the main reason for declining fish stocks can vary considerably between fishers, scientists, and politicians [7]. Fishers often perceive themselves as victims of a restrictive fishery policy and false representation in the media [8,9]. However, when it comes to the implementation of policies, environmental protection has long played a subordinate role to fisheries, at least in the EU [6]. Moreover, marine protected areas (MPAs) are often not effectively managed and hardly exclude fishing activities. They may even attract fisheries; a recent study showed that 59% of the European MPAs are trawled commercially and that fishing efforts are higher inside MPAs than outside those areas [10].

The coverage of MPAs in European sea basins will increase in response to the EU Biodiversity Strategy, which set a target to protect 30% of marine areas by 2030, of which 10% should be strictly protected. While fisheries depend on healthy fish stocks, which marine conservation can provide, the protection of marine areas is often met with resistance from the fishing sector due to access restrictions [11], and references therein. The foreseen increase in MPA coverage may exacerbate competition for the use of fishing grounds. In addition, the MPAs are supposed to be effectively managed, which will include, in some areas, the prohibition of mobile bottom-contacting fishing gear, further increasing pressure on fisheries. As the ban on fishing from MPAs is negotiated under the CFP, which is already largely distrusted by fishers, e.g., [12], it can be expected that they may feel again as bystanders in decisions that have severe impacts on their livelihoods.

While restrictive fishery regulations are one side of the coin, the other side also includes the support for maintaining fishing communities. Fishing communities and their populations have become an important aspect of fisheries management [13], and small-scale fisheries are specifically supported by the UN Sustainable Development Goals (SDG 14b). In Europe, small-scale fisheries have received little attention historically. However, this is changing because of resource crises and unsustainable practices of the larger-scale fisheries [14]. Small-scale and artisanal fisheries and the associated craftsmanship are an important part of the local cultural heritage in many coastal regions, as an identity-forming component of the occupational everyday culture. The fishing activities can furthermore increase the tourist attractiveness of coastal areas [15,16], and tourism in turn increases demand for local seafood [17].

In the Baltic Sea, tourism is an important economic sector. In the southern Baltic Sea, with its many natural beaches, tourists choose their destinations mainly because of those beaches [18]. The tradition of coastal fishing, with many small fishing harbors and the local sale of fish, can add to touristic attractiveness [19–21]. At the same time, many fish stocks in the Baltic Sea are in decline due to overfishing and climate change, generating negative headlines in the media, and the eutrophic state of the Baltic Sea often leads to algal blooms in the summer, both of which decrease touristic attractiveness but can also have adverse impacts on fisheries [22].

The future of especially small-scale fisheries in the Baltic Sea is uncertain and depends very much on how the fish stocks will evolve under climate change, if measures to restore them will be successful, and indeed what kind of measures will be implemented to not just restore fish stocks but also to maintain fisheries and fishing communities. The relevance of fisheries should thereby not only be measured in terms of profit but also in terms of their historic and cultural value for coastal communities [23]. There has been a change in the role, perception, and relevance of fisheries and fishers over time from providers of food to problematic exploiters of living resources, towards the preservation of their cultural heritage and attractiveness to tourists. However, is it possible to assess these ecological—social—economic changes holistically?

The ecosystem service concept provides a holistic and anthropocentric view on the (human) environment. Ecosystem services (ES) can be defined as the direct and indirect contributions of ecosystems to human well-being and are divided commonly into the categories of provisioning, regulating and maintenance, and cultural services [24]. Our aim was to develop an expert-based ecosystem service assessment (ESA), apply and evaluate the approach in two case studies in the eastern German Baltic Sea with distinct socio-economic settings, and critically evaluate the approach with respect to its applicability, transferability, and suitability for contributing to a sustainable approach to fisheries and management measures.

2. Materials and Methods

2.1. Study Area

The study area in the eastern German Baltic Sea stretches from Greifswald Bay (GWB, coastal case study) to the Pomeranian Bay—Rönnebank (PBR, offshore case study). Among the connecting features are the Natura 2000 areas, which cover the entire Greifswald Bay and most parts of the Pomeranian Bay—Rönnebank (Figure 1).

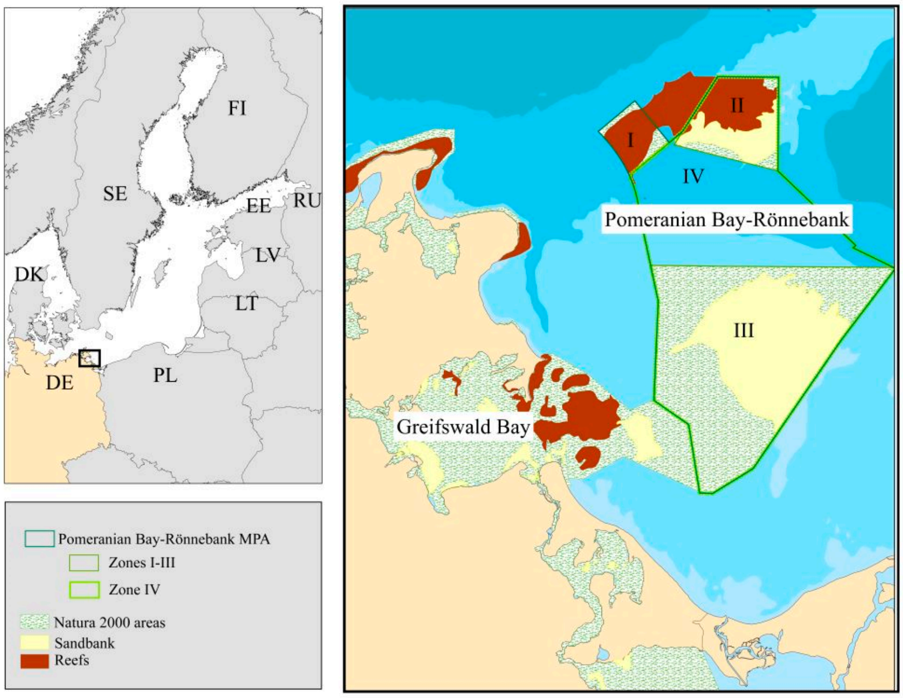

Figure 1. The Baltic Sea and the study sites Rönnebank—Pomeranian Bay and Greifswald Bay in the eastern part of the German Baltic Sea coast. The numbers I–IV refer to the different protection regimes (see text).

In addition to the Natura 2000 areas, Greifswald Bay harbors twelve designated nature reserves, five landscape protection areas and one UNESCO biosphere reserve in the northern part of the bay. The protected areas aim to preserve the varied coastal formations in the bay, such as salt marshes, reed belts, macrophytes, and shallow water areas with sandbanks as well as boulders, reefs, and sandy and muddy bottoms. The variety of habitats provides favorable spawning and feeding conditions for many fish species, both freshwater and marine ones. Greifswald Bay harbors many different fish species and it is an important spawning ground for the western Baltic herring stock [25]. Nowadays, only passive fishery is allowed, except for a special kind of bait fishing with trawls [26].

The Pomeranian Bay—Rönnebank is protected as a nature reserve according to the Protected Area Ordinance; in 2017 it gained the status of a "special protection area", which is protected under national law and was reported to the Helsinki Commission as a HELCOM MPA. The Pomeranian Bay—Rönnebank MPA represents a complex area that contains different protection regimes. Areas I-III, as shown in Figure 1, were included in the list of Sites of Community Importance (SCI) in the EU Habitats Directive (92/43/EEC) in 2008. The target habitats are reefs (areas I and II) and sandbanks (areas II and III) and the targeted species include harbor porpoises (area I–III), grey seals (area II), sturgeon, and twait shad (area III). Area IV was designated as a nature reserve in 2005 and was included in the list of Special Protection Areas (SPA) as a bird sanctuary for permanently residing as well as migratory species. A number of uses are forbidden in the Pomeranian Bay—Rönnebank. The prohibition of uses does not apply, explicitly, to shipping, military use (under international law), marine research (subject to some provisions) and commercial fishing. Since February 2022, a management plan for the Pomeranian Bay—Rönnebank MPA exists, consisting of several measures to achieve the protection targets [27]. With respect to fisheries, the main measure is aiming at an ecosystem-based management of fisheries in the scope of the CFP of the EU. As part of the development of a Common Recommendation for all Natura 2000 areas in the German Exclusive Economic Zone (EEZ) of the Baltic Sea, fishery management measures for mobile bottom-contacting gear were developed. These measures are adopted in the management plan for information purposes only, as they do not yet have a legal status and are still being discussed in the scope of the CFP and with neighboring countries. The measures include the prohibition of mobile bottom-contacting gear in (parts of) the Natura 2000 areas. In the Pomeranian Bay—Rönnebank MPA, this applies to areas I and II, and parts of area III. Another measure in the management plan aims at testing the possibility to perform active restoration of geogenic reefs.

2.2. Development of Scenarios and Selection of Ecosystem Services

We developed different management scenarios for each study site. The baseline scenario in each case represents the reference scenario to which the other scenarios are compared [28]. We developed the scenarios in a qualitative, descriptive way, drawing on official reports that provide hints for future management directions. These reports are from the Federal Agency for Nature Conservation, the Federal Maritime and Hydrographic Agency and the European Commission. The scenarios show possible future developments if certain policy decisions, regarding the allowed fisheries or the ecological state, were to be taken.

For the Pomeranian Bay—Rönnebank, the baseline scenario is a reference scenario for an undisturbed state of the area, i.e., no trawling activities taking place in the MPA. The scenario was visualized following the official definition by the EU of the habitat type “sandbanks which are slightly covered by sea water all the time” [29] (p. 8). The first scenario shows the area with the impacts of bottom trawling. Otter trawls can penetrate into silty fine sands up to 15 cm deep and up to 5 cm in sands [30]. For the second scenario, it is assumed that all fishing activities have been banned in the Rönnebank MPA and that a restoration measure—the insertion of geogenic hard substrates—has been implemented. This scenario was inspired by the management plan of the Pomeranian Bay—Rönnebank MPA, which foresees such a measure [27].

The baseline scenario for Greifswald Bay represents the current situation, in terms of ecological status and allowed fisheries. The present benthic aquatic plant diversity is low, with eelgrass (*Zostera marina*) being the predominant submerged macrophyte [31] and emergent vegetation being rare [32]. Water transparency is less than 2 m and hypoxia can occur occasionally [33,34]. Passive fishing gear is allowed [35]. The first scenario portrays a situation where the Good Ecological Status (GES) according to the Water Framework Directive is achieved and no commercial fishery takes place. The second scenario features the same ecological conditions as the baseline scenario but with the difference that both passive and active fishery are allowed and carried out in Greifswald Bay.

2.3. Ecosystem Service Assessments and Expert Interviews

Relevant ecosystem services for the case study sites were selected based on the Common International Classification of Ecosystem Services (CICES, V5.1), which presents a hierarchical definition of ecosystem services, divided into the categories “provisioning ES”, “regulating and maintenance ES” and “cultural ES”. For the Pomeranian Bay—Rönnebank, 16 ecosystem services were selected. The selected ecosystem services for Greifswald Bay have two additional cultural ecosystem services ("cultural and heritage", "landscape aesthetics") to account for the nearshore area of the study site. The selected ecosystem services and their definitions are presented in Table 1. Selection criteria for the choice of ecosystem services were the relevance to the topic and to the study area.

Table 1. The selected ecosystem services and their definitions.

	Ecosystem Service	Description
Provisioning service	Cultivated plants in aquaculture	Algae for food supply; seaweed as an insulating material, for cosmetics, as a source of energy (biogas powerplant)
	Wild plants	Benthic macroalgae and macrophytes harvested in the shallow sublittoral and littoral zone; macroalgae used for thickening agents, agar, and superconductor electrodes, in cosmetics; algae for energy production
	Cultivated animals in aquaculture	Seafood (mussels, fish); biogas from aquaculture waste
	Wild animals	Seafood (mussels, fish); zooplankton—jellyfish used to produce collagen for various purposes (materials, medicinal, biochemical, and genetic resources)
	Minerals	Sand extraction or nutrients, e.g., used for agriculture
	Sea space	Usable area for energy conversion (e.g., solar power, wind power, waterpower); use of water by commercial ships (e.g., cargo, gas, ferries); provision of space for construction (e.g., fairways)
Regulating and Maintenance service	Bioremediation	Detoxification of contaminants in soil and water; fixation by micro-organisms, plants, and animals
	Nutrient regulation	Denitrification; storage and fixation of nutrients
	Sediment stabilization and reallocation	Control of erosion; sediment displacement
	Gamete and seed dispersal	Self-regeneration of plants after disturbance by, e.g., bottom trawling; for the restoration of, for example, seagrass beds
	Nursery populations and habitats maintenance	Providing habitats for wild plants and animals that can be useful to us (nursery for several fish species, feeding and wintering area for sea birds and endangered sea mammals), including gene pool protection
	Biodiversity water column	Animals and plants biodiversity as benefit for humans
	Biodiversity benthic	Animals and plants biodiversity as benefit for humans
	Habitat diversity	Provision of suitable habitats for different species, for functional groups of species and for processes (abiotic and biotic parameters)
	Regulating carbon	Regulation of chemical composition of atmosphere and oceans by sequestration of carbon (climate regulation)
Cultural services	Active recreation	Using the environment for sport and recreation, e.g., diving, fishing, boat trips, sailing
	Nature aesthetics	Observational interactions with nature, e.g., wildlife watching (birds, seals, harbor porpoise); enjoyment of landscape
	Cultural and heritage	Things in the ecosystem that help people to understand the history or culture of where they live or come from, such as a historic village or city, a traditional fishing ground, history of sailors, or finding historic items that contribute to cultural heritage
	Science and education	Site of special scientific interest (Natura 2000) and for educational purposes
	Landscape aesthetics	The inherent beauty of nature
	Existence and bequest value	Value of nature as something to preserve for itself (species, habitats) and for future generations to enjoy

In each study site, the assessment was carried out by eight experts. Expert elicitation for ecosystem service assessments is common in ES research and can provide valuable local or regional knowledge [36–38]. We identified and contacted multiple local and regional experts in the fields of marine conservation, marine science, and fisheries in the Baltic Sea, who have a thematic or spatial relation to either one of the case study sites. This resulted in a spatial and professional limitation of the potential interview partners. In the Pomeranian Bay—Rönnebank case, the experts were contacted based on their knowledge of marine processes, benthic habitats, and bottom trawling. Eight experts agreed to take part in the Rönnebank MPA assessment. They came from two research institutes, a university, a federal agency, and a state agency, and covered expertise in ecosystem services, bottom-trawling impacts, benthic habitats, and marine management. In the case of Greifswald Bay, the experts were contacted based on their knowledge of fisheries (including fishing techniques, ecology, and socio-economic analyses), ecosystem services, and coastal zone management. Eight experts agreed to take part in the Greifswald Bay assessment. They came from three different research institutes with different thematic topics (fisheries, integrated coastal zone management, ecology, and social sciences) and covered expertise in ecosystem services, fishing techniques, and the Greifswald Bay ecosystem. The assessments were carried out in 2020 (Rönnebank MPA) and 2023 (Greifswald Bay).

The assessment sheets were adapted from [28] and were sent to the experts by email. An exemplary assessment sheet can be found in Table S1, along with the individual assessment scores given by the (anonymized) experts. Attached to the email was a guideline for the assessment with meta information, an instruction for the assessment, and a description of the scenarios. The assessment sheets contain the list of ecosystem services and their description (rows), and the scenarios (columns). The experts were asked to assess the relative importance (RI) of each ES for the respective case study area, ranging from 0 (no importance) to 8 (highly relevant) with steps 1, 2, and 4. Subsequently, the experts compared the baseline scenario to scenario 1 and scenario 2, respectively, and assessed the changes in the provision of each ES on a relative scale from −3 (very high decrease in the provision of an ES) to +3 (very high increase in the provision of an ES), with zero indicating no changes.

The expert-based assessments were complemented with interviews in the case of the Pomeranian Bay—Rönnebank. After completion of the assessment, a follow-up interview with each expert was carried out in the form of a guided expert interview. The guided expert interview is a widespread and methodologically well-elaborated method for obtaining expert knowledge [39,40]. The aim of the interviews was to clarify any questions the expert had, to discuss some points of the assessment that stood out or were unclear to the interviewer and to ask the expert opinion about the assessment of ecosystem services in general, and in particular for this study. The detailed method and results of the interviews are documented in [41]. Here, we only draw on the interviews to explain assessment results that seem contradictory.

The results of the Greifswald Bay assessment were to a large extent sufficiently clear and well explained in the comment section of the assessment sheet. Therefore, it was not necessary to conduct formal follow-up interviews with all the experts. Instead, only some experts were contacted to clarify any misunderstandings or to inquire about conspicuous assessment results. We furthermore complemented the expert-based assessment by reviewing regional statistics and reports on fisheries and tourism, and by drawing on scientific studies on the fish species and ecological conditions, in order to place the expert assessments in the social—ecological context of the case study area. The regional statistics on fisheries were obtained from the State Office for Agriculture, Food Safety and Fisheries Mecklenburg-Western Pomerania. The State Office publishes landing statistics of the small-scale coastal fisheries every year, since 1989, for each of the official fishing areas. Greifswald Bay is one of these fishing areas. The statistics on tourism were taken from the Statistical Office of the State Office for Internal Administration in Mecklenburg—Western Pomerania. The Statistical Office has published yearly tourism statistics since 2003.

3. Results

3.1. Relative Importance of Ecosystem Services in Greifswald Bay and the Rönnebank MPA

The provisioning service "wild animals" is regarded as the most relevant for both Greifswald Bay (Median: 8) and Pomeranian Bay—Rönnebank (Median: 6) by the experts (Figure 2). However, in the Pomeranian Bay—Rönnebank, the experts' opinion on this ES are also the most divergent, with an importance score ranging from 0 (not relevant) to 8 (highly relevant). Another provisioning service that, overall, was perceived as relevant, though with a scattering of scores, is sea space. In Greifswald Bay, the median expert score is 4, the second highest score among the provisioning ES; in the Rönnebank MPA, the median score is two, and, along with the provisioning ES "minerals", also has the second highest score.

The relative importance of the regulating service "nursery populations and habitat maintenance" is regarded by all experts as either high or very high (Median: 8, for both Greifswald Bay and Rönnebank MPA) (Figure 2). In addition, "habitat diversity" received high or very high scores, with median scores of 4 (GWB) and 6 (PBR). The regulating services of "biodiversity water column" and "biodiversity benthic" also received a median score of 4, but with a wider scatter ranging from low (biodiversity water column) and moderate (biodiversity benthic) to very high importance.

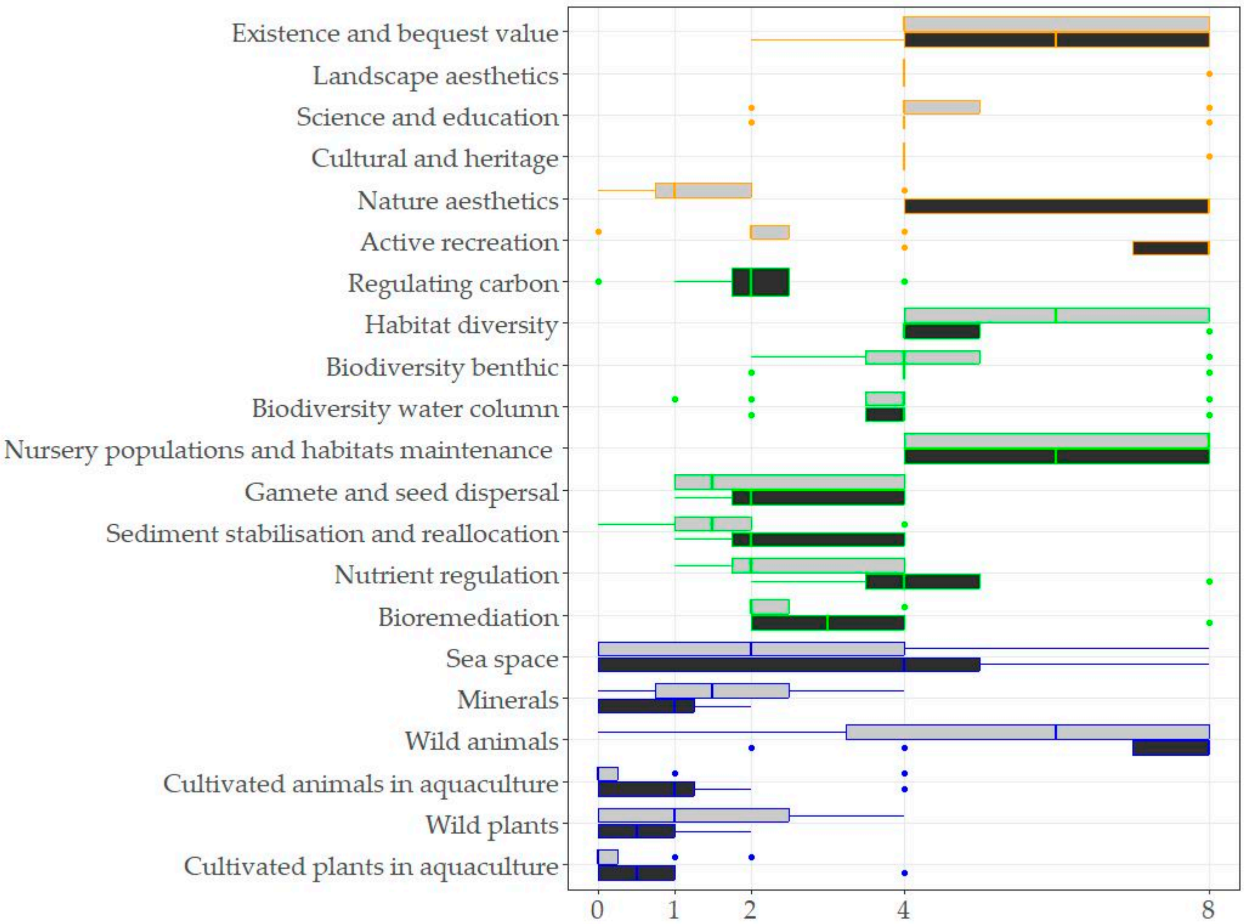

Figure 2. The relative importance of ecosystem services in Pomeranian Bay—Rönnebank (grey) and Greifswald Bay (black), for each ecosystem service category (blue: provisioning; green: regulating and maintenance; and orange: cultural). The scores range from 0 (irrelevant) to 8 (very important). The figure shows the boxplots of the impact scores given by the experts. The horizontal bars show the range of the first to the third quartile, with the vertical lines depicting the median. The horizontal lines depict the whiskers, based on the 1.5 interquartile range value, and the points depict the outliers.

Cultural services are regarded as the most divergent by the experts from Greifswald Bay and Pomeranian Bay—Rönnebank. In Greifswald Bay, the services "active recreation" and "nature aesthetics" received only high to very high importance scores, whereas in the Rönnebank MPA, these two services are perceived as much less important (median scores of 2 and 1, respectively) (Figure 2). The "existence and bequest value" service was, overall, also perceived as quite important for Greifswald Bay (Median: 8). In the Rönnebank MPA, this service was perceived as the most important cultural service for the area, along with "science and education", though with lower scores than in Greifswald Bay. Two cultural services, "cultural and heritage" and "landscape aesthetics", were only assessed for Greifswald Bay, and both have an overall high relative importance.

3.2. Impacts of Management Scenarios on Ecosystem Services: Pomeranian Bay—Rönnebank

Scenario 1: Trawling

The impacts of trawling in the Pomeranian Bay—Rönnebank would result in a decrease in ecosystem services, according to the experts. The highest decrease in the provisioning services overall is associated with "wild plants" and "wild animals" (Figure 3). However, two experts also foresee a low to high increase in "wild animals". In the follow-up interviews, it became clear that one of these experts referred to the use of the ecosystem service (if there is trawling, more fish are caught) and the other foresees a small increase in small disturbances (by bottom trawling) increasing biodiversity through bioturbation, though only if bottom trawling in the area is not too intensive. For "minerals", most experts do not foresee any impacts (no increase or decrease), as the scenario does not affect the availability of sand. For the regulating services, a decrease is especially seen in the "biodiversity benthic" and also in the "habitat diversity", "nursery population and habitats maintenance" and "bioremediation" services. The only increase in regulating services under this scenario was assessed by one expert for the "biodiversity water column" and was based on an expected increase in nutrient supply and a decrease in feeding pressure by filter feeders; however, the expert commented that this presumption was weakly supported. The impacts of trawling on cultural services are regarded to be highest for the "existence and bequest value" (Median: -2), with a medium decrease in "active recreation" and "science and education". One expert foresees a low increase in "science and education", argued from the point of view of environmental education or science, which makes a disturbed area interesting to study (in comparison to an undisturbed area).

Scenario 2: Reef restoration

The use of geogenic hard substrate in the Rönnebank MPA would, overall, result in an increase in ecosystem services, according to the experts; however, there is less consensus in the scoring by the experts for this scenario. The overall highest increase in the provisioning services is foreseen for "wild animals" (Figure 3). However, one expert assessed this service as being not impacted and another expert expects a high decrease in "wild animals", due to a confusion with the provision and use of the ES, as the expert argued that there is a decrease in "wild animals" (i.e., a decrease in fish catches, according to the expert) because no fishing is allowed. The impacts on "minerals" are perceived as having a low to medium decrease, or none at all.

According to the experts, the regulating services mostly increase under this scenario, with the highest increase expected for the "nursery populations and habitats maintenance" and the "biodiversity benthic", with less consensus also for "habitat diversity".

An overall low increase is expected for all cultural services. However, one expert foresees a low decrease in "science and education" and two experts expect a low decrease in the "existence and bequest value". With respect to the latter, one expert commented that the value decreases because of human interference when adding hard substrates.

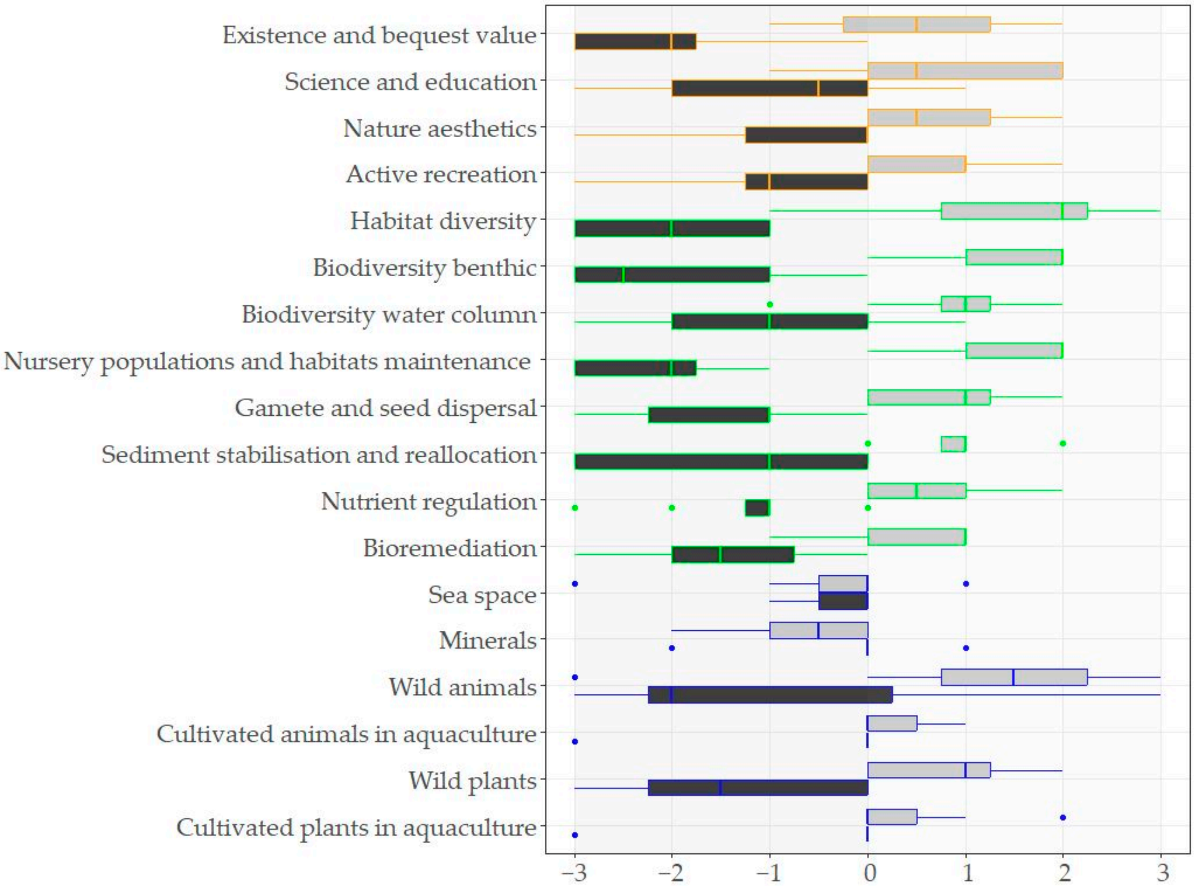

Figure 3. The relative changes in ecosystem services in the Pomeranian Bay—Rönnebank from the baseline scenario (no trawling) to Scenario 1 (black; trawling) and Scenario 2 (grey; reef restoration), for each ecosystem service category (blue: provisioning; green: regulating and maintenance; and orange: cultural). A score of 3 represents a high increase and a score of −3 a high decrease in ES. The figure shows the boxplots of the experts' scores.

3.3. *Impacts of Management Scenarios on Ecosystem Services: Greifswald Bay*

Scenario 1: Good Ecological Status without fishing activities

Scenario 1 mostly results in an increase in the ecosystem services in Greifswald Bay, especially in the regulating services (Figure 4). For the provisioning service "wild animals", there are divergent perspectives as to whether or not the ban on fishing and improved ecological status would result in a decrease in that service; the scores range from −1 (low decrease) to 3 (high increase). With respect to the expected decrease in the provisioning service "cultivated animals in aquaculture" by two experts, one of them commented that the decrease in eutrophication results in less food for cultured animals. The highest increase in provisioning services is expected to be for "wild plants" (Median 1); two experts commented that a ban on fishing relieves the benthic plants of disturbances, resulting in a higher provision of wild plants.

The highest increase in regulating services is expected for "habitat diversity" (Median: 3), "biodiversity benthic" and "nursery population and habitats maintenance" (Median: 2.5) (Figure 4). Only one expert foresees a decrease in the regulating services "bioremediation", "nutrient regulation" and "regulating carbon".

The provision of the cultural services "active recreation", "science and education", and "existence and bequest" would experience the highest increase (Median: 2) under this scenario, according to the experts. Only for "cultural and heritage" some of the experts expect a low to high decrease. Two experts commented that a ban on fishing would result in the loss of the fishing tradition in Greifswald Bay.

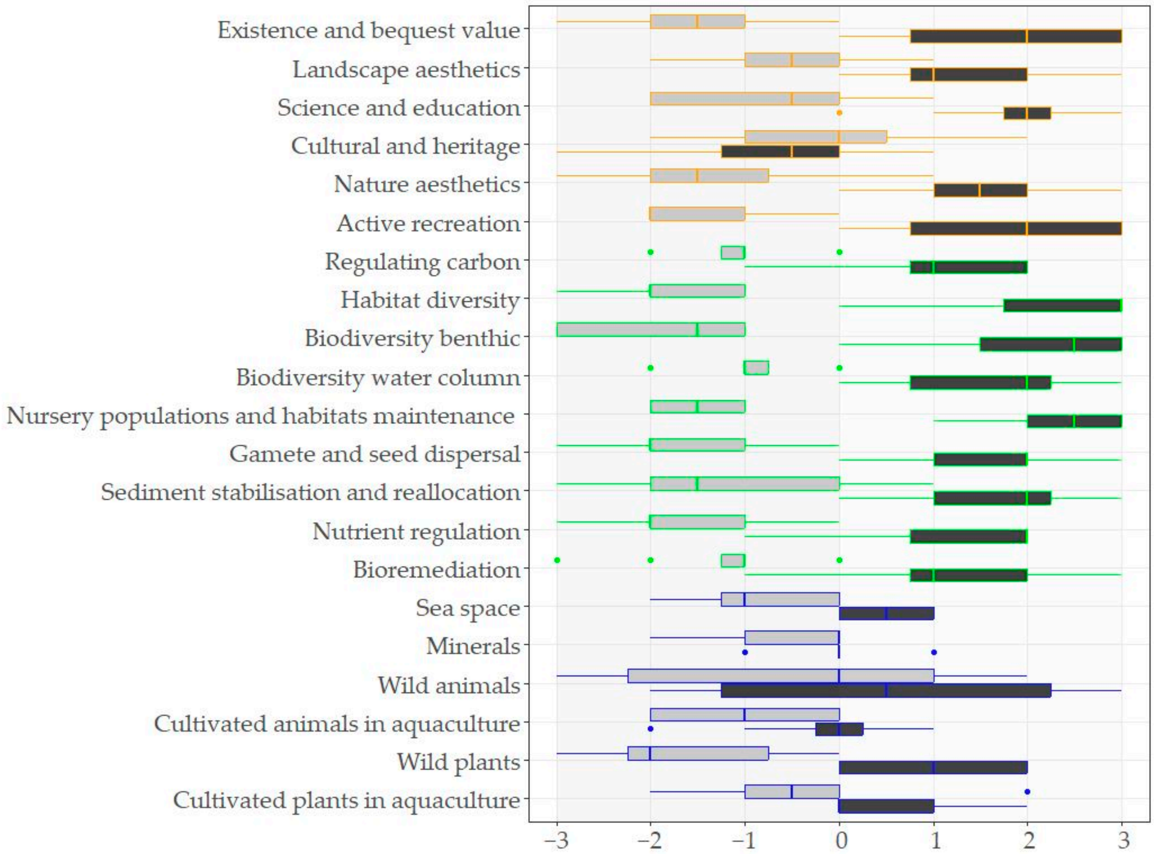

Figure 4. The relative changes in ecosystem services in Greifswald Bay from the baseline scenario (current ecological status and passive fishery) to Scenario 1 (black; good ecological status without fishery) and Scenario 2 (grey; current ecological status and a passive as well as an active fishery), for each ecosystem service category (blue: provisioning; green: regulating and maintenance; and orange: cultural). A score of 3 represents a high increase and a score of −3 a high decrease in ES. The figure shows the boxplots of the experts' scores.

Scenario 2: Current ecological status with passive and active fishery

The permission of both active and passive fishing gear in Greifswald Bay would result in an overall decrease in ecosystem services, according to the experts. The highest decrease in the provisioning services is expected for "wild plants" (Median: −2) (Figure 4). Divergent perspectives among the experts exist with respect to "wild animals", with scores of −3 (high decrease) to 2 (medium increase). The provisioning service where a majority of experts foresee no impacts is "minerals".

For the regulating services mostly low to high decreases in the provision of services is expected, with one exception (Figure 4). The overall highest decreases are expected for "nutrient regulation", "seed dispersal" and "habitat diversity". Only decreases are expected by all experts for the services "nursery population and habitat maintenance", "biodiversity benthic" and "habitat diversity".

Mostly, decreases are also foreseen for the cultural services, with the highest decrease in "active recreation". The most divergent perspectives occur in the assessment of "cultural and heritage", with scores including no impact, a medium decrease, and a medium increase.

3.4. The Ecosystem Service Assessments within the Social-Ecological Context of Fisheries

The most important provisioning service for both Greifswald Bay and the Rönnebank MPA is "wild animals", in the experts' perception. For centuries, Greifswald Bay has been an important fishing ground in the Baltic Sea, especially for one specific fish species—herring (*Clupea harengus*). Until 2000, 60–70% of all herring caught in German coastal waters came from Greifswald Bay and up to 50% of all fish [42], even though the bay only covers an area of ~500 km^2. In comparison, the Rönnebank MPA covers an area of ~2000 km^2 but the ecosystem service of "wild animal" is not considered as relevant for this area by the experts. The catches of all fish species from the last three decades in the coastal waters of Mecklenburg—Western Pomerania (MV) show a continuous decline from 2015 onwards. In Greifswald Bay, the decline had already started by the end of the 2000s, and here primarily due to the decline of the herring fishery (Figure 5e). Fishing boats moored in the harbor are now a common sight in Freest, which is located in the southeastern part of the bay and is one of the most important fishing harbors in the area (Figure 5a). However, the local fishing cooperative is still an important employer, with 24 active fishers and 23 employers on land as of 2019 [43]. In addition, the fishery forms an important part of the town identity and culture (e.g., fishing festivals), fish restaurants and stalls are common and attract tourists (Figure 5b). Tourism has been on a continuous rise (except for during the pandemic years) in MV since the reunification of Germany, and small marinas with sailing boats have become a common sight (Figure 5c,f). There is a temporal, though not a causal, coincidence in this development, and, in terms of employment, tourism has overtaken the importance of fisheries.

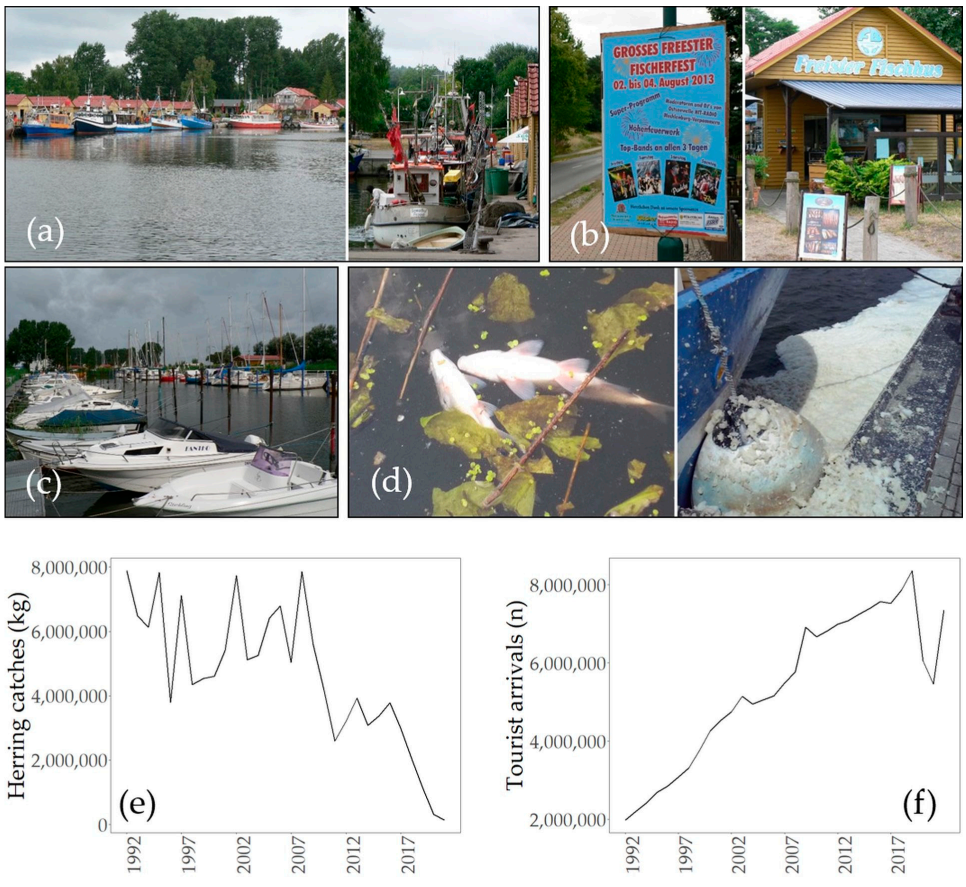

Figure 5. Social-ecological characteristics of the case study area: the fishing harbor of Freest at Greifswald Bay (**a**); with fish festivals and fish restaurant (**b**); increasing recreational uses such as sport-boat harbors (**c**); and environmental problems (**d**). The herring catches from Greifswald Bay decreased from 2010 onwards (**e**), whereas tourism numbers have been on a continuous rise for 30 years (numbers shown for the entire state of MV) (**f**). Graphs on fish and tourism statistics are based on data from [42,44]. Photos by G. Schernewski.

The decline of the fishery in Greifswald Bay is partly caused by overfishing. The herring in the bay is managed as part of the western Baltic Sea herring stock, which has experienced high fishing pressure for several decades [45]. In the case that no more fishing would occur, the assessment results show an expectancy of an increase in the service provision, i.e., more fish becomes available again. This would certainly be the case, to some extent. What the assessment does not reveal is that overfishing is not the only problem or cause of declining herring fish stocks in Greifswald Bay. The main cause seems to be climate change and the associated increasing water temperatures, which result in a temporal mismatch of herring larvae and their food source, namely, zooplankton [46]. There are a range of other pressures (summarized by [47]), including eutrophication and the resulting decline in vegetation, since herring attach their eggs to vegetation [25].

The ecological status of Greifswald Bay is unsatisfactory in the classification of the Water Framework Directive, in particular with respect to phytoplankton and other aquatic fauna [48]. The target values for water transparency (Secchi depth) are not met, nor are those for nitrogen and phosphorus compounds. The elevated nutrient levels in the Baltic Sea since the 1950s have fueled primary production, which has contributed to high fish production in the past [49]. However, eutrophication has also led to a decline in the distribution of macrophytes, reducing spawning grounds for important fish species [50]. Excess nutrient inputs can furthermore cause algae blooms, occasionally resulting in hypoxia and, subsequently, fish kills (Figure 5d). The high nutrient inputs have also driven the increase in cyanobacteria blooms that deteriorate water quality, with negative impacts on the recreational use of coastal waters [51]. An improvement in the ecological status of Greifswald Bay would thus be beneficial for fish habitats as well as for recreational use, which is also reflected in the expert-based assessment.

Recreational use becomes less important the further away the focus area is located from the coast, which is reflected in the relative importance score of the Pomeranian Bay—Rönnebank assessment. Recreational use is also less impacted by fishing activities or a ban thereof in the offshore area. The more relevant cultural service in the offshore area is "existence and bequest", which decreases when bottom trawling takes place, according to the experts. As the "existence and bequest" service decreases along with habitat diversity and benthic biodiversity, as well as nursery populations and habitat maintenance in the bottom-trawling scenario, it can be assumed that these habitats have an existence and bequest value. In the Pomeranian Bay—Rönnebank MPA, the protected habitats include reefs and sandbanks (cf. Section 2.1). The German Federal Nature Conservation Act furthermore protects the macrophytes biotope. This represents the areas with the locally highest species diversity in the MPA despite their small-scale distribution. These areas are furthermore used by many mobile species, including both invertebrates and fish, for protection from predators [52]. The macrophyte stands are mainly associated with the reef areas of the MPA (area II), where no bottom trawling occurs, and, to a lesser extent, with hard soils and fields with mussel shells in area III, where bottom trawling indeed takes place.

4. Discussion

4.1. Transferability of the Assessment Approach: ESAs in Data-Scarce Regions

The context of the case study area—declining fisheries, changing employment patterns, environmental degradation—is similar to other coastal regions and fishing communities in Europe [53,54]. The socio-economic context may differ, the allowed fishing techniques vary and also the scale of the environmental problems; however, one common aspect is the decline in fish catches. The approach, as such, can be easily applied to other European coastal regions. The ecosystem services in this study are generally defined enough to be applied somewhere else and follow CICES, the ecosystem service classification most commonly used in Europe [55].

To what purpose, though, may the approach be applied? In Europe, fishing is regulated by international and national laws and at the onset, the CFP was very much a top-down approach, which changed somewhat through the establishment of Regional Advisory Councils (RAC) [56]. However, the RACs did not manage to truly involve local stakeholders and communities in the decision-making processes, which is a prerequisite for the co-management of fisheries. Co-management, or community-based management of fisheries, has (re)emerged as a sustainable approach to fishery management. It requires the active participation of fishers and taking collective choices and decisions that are prioritized over individual needs [56]. In such a context, our approach is supportive in bringing together local stakeholders. It helps to structure and guide a discussion process, can gather different perspectives on alternative management scenarios, and supports a holistic understanding of the interactions between resource use, the natural environment, and cultural impacts. Such a holistic view is a prerequisite for a sustainable approach to fisheries and management measures [57–59].

To reflect on the assessment results within the social-ecological context of the case study area, we reviewed publicly available information, from regional statistics, reports, and the scientific literature, which was possible as the data were readily available. However, if the aim is to guide and structure a discussion or decision-making process, then it may not necessarily be required to compare the assessments of experts or stakeholders with other data sources. Data-scarce regions may also be more likely to coincide with regions where fisheries are still vital for subsistence and provide the main source of income. In these areas, collective decision-making on management scenarios is presumably even more important. Our approach, a comparative ecosystem service assessment, has the advantage that it can be based on either data or on experts, and is thus also applicable in data-scarce areas.

Furthermore, the International Panel on Biodiversity and Ecosystem Services (IPBES) advertises for the inclusion of traditional and indigenous knowledge into ecosystem service assessments [60], which can be used just as well, or, even better, to set the social—ecological context of a study area. In data-scarce regions, ecosystem service assessments often depart in household surveys or participatory mapping approaches, e.g., [61,62], where our approach could be a complement to structure the information in preparation and support of a discussion process. In that case, the ecosystem services used in this study would need to be carefully revised with local stakeholders to capture the dominating uses and worldview. In a study in the Tana River estuary in Kenya, for example, the provisioning services included mangroves for burning, and cultural services included "cultural shrines" [63].

4.2. Reflection on the Scenarios: Nature Protection vs. Fisheries

In the offshore case study, we introduced two realistic management options that are mentioned in the management plan of the Pomeranian Bay—Rönnebank MPA. While negotiations are still ongoing in the Baltic Sea, the process for the German North Sea MPAs has been completed and bottom trawling is no longer permitted in some areas of the MPAs. This shows that it is very likely that bottom trawling will indeed be banned in parts of Pomeranian Bay—Rönnebank. The involved experts clearly expressed the overall gain in ecosystem services that a ban on bottom-trawling would achieve compared to present fisheries. Despite the decline in fish catches, it shows that a ban on bottom-contacting fisheries in MPAs would have other societal benefits, e.g., maintaining habitats, and existence and bequest values (cf. Figure 3). In the medium- to long-term, it may even lead again to an increase in fish catches due to spill-over effects from the protected area, though the magnitude of effects is debated [64,65].

We furthermore introduced the active restoration of reefs as one management measure, which goes beyond protecting habitats by aiming for the restoration of lost habitats. In the management plan of the Rönnebank MPA, a step-wise approach towards reef restoration is laid out, by first testing the reef restoration in a small area, monitoring the effects and then, if appropriate, examining larger areas for the application of hard substrate [27]. Furthermore, it would only be applied to those areas where habitats and biotopes were damaged by (historical) uses in the MPA and where previously reefs did exist. Restored reefs can provide important ecological functions as a habitat-forming substrate for hard bottom-dwelling species (mussels, snails, crabs) and as a substrate for brown and red algae communities [66]. The experts generally judged it as an option that would lead to an increase in the provision of almost all ecosystem services.

One of the ecosystem services for which a decrease is also expected is the existence and bequest value. The reasoning by one of the respective experts was that the reef restoration would change the existing habitats in the area with negative effects on the existence and bequest value. The scenario description should have been clearer, specifying that boulders would not just be dumped on sandy areas, but that the intention is to restore areas where reefs once existed. It is still an indication, though, that such management measures need to be carefully designed and communicated to avoid conflicts. In the preparation of such a measure, an ecosystem service assessment could be used as well for structured stakeholder discussions and to clarify possible misunderstandings. Stakeholder involvement is furthermore an important aspect of planning and conducting restoration projects [67].

The existence and bequest value service was assessed as the most relevant among the cultural services in the Rönnebank MPA. It could be because it is a protected area, with habitats and species that are known to be worthy of protection. However, Greifswald Bay is just as well protected, yet the other cultural services are deemed more relevant. The differences could be simply because it was a different group of experts. Another explanation may be that there is a hierarchy of values, with use values (e.g., recreational use of an area) ranking highest, followed by non-use values that have no immediate or tangible benefits. The rank of priorities likely varies considerably between individuals, but the assessment result could be a hint that the proximity of the area plays a role. Nearshore areas are more intensively also used for recreational purposes. Therefore, these uses are prioritized, and intrinsic values only become important where no other values apply, as in the case of the Rönnebank MPA, which is further offshore and where there is little recreational activity. However, this result cannot be generalized. Other studies showed the high importance of existence and bequest values, even at the cost of other services that were sustaining the livelihood of the coastal community [63,68].

While the Rönnebank case focused on the protection status and a restoration measure, the Greifswald Bay assessment concentrated on fisheries in combination with an improvement in ecological status. The results show that the overall provision of most services is assumed to increase if the bay is in a good ecological status without fisheries. In order to maintain the current fishery, fishing pressure and nutrient inputs should be reduced in order to allow for the recovery of spawning grounds. The case of the Greifswald herring shows that fisheries depend on healthy marine ecosystems and that the decline in fish stocks is not only due to overfishing, but also due to human-driven impacts such as high nutrient inputs and greenhouse gas emissions.

Both cases also exemplify the dichotomy of harvesting marine living resources—the maintenance of habitats is important for the continued provision of wild fish populations and at the same time, the use of the ecosystem service "wild animals" puts pressure on coastal and marine habitats.

4.3. The Changing Relevance of Fisheries through the Lens of Ecosystem Services

In terms of percentage in gross domestic product (GDP) or contribution to secure food and income, fisheries do not play an important role in most European countries [69,70]. This is even more true for small-scale fisheries (including artisanal and coastal), which only have a share of around 5% of the landings, despite accounting for the majority of active vessels [23]. Compared to earlier centuries, when fishing was essential to the wealth of the Hanseatic cities and even fueled wars by providing a durable source of food (e.g., salted herring), the loss of economic importance is obvious. This loss of importance and relevance, however, does not compel an equal loss in the cultural significance, or for individual households and coastal communities. A recent report by the European Parliament emphasizes the importance of small-scale fishing for local development and employment and the preservation of local cultural traditions [23], in line with target 14.b of the SDG "life below water". In some Baltic Sea coastal communities, the dependence on fisheries, in terms of employment, was still quite relevant around 10 years ago [53]. In the case of the herring fishery in Greifswald Bay, however, fish catches have been on a continuous decline since then (cf. Figure 5).

In a study on climate risk to European fishing communities, the creation of alternative employment opportunities is presented as particular relevant for southern Baltic Sea countries [70]. One such alternative would be tourism, which has been on the rise in the region and will continue to grow, regardless of the setback in the pandemic years. It is expected that climate change, i.e., warmer temperatures, will result in even higher tourism numbers at the German Baltic Sea coast, and thus may provide alternative employment opportunities. To what extent, however, could tourism also be a supporter for fisheries? Part of the holiday experience on the German Baltic Sea coast are the small fishing boats in the harbors and the sale of fish buns. However, it is a fair assumption that the tourists would come regardless of whether or not coastal fisheries practically still exist. The fish sold in the buns are mostly sourced from somewhere else already and the sight of the fishing boats is so common, because they stay almost permanently in the harbor—without going out to harvest fish. So, one may argue that tourism presents suitable alternative employment for fisheries without being very dependent on an active fishery itself (even if some authors argue otherwise, e.g., [71]). Does it imply that coastal fisheries will continue to decline and eventually vanish?

Drawing again on the example of the herring fishery in Greifswald Bay, the Thünen Institute of Baltic Sea Fisheries estimated that a reduced herring fishery can be maintained, with catch rates of around 20,000 tons per year (for the entire western Baltic Sea), which is much less than it used to be but much higher than the last few years [47]. It would be enough to maintain some of the fleet and preserve the cultural heritage related to the fishery, such as its associated skills and the craftsmanship of boat building. Otherwise, a situation similar to that in the Vistula lagoon in Poland could arise, where the small fishing boat museum seems to be all that remains of the traditional and cultural heritage of fishing, and where fishers are paid to leave their boats in the harbor [72]. If not practiced, skills will be lost, and indeed, it is already difficult to recruit fishers—as the future is dire and still today it is a physically straining and often dangerous profession, not adding to its attractiveness [23].

If we take the ecosystem service concept as a lens with which to trace the changing relevance of fisheries over time, we may distinguish different phases. If one had asked people from the Baltic Sea to assess the importance or value of fish during the heyday of the Hanseatic league, it is likely that they will have valued it primarily for its economic importance and as a source of food (i.e., as a provisioning service). The name "silver of the sea" for herring is not just literal but also reflects this economic value, as does the saying that the brick buildings of the Hanseatic city of Lübeck were built on herring money. With the collapse of fish stocks in the 20th century and an increasing environmental awareness in general, the regulating ecosystem service became important in the sense that it has become important to protect marine habitats and species and avoid the destruction of habitats and the detrimental effects of overfishing. Increasing conflicts occurred between fisheries and marine conservation, which continue today. Another dimension that has become important now, however, is the cultural aspect of fisheries, in particular, small-scale and artisanal fisheries, which are well reflected in the cultural ecosystem services.

5. Conclusions

From the expert assessment in our case studies, we can conclude that restriction for fisheries, improvement of the ecological state, and restoration measures would result in an overall increase in ecosystem services despite the potential decline in fishing yields. However, the extent to which other societal benefits resulting from the increase in ecosystem services would be prioritized over fishing depends very much on the importance attached to fishing and the status of the fishery. For the European—Baltic context, we can conclude that fishing in earlier days served mainly as a provisioning service but has experienced a decline in relevance, even though fisheries are still important for some coastal communities and are part of the cultural heritage of the region. The negotiations under the CFP for the exclusion of bottom trawling from MPAs in the German EEZ furthermore shows that nature protection or ecological sustainability is becoming more important than protecting the interests of the fishing industry. At the same time, small-scale fisheries, and their potential for contributing to sustainable fisheries, are receiving more attention at the European and UN level. Small-scale fisheries can contribute to the sustainable development of coastal communities and are important for maintaining coastal identities and heritage. Our example from Greifswald Bay shows that a cultural heritage may be maintained because it also serves as a tourist attraction. However, it also shows that fishing pressure and nutrient inputs need to be reduced to maintain even a small fishery, and that the fisheries are very dependent on the ecological state of the marine area. In coastal areas, the choice of which uses or ecosystem services to prioritize should be a societal decision. In such contexts, our approach will be beneficial to structure the discussion and support the decision-making process. Ecosystem services cover the three pillars of sustainability and support a holistic view on management measures. The present approach brings together different stakeholders and illustrates who (dis)benefits from the decisions, which is needed as a basis for negotiating the redistribution of costs and benefits necessary for socially just decisions. If our approach is used in decision-making processes, it is recommended to carefully select the invited stakeholders, and to be aware that stakeholder selection can already introduce bias and imbalance. In our assessment, we have only involved a limited number of experts, which has also introduced bias into the results and should be kept in mind when interpreting them. While the results of the assessment thus cannot be generalized, the approach, as such, is easily transferable to other areas. It should be applied when holistic perspectives are needed, as it goes beyond the economic importance of fisheries. It shows both the interdependence between fisheries and healthy marine ecosystems and the relevance for coastal communities. As such, it contributes to a sustainable approach to fisheries and the design of management measures.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su152215732/s1, Table S1: Ecosystem Service Assessment sheets: templates and results.

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