Ecosystem Services of Seagrass in the Western German Baltic Sea

Abstract

Humans are dependent on coastal ecosystems as they provide essential supporting, provisioning, regulating and cultural ecosystem services. Seagrass meadows play an important role in coastal systems as they provide a variety of ecosystem services such as sediment regulation, nutrient and carbon storage, provision of habitat and primary and secondary production.

This study assesses the importance of the ecosystem of seagrass meadows (*Zostera sp.*) in the Baltic Sea of Schleswig-Holstein and examines the dependency of seagrass density and the support of ecosystem service. Despite its importance for the marine environment, seagrass meadows are rarely appreciated and nowadays declining all over the world which could cause severe harm and costs. An interdisciplinary research and methods to assess and quantify such ecosystem services is necessary to fully understand the ecological role of seagrass in the Baltic Sea and to be able to provide effective conservation and management strategies.
Introduction

Ecosystem Services

The term ecosystem describes the community of living organisms interacting with each other and with their non-living environment and includes many different components (Garpe et al., 2008; MEA, 2003). Living organisms include any form of life e.g. bacteria, plants, animals and humans. The non-living, physical environment with which the living organisms interact comprises components such as water, soil and nutrients (Garpe et al., 2008).

Ecosystem Services (ES) are defined as “benefits people obtain from ecosystems” (MEA, 2003). They are the benefits, functions and processes that support, sustain and fulfill human life (Garpe et al., 2008). Some of these benefits are essential for human life, others have the potential to create economic opportunities, add to human health or cultural identity.

There is a wide array of concepts for the valuation and classification of ecosystem services (Hasler et al., 2016) but the most commonly used categorization is:

- **Supporting ES/ Integrity variables** that maintain the conditions for life
- **Provisioning ES** such as food and water
- **Regulating ES** such as coastal protection and climate regulation
- **Cultural ES** such as recreational and spiritual benefits (MEA, 2003).

Many people are unaware of the existence of ES and the direct and indirect benefits humankind obtains from different ecosystems, how we contribute to their destruction and what this would mean for our personal well-being or economic development. The assessment of ecosystem services is therefore a tool to improve the understanding of the importance of ecosystems for humans, to raise awareness about the threats and the consequences that would arise from interfering and destructing certain ecosystems.

Seagrass and its ecosystem services

Worldwide there are 60 species of seagrass forming beds in the subtidal and intertidal area of coastal waters. Two eelgrass species can be found in the Baltic Sea: *Zostera marina* and *Zostera noltii* which are present at 80% of the East coast of Schleswig-Holstein and cover more than 100 km². Eelgrass is a flowering plant that is pollinated under water (LLUR et al., 2014). It can also reproduce vegetatively by building a network of subterraneous rhizomes. This network allows seagrass to build very dense stocks with a sprout density of up to 2500 sprouts per m². The biomass varies significantly during the times of the year. Seagrass is especially vulnerable to eutrophication, high water temperatures, low oxygen content, hydrogen sulfide and changes in the biotope (Bobsien, 2014).
At first appearance seagrass looks like an unimpressive, almost boring marine plant that does not have any interesting characteristics or value to us humans. But the simple appearance is misleading: Seagrass meadows provide and support numerous ecosystem services which are very valuable for us humans. They serve as habitat for juvenile fish and invertebrates (Borum et al., 2004), provide oxygen (Meyer and Nehring, 2006), as well as materials for building and packing (Garpe et al., 2008). Their genetic resources are promising when it comes to the development of biochemical products (POSIMA, 2018). They contribute to the regulation of global climate (Fourqurean et al., 2012), local coastal protection (Borum et al., 2004) and nutrient cycling (Meyer and Nehring, 2006). Seagrass can be considered as a natural filter of some elements that determine the quality of coastal waters (Fourqurean et al., 2012). Their cultural value is also not to be underestimated due to the provision of cultural and natural heritages (Garpe et al., 2008).

So even if we would think that seagrass does not provide any services for you personally, it generates parts of the oxygen that we are breathing, it stores carbon and therefore mitigates global warming, it protects the sand on the beaches for our holidays from being washed away and besides many other services, without seagrass meadows we would have much less fish on our plate.

Despite the important role of seagrass meadows, they are today among the most threatened ecosystems in the world’s oceans (Namba et al., 2018). Seagrass and its ES have not been completely investigated yet, so we cannot even imagine the losses that would arise from destroyed seagrass meadows.

Determining the importance of seagrass meadows and the ES they provide is essential for the proper management and conservation of these ecosystems. It is not sufficient to assess the ecosystem services eelgrass provides in general, but it is necessary to examine the local importance and to quantify these ecosystem services. Even if site specific studies and quantitative estimation of ES are still under development and can be quite subjective, they hold a high potential to allow a better estimation of their value and to better apply effective conservation measures in specific local areas.

Research questions

1. Which ecosystem services are provided and supported by *Zostera* sp. beds in the Baltic Sea?
2. How can the provision of these ES be rated in general and what is the correlation between the seagrass density and ES scores?
3. How is the distribution of the ES scores for different ES in the study area?
Methods

Study area
The Baltic Sea is a semi-enclosed sea with comparably low regionally variating salinity. For this study the seagrass at the Baltic Sea coast of Schleswig-Holstein has been examined. The focus for the created maps has been placed on two sections within the study area: Kieler Förde & the coast section at the mouth of the river Schlei.

Fig. 1 Study area and smaller study sections in the Baltic Sea of Schleswig-Holstein

Model of seagrass distribution and density
Surveys of seagrass meadows were conducted along the coastline of the Baltic Sea in Schleswig-Holstein in the summers between 2010 and 2015. Different methods were used for parallel and vertical transects: Scuba diving, kayaking, photo and video transects. Besides the occurrence and estimated density of seagrass meadows at certain GPS positions, data like depth, slope inclination, wave exposition and Secchi depth was collected. A GIS model was developed that took these factors into consideration and created a grid of points where each point had a certain probability of the occurrence of sea grass. This prediction (in %) described at the same time the predicted density of seagrass (in %). The survey data and resulting model was provided by courtesy of Dr. Ivo Bobsien and his working group (LLUR and GEOMAR Kiel).

Modeled grid points at a location deeper than 7.9m were deleted from the dataset due to the fact that Zostera meadows do not grow deeper than 7.9m in the Baltic Sea (Schories et al., 2009). Seagrass patches with a density less than 10% were not displayed in the maps, as a seagrass meadow in this study is defined to have a density larger than 10%.
Ecosystem service matrix

49 ecosystem services were listed in a matrix in order to be able to compare the two ecosystem types: sandy sediment with seagrass and sandy sediment without seagrass. A literature research, interviews with experts and estimations by student groups were conducted to be able to estimate the importance of the ecosystems for each ecosystem service. The values assess the qualitatively scored average annual flow of services, or in other words, describe how strong the land cover type (sandy bottom with seagrass or without seagrass) support the given ecosystem service. The values range between 0 and 100, with 0 being a not correlated ecosystem service to the ecosystem and 100 being an important ecosystem services provided by that ecosystem. The applied ecosystem service matrix system has been developed by the Department of Ecosystem Management of Kiel University with contribution of the BACOSA project.

Seagrass generally contributes to many ecosystem functions. However, there are genera- and bioregional variations and seasonal and temporal differences as well as intra-specific variations which could highly affect the valuation of benefits (Nordlund et al., 2016). In this study, these variations were taken into account as best as possible and all values represent mean estimated values at optimal conditions for the specific ES. The estimated values do not take density into consideration yet, they assume the optimal density for the provision of each ecosystem service.

Model of density dependent ES distribution

In order to assess a precise local provision of ES by seagrass, maps were created based on the maps of the modeled seagrass densities. The dependency of ES on the density of seagrass meadows has been estimated in numerical values and graphs were created displaying these relationships. The modeled seagrass densities were divided into 10 classes and an ES score value between 0 and 100 has been assigned to each class for each ES, depended on the values estimated in the graphs. The newly created classes and values were displayed in one map per ES and showed the different estimated dependency of ES on seagrass density.

These maps have been created exemplarily for the ecosystem services: oxygen provision, seafood provision, global climate regulation, coastal protection and recreation.

Other general assumptions:

In order to rank the ecosystem services and their role in the ecosystem, seagrass meadows as a whole were included in the assessment, including the submerged seagrass meadow itself, but also beach wrack on the beach and in all other places where it can be used after taking it out of the natural environment.
Results

Ecosystem Services of Seagrass

Major disparities in the values comparing the ecosystem services of the two coverages sand and seagrass were found. Most ecosystem services were stronger supported by sandy bottom with seagrass compared to bare sandy bottom. More than 20 ecosystem services reach a score higher than 50. Ecosystem services like biodiversity, habitat of fauna, seafood, oxygen, global climate regulation, flood protection, sediment stabilization, recycling of matter, nutrient regulation, water purification and others reached a score over 70.

Minerals, free swimming enjoyment and recreation and tourism scored the only values that are significantly higher for ecosystems without seagrass. All other ecosystem services are stronger supported by areas where seagrass occurs (Fig. 2 and Tab. 1).

Fig. 2 Ecosystem Service Profile of Sandy bottom with seagrass and sandy bottom without seagrass
In all four categories the ecosystem services are stronger supported by ecosystem where seagrass occurs. Integrity variables and regulating ecosystem services are up to four times stronger provided by ecosystems with seagrass compared to sandy bottoms without seagrass cover. Seagrass plays an important role in providing ecosystem services especially when it comes to integrity variables and regulating services (Fig. 3).

![Fig. 3 Average of the qualitatively scored values of how strong ecosystem types sandy bottom with and without seagrass supports the ecosystem services in the four categories of ES](image)

**Model of densities**

The model shows a distribution of seagrass along most of the coast of Schleswig-Holstein with different densities and different hot spots of seagrass (Fig. 4 in Appendix). A validation process found an 84% accuracy of the model when comparing the few points in the grid where seagrass density was modeled and measured. The densities of seagrass at the Kieler Förde are generally higher than the ones at the Schlei mouth.

**Model of ecosystem services**

The ES maps can be found in the Appendix (Fig. 5-9). Fundamental differences between the single maps are visible. Ecosystem services with a positive correlation between the density and the ES provide obviously a higher ES at shallower areas where the density is generally higher. Negatively correlated ES with density have higher scores in deeper areas. Ecosystem services like global climate regulation (Fig. 8) and the provision of oxygen (Fig. 5) are estimated as linear correlations. Ecosystem services like coastal protection (Fig. 7) and provision of seafood (Fig. 6) is considered to have a more exponential correlation with seagrass density. The ecosystem service recreation and tourism (Fig. 9) is considered to be negatively correlated to seagrass density.

While the Kieler Förde section is stronger in providing most of the ecosystem services, the section of the Schlei mouth provides a stronger service in the recreation and tourism sector.
Discussion

Ecosystem services of seagrass in the Baltic Sea

A selection of important ecosystem services provided by seagrass is described below, to justify the qualitatively scored values (Appendix Tab. 1). Some ecosystem services are summarized here, because explanations for the valuation are similar. All ecosystem services can be found in Tab. 1.

Integrity variables

Biodiversity

Seagrass meadows are the base for diverse and productive benthic fauna (Garpe et al., 2008). In comparison with a sandy bottom with no seagrass cover, the plants are an important ecological structural element which offers a variety of habitat to all kinds of species (Meyer and Nehring, 2006). Seagrass is an ecosystem engineer, as it is able to modify the environment in a way that biodiversity increases, which is essential for ecosystem functions (Bobsien, 2014; Schmidt et al., 2011).

Nutrient cycling

Nutrients retention is occurring because of the reduced erosion of sediments in seagrass meadows. There is a significant increase in nutrient supply and an accumulation of organic matter (Meyer and Nehring, 2006). This retention and regulated cycling of nutrients can have positive effects on other marine ecosystems.

Habitat of fauna

Dense seagrass meadows provide several habitats and microhabitats in the leaves and the network of rhizomes. Irradiance, currents and the visibility are reduced inside the meadows and organic matter is accumulated, which makes seagrass a very different and important habitat compared to the surrounding sandy and stony ecosystems in the Baltic Sea (Borum et al., 2004). It provides particularly important ecosystem services for young fauna and fauna that needs to be protected from predators but also from drifting (Borum et al., 2004; Meyer and Nehring, 2006). Many species highly depend on eelgrass during different life stages, e.g. as nursery or feeding ground for fin- and shellfish as well as invertebrates and birds (Borum et al., 2004; Garpe et al., 2008).
Provisioning services

Food

Seagrass could generally be used as a source for human nutrition, but it is not a common practice (yet). The project POSIMA suggest that the use as a dietary supplement could be possible, but further research need to be done in that field (POSIMA, 2018).

Biomass for energy (fuelwood)

Seagrass or beach wrack has a potential to be used as biomass for energy production. The use is just possible if collected seagrass is separated from algae, which is a difficult and expensive process and makes it economically not valuable yet (POSIMA, 2018).

Livestock & fodder

In historical times, beach wrack has been used intensively as cattle bedding and as food for pigs, rabbits and hens (Borum et al., 2004). An utilization as food for fish farms should also be possible and could play a role in future aquacultures (POSIMA, 2018).

Seafood

As seagrass meadows play an essential role in supplying habitat for many species, including ecologically and commercially important species, it is a major factor for seafood production in the wild (Fourqurean et al., 2012; Pihl et al., 2006). It is especially important for fish recruitment and invertebrate species, like shellfish. After the loss of seagrass meadows in an area at the archipelago of the Swedish Skagerrak 100% recruitment of Atlantic Cod has been lost (Pihl et al., 2006). This illustrates the significant dependency of seafood on healthy seagrass meadows and the consequences arising from seagrass loss.

Oxygen

Primary and secondary production is very high in seagrass meadows, which makes it one of the most productive ecosystems on earth (Borum et al., 2004; Fourqurean et al., 2012). As a side product of photosynthesis, oxygen is released from the plant’s leaves and roots to the surrounding water and to otherwise anoxic sediments which leads to positive changes in lower water layers and in the benthos (Meyer and Nehring, 2006).

Biochemicals & genetic resources

The scientific investigation of genetic resources of seagrass and possible use of its microbiological substances is in full swing and there is a high potential for the future (Nordlund et al., 2016). The production of ethanol and plastic and the use of its polysaccharides seems promising, as well as the
use of its carrageenan (Garpe et al., 2008; POSIMA, 2018). Already today constituent of seagrasses are used for medical purposes like skin diseases and varicose veins (Borum et al., 2004).

**Mulch/ Compost/ Fertilizer**

Seagrass can be used for soil amendment, which was a common practice in historical times (Garpe et al., 2008). It helps to capture moisture in the soil and when it decomposes, the minerals and trace elements are released, which supports plant growth. Its salt content is a natural repellent for insects and pests (POSIMA, 2018). However, industrial products are more cost-efficient nowadays, which explains why the use is not very widespread.

**Fiber (Packing & Building material)**

Dried *Zostera* plants suit very well as packing and building material. It can be used as filling material for chair seats and mattresses and as packing material e.g. to ship fresh fish. Furthermore, roofs can be covered with the plants and it can serve as insulation material in house walls, as a constituent of dykes and to produce other products like “erosion control mats”. Most products are fire resistant and have very good insulation properties (Garpe et al., 2008; POSIMA, 2018).

**Regulating services**

**Global climate regulation**

Seagrass meadows have a very high capacity to store carbon. It is estimated that seagrass beds can store up to 83,000 tons of C m$^{-1}$ which is a huge amount compared to a typical terrestrial forest which stores just around 30,000 tons of C m$^{-1}$ (Fourqueran et al., 2012). Some references even say that the estimated numbers are underestimated, because below ground characteristics are neglected in the calculations and might be even more relevant than assumed (Nordlund et al., 2016).

Even so they are just found at 0.1% of the ocean floor, they are estimated to store more than one fifth of the total “blue carbon”, the total oceanic carbon burial (Borum et al., 2004; Fourqueran et al., 2012; Röhr et al., 2016). This can be explained by the high primary productivity, filter capacity, low decomposition rates at deeper anoxic sediment layers of the oceans and the non-existence of fires underwater. This highlights further the important role seagrass plays in global climate regulation and in mitigating climate change.

**Coastal protection (Sediment stabilization)**

The roots of *Zostera* plants stabilize the sandy sediment. The plant body reduces the resuspension of the sediment by currents and waves by changing the hydrodynamics and reducing the water motion.
The sediment in the seagrass meadows is not just stabilized by the plants and their roots but there is actually sediment produced in this ecosystem. Shells, skeletons or spines of animals using the meadows as their habitat will eventually break down and form, with other organic matter, a net source of sediment and soil (Borum et al., 2004). Additionally to that, organic carbon and nutrients accumulate in seagrass beds (Bobsien, 2014).

All these processes of stabilizing the sediment and dissipating of wave energy results in a reduction of erosion. Even when leaves get detached and accumulate on the beaches, they are contributing to the reduction of erosion as the beach wrack also dissipates wave energy and reduces the risk of beach sand to be eroded by wind (Borum et al., 2004).

**Water purification**

Particles in the water column are filtered out, absorbed and stored in the soils by seagrass plants (Fourquean et al., 2012). The ecosystem favors the retention of dead and living particles and therefore controls the transparency of the water. Furthermore, the acquisition of inorganic nutrients allows seagrass to control phytoplankton. The lower abundance of phytoplankton results in clearer water and higher irradiance in deeper water depths (Borum et al., 2004).

**Cultural services**

Cultural ecosystem services can be difficult to assess and especially to quantify as many of them are based on subjective opinions and estimations (Nordlund et al., 2016). One has to keep in mind, that these estimations are made as objective as possible but depend completely on the observer and can vary totally when done by somebody else.

**Recreation & tourism**

Recreation, for example, is a very typical topic where opinions are divided whether seagrass supports this ecosystem service or not. On the one hand seagrass helps to filter suspended matter from the water and thus improve the water quality, as well as it releases oxygen to anoxic sediment layers which reduces unpleasant smells. On the other hand it can be annoying when swimming and it can develop a bad smell when lying on the beach as beach wrack. Additionally, eelgrass meadows are good sites for recreational fishing (Gundersen et al., 2017).

**Cultural heritage**

Historically, the use of seagrass as building and packing materials was very common and a part of the northern culture (Borum et al., 2004). Seagrass could still be used as such materials, but even if not is the cultural heritage an important service.
**Natural heritage**

Seagrass meadows are important ecosystems including a comparably high biodiversity and the support and provision of many ecosystem services. Humankind has inherited them from past generations and they need to be maintained in the present and future to assure that the ecosystem services mentioned above are not getting lost.

**Model of ecosystem services**

The density model has been built on the data basis of measured data with a very high accuracy. However one has to keep in mind that all created maps base on probability data and do just try to approach the reality as best as possible.

Ecosystem services like global climate regulation (Fig. 8) and the provision of oxygen (Fig. 5) are estimated as linear correlations, as they are not directly dependent on the density of the seagrass meadows itself. The more plants there are, the more oxygen is produced or carbon is stored. How dense the seagrass bed itself it, does not influence or support the named ecosystem services.

Ecosystem services like coastal protection (Fig. 7) and provision of seafood (Fig. 6) are considered to have a more exponential correlation with seagrass density, because they are estimated to be directly dependent on the density of the seagrass meadows. Single plants are not contributing to coastal protection or seafood provision, but very dense areas with many plants and especially many roots are contributing significantly to the ecosystem services. The function of seafood provision is estimated to decrease if the density of seagrass is too high, because of limited space for living organisms like fish or invertebrates. As many marine animals highly depend on seagrass structures, the ecosystem is rated with very high values beginning from a density of 50%, which explains why this map is noticeable darker than the others (Fig. 6)

The ecosystem service recreation and tourism (Fig. 9) is considered to be negatively correlated to seagrass density as seagrass disturbs free swimming enjoyment. On the other hand it also purifies and filters water but the disturbance factor is considered to be stronger for most people.

The resulting findings are based on these assumptions and estimations of values concerning the relation of ES and seagrass density. This is a quite subjective and theoretical method and can lead to mayor errors and misunderstandings. Quantitative assessments and measurements of all factors related to ES should be conducted in order to get more precise estimations, but this would include high costs and would be quite time and labor-intensive.
But even if many factors were estimated and others were not considered in the model, this theoretical approach can be seen as a possibility to qualitatively and quantitatively examine ES in very small areas. It is a first step in evaluating ES quantitatively by estimations using the new system with values from 0-100. On top of that the theoretical correlation of density and ES treated in this study can be a complete new way how to describe and assess ES in certain local areas.

Further studies should focus on how to estimate or even measure those factors more precisely in order to create models which are less theoretical and closer to reality. It is additionally important that similar studies about ES will be conducted for ecosystems all over the world to be able to broaden the knowledge about ES and how to protect them.

Several regulations and projects are focusing on raising awareness and try to investigate how to conserve seagrass meadows or how to restore old and plant new beds. Restoration costs of artificial seagrass beds are estimated to be 5300 €/ha (Garpe et al., 2008). But still, many people do not know anything about the importance of seagrass and their provision of ecosystem services. It is much underestimated and unappreciated which makes it even more vulnerable. We are dependent on ecosystem services and quantifying them with a method explained in this study is the first step of explaining it to the people. Maybe the concept of ecosystem services can be the only chance for threatened ecosystems like seagrass meadows to get more attention when people start to understand their importance—not just for marine systems but for every single human being on this planet.

**Conclusion**

Seagrass meadows support a variety of ecosystem services in all four ES categories. Especially integrity variables and regulating ES are very strongly supported by eelgrass covered sandy bottom.

In the Baltic Sea of Schleswig-Holstein, seagrass is considered to be found in large patches in most parts of the coast. The density varies and so does the provision of different ecosystem services.

For recreation and tourism, dense seagrass meadows are estimated to have a negative impact on the provided ecosystem service of free swimming and smell enjoyment. However the majority of examined ES are positively correlated with the density of seagrass meadows. While some of these ES are independent from the density of the meadows and just linearly correlated (e.g. oxygen provision, climate regulation), some others are highly dependent on a dense and strong network of submerged plants (e.g. seafood provision, coastal protection).

This study is a very general and quite theoretical attempt to estimate qualitatively and quantitatively the capacity of the provision of ecosystem services of seagrass. However many values base on
estimations, this study has been able to outline the importance of seagrass and especially the importance of dense and heathy seagrass meadows in the coastal zone as it provides so many services.

However seagrass plays such an essential role in coastal ecosystems and provides so many ecosystem services, the meadows have declined drastically worldwide in the last century. The loss of these services would cause significant threats and costs and have to be avoided by effective conservation measures which can be implemented with the knowledge of such ES evaluations and estimations.

References


## Appendix

### Tab. 1 Ecosystem Services
Matrix of sandy bottom with seagrass cover and sandy bottom without seagrass cover for ecosystem services of the four main ecosystem services categories. Values range from 0 to 100, with 100 being the highest possible value for an ES to reach.

<table>
<thead>
<tr>
<th>Category</th>
<th>Ecosystem Services</th>
<th>Sandy bottom with seagrass</th>
<th>Sandy bottom without seagrass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integrity variables</td>
<td>Abiotic heterogeneity</td>
<td>60</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Biodiversity</td>
<td>80</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Biotic water flows</td>
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<td>5</td>
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<tr>
<td></td>
<td>Metabolic efficiency</td>
<td>70</td>
<td>10</td>
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<td></td>
<td>Exergy capture</td>
<td>70</td>
<td>5</td>
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<tr>
<td></td>
<td>Nutrient cycling</td>
<td>80</td>
<td>10</td>
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<tr>
<td></td>
<td>Storage capacity</td>
<td>70</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Habitat of fauna</td>
<td>90</td>
<td>20</td>
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<tr>
<td>Provisioning Services</td>
<td>Human nutrition</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Biomass for energy</td>
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<td>5</td>
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<tr>
<td></td>
<td>Livestock &amp; fodder</td>
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<td>5</td>
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<tr>
<td></td>
<td>Timber</td>
<td>5</td>
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<td>Wild food</td>
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<td></td>
<td>Fish and Seafood</td>
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<tr>
<td></td>
<td>Flotsam, beach wrack and algae</td>
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<td>Ornamentals</td>
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<td>Oxygen</td>
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<tr>
<td></td>
<td>Mulch, Compost &amp; Fertilizer</td>
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<td>Drinking water</td>
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<td>Abiotic energy</td>
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<td>Minerals</td>
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<td></td>
<td>Filling &amp; packing material</td>
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<td>Insulation &amp; building material</td>
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<td>Biochemical use</td>
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<td>Erosion regulation, water</td>
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<td>Broad scale recycling of matter</td>
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<td></td>
<td>Nutrient regulation</td>
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<td></td>
<td>Accumulation of nutrients, pollutants</td>
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<td></td>
<td>Water purification</td>
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<td>Pest and disease control</td>
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<td>Pollination</td>
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<tr>
<td>Cultural Services</td>
<td>Recreation and tourism</td>
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<tr>
<td></td>
<td>Transparency of water column</td>
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<td>Free swimming enjoyment</td>
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<td>Smell enjoyment</td>
<td>5</td>
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<tr>
<td></td>
<td>Landscape aesthetics &amp; inspiration</td>
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<td>Knowledge Systems</td>
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<td>Cultural heritage</td>
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<td>Regional identity</td>
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<td>Natural heritage</td>
<td>80</td>
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Distribution of modeled density of seagrass meadows in the Baltic Sea of Schleswig-Holstein

Fig. 4 Distribution of modeled density of seagrass meadows in the Baltic Sea of Schleswig-Holstein
Ecosystem service scores for the ecosystem service: generation of oxygen based on modeled density distribution and estimated correlation of the ES and the density of seagrass.
Fig. 6 Ecosystem service scores for the ecosystem service provision of seafood based on modeled density distribution and estimated correlation of the ES and the density of seagrass.
Ecosystem service scores for the ecosystem service: coastal protection

Fig. 7 Ecosystem service scores for the ecosystem service coastal protection (flood protection/ sediment stabilization/ erosion regulation) based on modeled density distribution and estimates correlation of ES and the density of seagrass
Ecosystem service scores for the ecosystem service: global climate regulation

Fig. 8 Ecosystem service scores for the ecosystem service regulation of global climate based on modeled density distribution and estimates correlation of ES and the density of seagrass
Ecosystem service scores for the ecosystem service: recreation and tourism based on modeled density distribution and estimates correlation of ES and the density of seagrass.