Ecol Res (2018) 33: 1255–1274
DOI 10.1007/s11284-018-1643-8

ORIGINAL ARTICLE

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Ecosystem services provision today and in the past: a comparative study in two Baltic lagoons

Received: 7 March 2018 / Accepted: 22 June 2018 / Published online: 13 August 2018

Abstract The European Biodiversity Strategy asks EU Member States for an assessment, mapping and valuing of Ecosystem Services (ES). While terrestrial ES concept is advanced and different tools are available, they are largely lacking for coastal and marine systems. We develop a stepwise methodological process to assess ES in coastal and marine systems which we name Marine Ecosystem Services Assessment Tool. We applied it to two large Baltic lagoons, the Szczecin and the Curonian Lagoons demonstrating a quantitative and qualitative assessment approach. Firstly, an initial status is defined reflecting, according to the European Water Framework Directive, a past situation when the ecosystems where in a so called good ecological state. In both Baltic lagoons, this refers to a situation around 1960. Secondly, a present state is defined, assessed and compared to the initial status. Increasing anthropogenic impacts in Szczecin Lagoon caused an overall decrease ecological status which may influence the system's ability to provide services. Assessing ES changes semi-quantitatively via 39 indicators and 22 services, we show a decrease in provisioning and regulating and maintenance and an increase of cultural services' provision. According to 15 expert valuations, the Curonian Lagoon displays no changes in provisioning but an increase in regulating and maintenance and cultural service provision. We discuss how these results can serve different marine management approaches and support different polices. Through our application we show how the tool can be used to assess ES changes over time and thus provide key information on sustainable use and ES for future generations.

Keywords CICES · Water Framework Directive · Szczecin Lagoon · Curonian Lagoon

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s11284-018-1643-8) contains supplementary material, which is available to authorized users.

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Introduction

Environmental changes due to human impacts take place at unprecedented rates, leading to situations where it is imperative to act and safeguard ecosystems from future damages (Hofmann et al. 2015). One way of raising awareness regarding the importance of environmental conservation is by demonstrating how important ecosystems act as contributors to human wellbeing and as providers of our most basic needs. This is the backbone of the concept of Ecosystem Services (ES), which the Millennium Ecosystem Assessment (Millennium Ecosystem Assessment 2005) describes as "the benefits humans obtain from the environment". The concept arose from early concerns about environmental degradation but in the past decades has "developed to a formal body of knowledge, policy and research, oriented at valuing and protecting valuable ecosystems" (Chaudhary et al. 2015). The concept has developed as a multidisciplinary research topic integrating environmental, social and economic sciences to represent the different dimensions that human wellbeing comprises (Jacobs et al. 2016).

The ongoing integration into policy and research pushed the ES idea from a theoretical into an operational concept. At first, it served to name, classify and organize services. The Millennium Ecosystem Assessment (2005) led the development of classification systems to assess services, grouping them into Provisioning, Regulating, Cultural and Supporting ES. Many classification systems have been developed afterwards and are available in literature (De Groot et al. 2002; Beaumont et al. 2007; TEEB 2010). However, this ongoing development is problematic in the sense that there is not yet a standard classification. Aiming at providing one, Roy Haines-Young and Potschin (2013) coordinated the development of the Common International Classification on Ecosystem Services (CICES). This classification hierarchically organizes ES into sections, divisions, groups and classes. Furthermore, CICES is the classification used by the European Commission (EC) in projects and policies related to the topic (European Commission 2011; Maes et al. 2015). These policies and projects aim to assess ES through quantification. For services that cannot be directly quantified indicators are used as proxies (Egoh et al. 2012). Nowadays, many indicator sets have been developed and are available in literature with different levels of complexity (UNEP-WCMC 2011; Böhnke-Henrichs et al. 2013; Hattam et al. 2015; Maes et al. 2016). The project Mapping and Assessment of Ecosystems and their Services (MAES) from the EU Commission has developed indicator sets for different habitats both terrestrial and marine. To find a relation between indicator sets and classifications is a challenge. For this one of MAES advantages is the correspondence with CICES classification, as it makes it easier for researchers to find suitable indicators for ES.

Initially developed to be applied in a terrestrial context, a big discrepancy exists when comparing application of the concept to the marine realm. Liquete et al. (2013), highlights this discrepancy by comparing the number of publications with the term ecosystem services. In 2012–2013, out of 5025 articles, only 150 were related to marine assessments. This reveals severe knowledge gaps regarding the assessment, operationalization, and valuation of coastal and marine ES.

Yet, coastal and marine waters do in fact provide humankind a wide and important array of ES, contributing directly and indirectly to different dimensions of human wellbeing. Coastal zones host more than 45% of the global population and 75% of the world's largest urban agglomerations (Turner et al. 2014). Furthermore, it is expected that by 2030 these areas will contain three-quarters of a far larger human population (Hinrichsen 1998). Thus, coastal areas are among the most valuable socio-ecological systems (Costanza et al. 1997). Around the Baltic Sea, countries depend on their proximity to the waters as a driver of their economy and for sustenance of social life. The Baltic Marine Environment Protection Commission—Helsinki Commission (HELCOM) and EU give emphasis to this in their strategies.

Those strategies cover also the so called transitional water bodies. These make the connection between land and sea. Three of the biggest coastal lagoons in Europe are in the Baltic Sea. Coastal lagoons are ecologically important acting as a filter or purification systems against anthropogenic pollution, and at the same time are essential areas for biota (Vasconcelos et al. 2011). They provide a set of ecosystem services that affect not only the area of the lagoon but also its vicinity. The Szczecin Lagoon, located in the border between Germany and Poland, and Curonian Lagoon located in border between Lithuania and Russia, are examples of coastal lagoons which have and still play a role as driving factors for the local economy and social well-being. These lagoons and the Baltic Sea in general, have been continuously affected by humans. Impacts, namely eutrophication (Schernewski and Wielgat 2001; Fleming-Lehtinen et al. 2015) led to water quality degradation and an overall decrease of ecological status. As a potential consequence the natural capacity to provide ES can be diminished and adversely impact socio-economic systems.

It is therefore important to assess changes in ES and develop management plans that ensure a sustainable use. The EU has been working on the integration of the ES concept in their directives and management actions (Bouwma et al. 2016). Action 2 of the Biodiversity 2020 Strategy (European Commission 2011) asks Member States (MS) to maintain and restore their ecosystems and services. Accordingly, Marine Spatial Planning (MSP) and Integrated Coastal Zone Management (ICZM) approaches make use of the ES concept. Together with the Water Framework Directive (WFD) (Directive 2000/60/EC 2000) and Marine Strategy Framework Directive (MSFD) (Directive 2008/56/EC 2008), the management goal is to achieve a better environmental and ecological status of marine waters such that a sustainable use of ES can be ensured. The two-fold question that arises is: How has ES provision changed over time and how can this information be used to define future management options?

The main objectives of our study are therefore to: (1) present and apply a computer aided tool to assess ES changes over time for two exemplary coastal lagoons (Szczecin and Curonian), and (2) test the suitability of a set of corresponding indicators and critically analyse the tool through two different approaches (quantitative and qualitative), and thus provide information on how the results of both approaches could support sustainable management strategies.

Study area and methodology

Study area

The two coastal lagoons chosen for this study are located in the Baltic, the Szczecin and Curonian Lagoons (Fig. 1). We chose these lagoons due to their similarity in hydrodynamics, physical–chemical and biological characteristics. According to the Water Framework Directive Typology (European Commission 2000), both lagoons are classified as B1 water body type. Moreover, common to both lagoons are the similar socio-economic dynamics with almost similar human activities exploring the lagoons' services. A progressive decrease of water quality and overall ecological status over time is also mutual to both lagoons. This happened mainly due to

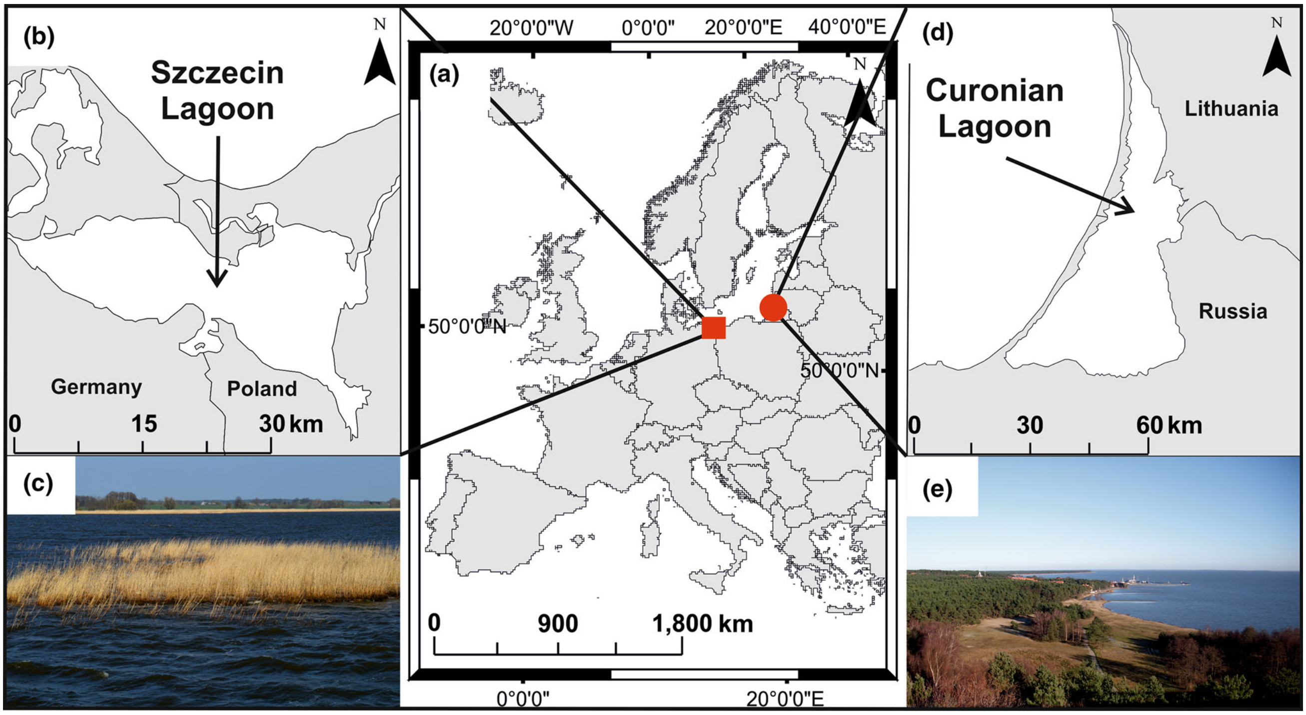

Fig. 1 Location of the study area: **a** location of both lagoons in European context, **b** Szczecin Lagoon located between Germany and Poland, **c** overview picture of the lagoon showing a reed belt, **d** Curonian Lagoon located between Lithuania and Russia, **e** overview of the lagoon from a sand dune (color figure online)

problems of excess of nutrients leading to eutrophication and human pollution. We therefore consider the lagoons as suitable case studies to be compared. For this study we only refer to the Lithuanian part of the Curonian Lagoon due to data availability.

Szczecin Lagoon

The Szczecin Lagoon, also referred to as the Oder Lagoon, is located in the border between Germany and Poland and is one of the largest coastal lagoons in Europe. Comprising an area of 687 km^2, the average depth of the lagoon is 3.8 m (Schernewski et al. 2012a). The lagoon connects to the Baltic Sea by 3 outlets, but its water dynamics are largely dominated by the discharging Odra (Oder) River. In fact, the average salinity of 1.5 PSU denoted a minimum influence of the Baltic (6–7 PSU) in water exchange, which is about 55 days (Schiewer 2008). The lagoon supports a variety of fish, birds and other vertebrate and invertebrate species and emerged and submersed flora. It serves as a nursery and spawning grounds and resting area for birds. Due to its importance, the lagoon is under different protection status, both international and national, being part of the Natura 2000 network (Wolnomiejski and Witek 2013).

Located along the shoreline many settlements directly or indirectly depend on the lagoon. Tourism and fisheries are the main socio-economic activities in the area. On the German side around 5 million overnight stays each year depict the importance of tourism as an economic driver. The lagoon also serves as a shipping corridor to the port of Szczecin and is used during the year for sailing and other recreation activities.

Despite its importance the lagoon has been suffering from anthropogenic impacts, hampering the provision of ES. Nutrient loads to the lagoon have created eutrophication problems, decreasing water quality and overall ecological status to a eutrophic state (Radziejewska and Schernewski 2008). This poses a threat to the deliverance of ES and impact on the different socio-economic dimensions and dynamics of the area surrounding the lagoon.

Curonian Lagoon

Located at the border between Lithuania and Russia, the Curonian Lagoon is the biggest coastal lagoon in Europe. It has a surface area of 1584 km^2 (Čerkasova et al. 2016), and an average depth of 3.8 m (Žaromskis 1996). The lagoon is only connected with the Baltic Sea by one outlet near Klaipeda city (Lithuania), and the water exchange time is 81 days (Schiewer 2008). The lagoon shows salinity gradients with mean values between 0 and 7 PSU (Christian et al. 2008), and its hydrodynamics are mainly influenced by the freshwater discharge of Nemunas River and wind action (Umgiesser et al. 2016).

Like the Szczecin, the Curonian Lagoon is also very important from a biodiversity point of view supporting different marine and brackish species and serving as nursery area for fish and wintering grounds for birds. The lagoon has a large resident colony of cormorants that play a major role in the food web dynamics of the lagoon (Žydelis and Kontautas 2008), which has also been influenced by the arrival of invasive and alien species (Zaiko et al. 2007). Similarly, the lagoon is under different international and national protection status as Natura 2000 and Ramsar sites (Gasiūnaitė et al. 2008).

The main economic activities in the Curonian Lagoon are Klaipeda's Port activities, tourism and fisheries. Klaipeda's port, located at mouth of the lagoon is the main economic driver of the region's industry. Around the lagoon many settlements rely on local tourism as their main source of income. The Curonian Spit, which is a Protected area and UNESCO Heritage site and visited annually by around 400,000 visitors (Povilanskas and Armaitienė 2014), separates the lagoon from the Baltic Sea. Fisheries is considered a small scale economic activity although in some cultural events they can play a role in families' economics.

Despite its importance, the Curonian Lagoon faces similar problems as the Szczecin. Eutrophication events and summer blue algae blooms cause a decrease in water quality and transparency (Newton et al. 2014), which negatively influences and impacts the socio-economic dynamics of the area.

Methodology: Marine Ecosystem Services Assessment Tool (MESAT)

We present a newly developed methodological approach and tool to address changes in ES provision over time for transitional and coastal waters. Named the Marine Ecosystem Services Assessment Tool (MESAT), it builds on the premise that changes in ecosystems structures and functions may influence a system's ability to provide ecosystem services. The tool can be freely downloaded from the BONUS BaltCoast website (http://www.baltcoast.net).

Concept and description of the tool

Through the Water Framework Directive and the Marine Strategy Framework Directive, the EU aims at achieving a good ecological status (GES) of European water bodies and integrate ES into management strategies. An unanswered question, however, is how does this GES translate into terms of ES provision? To answer this question, we compare a point in time when the water bodies were in a GES to a present status. We then assess the difference in ES provision in both states. For this we developed a tailor made, easy-to-use, computer-aided spreadsheet tool that assesses relative changes in ES provision through indicators. These relative changes are then allocated into so called "categories of change" used to represent an increase, decrease or no change of services provision over time. The tool was developed in MS Excel format and can thus easily be used by for example public administrations charged with ES assessments. Within the tool are guidelines providing all the necessary information for a practical assessment with automatically generated graphical outputs.

To spatially define the assessment units used in the tool, we used the WFD Water Body Typology, which is an accepted division of water bodies and publicly available information. The same WFD guidelines are used in the tool to define the initial ecological status. The Directive suggests that a good ecological status can be inferred from reference ecological conditions.

Classification and indicators

The classification chosen was the CICES version 4.3 developed by Roy Haines-Young and Potschin (2013) for its current application in EU assessments. The classification divides ES into provisioning, regulating and maintenance and cultural. Furthermore, it hierarchically separates sections into divisions, groups and classes of ES. The hierarchical organization allows to provide results in different aggregation levels. Version 4.3 of CICES includes 48 classes of ES, hence for the application of marine and coastal areas we excluded terrestrial related services and ended up with 31 classes (Table 1).

To assess services, we employ indicators. The EU project MAES (Maes et al. 2016) indicator set has a direct correspondence to CICES. Furthermore, MAES defined indicators for marine, coastal and transitional waters. One problem was that many services in MAES were represented by the same indicator. A solution was to keep some MAES indicators and define ourselves new indicators to fill in the gaps. Criteria were representativeness for the service, suitability, data availability, ease of understanding and the use of expert judgement. After several refinements, our present indicator set is composed of 54 indicators (Table 1).

In summary, the provisioning section is composed of 10 services represented by 14 indicators, the regulating and maintenance composed of 11 services and 27 indicators, and the section Cultural services is represented by 10 services and 13 indicators. A full explanation regarding the meaning of each indicator and its units can be found in Table S1.

Assessment process

The assessment framework of MESAT follows 4 steps: definition of the study area, definition of both initial and present status, assessment of services and visualization of results. Figure 2, available in the guidelines of the tool (BONUS BaltCoast website—http://www.baltcoast.net), shows on the left-hand side the visualization of the steps, and on the right-hand side the description of each step and provides the necessary information to complete the assessment in an intuitive way.

Table 1 Classification and indicators used in the Marine Ecosystem Services Assessment Tool Framework

ES classification (modified from CICES v4.3)				Indicators (proposed and from MAES)	
Section	Division	Group	Class	Indicator	Units
Provisioning services	Nutrition	Biomass	Wild plants, algae and their outputs	*Harvest of wild plants, algae*	ton $year^{-1}$ km^{-2}
				No. of species of wild plants, algae	No. km^{-2}
			Wild animals and their outputs	Landings (wild animals)	ton $year^{-1}$ km^{-2}
				Landing of key market species (wild animals)	ton $year^{-1}$ km^{-2}
			Animals from in situ aquaculture	*Harvest* (*animals from aquaculture*)	ton $year^{-1}$ km^{-2}
				No. of species (animals from aquaculture)	No. km^{-2}
			Plants and algae from in situ aquaculture	*Harvest* (*plants, algae from aquaculture*)	ton $year^{-1}$ km^{-2}
				No. of species (plants, algae from aquaculture)	No. km^{-2}
		Water	Surface water for drinking purposes	Use of water for drinking	m^{-3} km^{-2}
	Materials	Biomass	Fibers and other materials from plants, algae and animals for direct use or processing	Harvest of materials from plants, algae and animals for direct use or processing	ton $year^{-1}$ km^{-2}
			Materials from plants, algae and animals for agriculture	Harvest of materials from plants, algae and animals for agriculture, fodder	ton $year^{-1}$ km^{-2}
		Water	Surface Water for non-drinking purposes	Use of water for non-drinking	m^{-3} km^{-2}
	Energy	Biomass-based energy resources	Plant based resources	Use of plant-based resources for energy	ton $year^{-1}$ km^{-2}
			Animal based resources	Use of animal-based resources for energy	ton year−1 km^{-2}
Regulating and maintenance services	Mediation of waste, toxics and other nuisances	Mediation by ecosystems	Filtration/sequestration/storage/accumulation by ecosystems	N-fixation	kg $year^{-1}$ km^{-2}
				Burial of P	kg $year^{-1}$ km^{-2}
				Denitrification	kg $year^{-1}$ km^{-2}
			Dilution by atmosphere, freshwater and marine ecosystems	Average of beach closures per year	No. km^{-2}
	Mediations of flow	Mass flows	Mass stabilization and control of erosion rates	*Extent of selected emerged, submerged and intertidal habitats*	km^{-2} km^{-2}
			Buffering and attenuation of mass flows	Sediment accumulation rate	cm $year^{-1}$
		Liquid flows	Flood protection	Shoreline erosion rate	mm $year^{-1}$ km^{-2}
				Maximum depth (to calculate maximum wave height)	m
				Design-basis flood	m
	Maintenance of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Maintaining nursery populations and habitats	Submerged and intertidal habitats diversity	No. km^{-2}
				Occurrence of oxygen concentration < 6 mg/L	days $year^{-1}$
				Secchi depth	m
				Species distribution	km^{-2} km^{-2}
				Nursery areas	km^{-2} km^{-2}
				% of nursery areas which are protected	km^{-2} km^{-2}

Table 1 continued

ES classification (modified from CICES v4.3)				Indicators (proposed and from MAES)	
Section	Division	Group	Class	Indicator	Units
		Pest and disease control	Pest and disease control	Harmful algal bloom outbreaks	No. km^{-2}
				Presence of alien species	No. km^{-2}
		Soil formation and composition	Decomposition and fixing processes	*Nitrogen removal*	%
				Water residence time	months
		Water conditions	Chemical condition of salt waters	Nutrients concentration	mg L
				Salinity	PSU
				Oxygen concentration	mg L
		Atmospheric composition and climate regulation	Global climate regulation by reduction of greenhouse gas concentrations	*C stock*	tonC km^{-2}
				C sequestration	tonC $year^{-1}$ km^{-2}
				pH	
				Primary production (PP)	tonC $year^{-1}$ km^{-2}
			Micro and regional climate regulation	Evaporation rate	Per km^{-2}
Cultural services	Physical and Intellectual interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Physical and experiential interactions	Experiential use of plants, animals and land-/seascapes in different environmental settings	No. of visitors taking part in activities related to biota	No. $year^{-1}$ km^{-2}
			Physical use of land-/seascapes in different environmental settings	No. of tourists (within 1 km of coastal zone)	No. km^{-2}
				No. of ship berths in the marinas	No. km^{-2}
				No. of tourist boat	No. * capacity km^{-2}
		Intellectual and representative interactions	Scientific and educational	*Scientific studies, Documentaries, educational publications*	No. $year^{-1}$ km^{-2}
				Visits to scientific and artistic exhibits	No. $year^{-1}$
			Heritage, cultural	No. of cultural and heritage sites	No. km^{-2}
			Entertainment	No. of movies and broadcasts in the area	No. km^{-2}
			Aesthetic	No. of pictures	No. $year^{-1}$ km^{-2}
	Spiritual, symbolic and other interactions with biota, ecosystems, and land-/seascapes	Spiritual and/or emblematic	Symbolic	No. of Red List and iconic species	No. km^{-2}
			Sacred and/or religious	No. of religious events (within 1 km of coastal zone)	No. km^{-2}
		Other cultural outputs	Existence	No. of offers for health treatments (within 1 km of coastal zone)	No. * capacity km^{-2}
			Bequest	*Extent of marine protected areas*	km^{-2} km^{-2}

The classification is a modified version of the CICES classification by Haines-Young and Potschin (2013). The indicator list builds on the adopted indicators from MAES (Maes et al. 2016) (in the list in italic), and newly developed ones

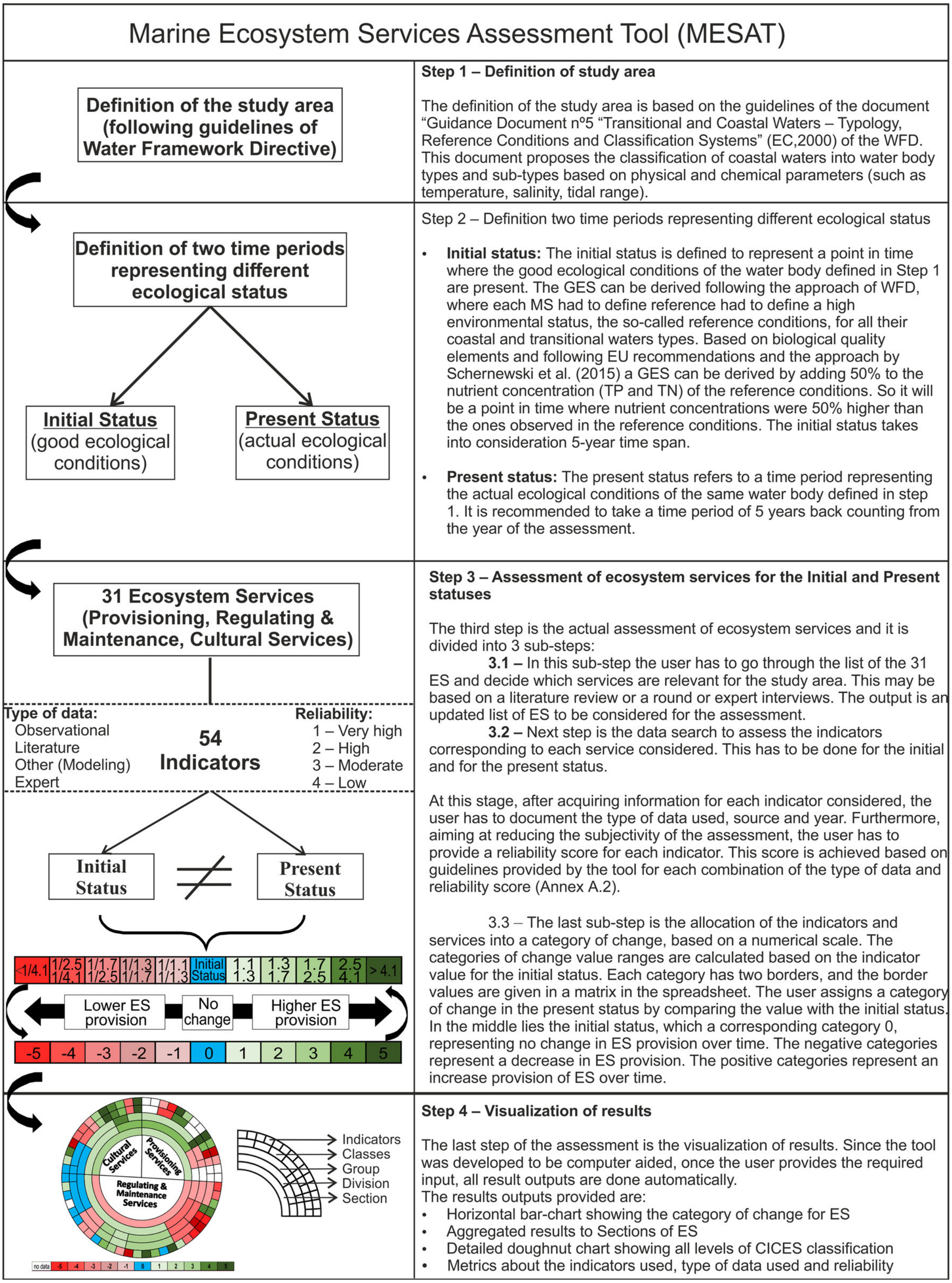

Fig. 2 Marine Ecosystem Services Assessment Tool (MESAT) Framework. Different horizontal boxes represent the different steps used to perform an assessment using MESAT. On the left-hand side, a more schematically view of the process and on the right-hand side are the guidelines the users must follow to fulfil the assessment. Modified from Inácio et al. (2017). Information regarding reliability score can be found in Table S2. The image of step 4 represents a one of the possible graphical representations of the MESAT, a magnified version of this image can be found in Fig. S1 of ESM (color figure online)

In step 3, the difference between indicator values is allocated into a category of change, represented in Fig. 2 by two scales. The upper scale is a numerical fractional scale where the upper and lower values correspond to the boundaries of each category of change. The categories are calculated by multiplying the boundary values with the indicator value for the initial status. The second scale (from − 5 to 5) is a Likert scale which was chosen just to simplify the representation of the results. Using this scale also makes it easier to communicate the results to different audiences.

In step 4, one of the outputs generated by the tool is an aggregated representation of the results. The aggregation is done by a simple averaging of the categories of change of each hierarchical level of CICES. For example, each class is an average of the considered indicators, each division level is an average of the corresponding classes of ES, and so on until we have an aggregation to section of ES which is an average of the groups of ES.

Typology of assessment

The tool was developed to be used for qualitative, semi-quantitative and quantitative approaches, fitting to the needs of different users. The results indicate a relative change for each ES and can be aggregated to the hierarchical composition. To test and demonstrate this, we apply the MESAT in a semi-quantitative way to the case study of Szczecin Lagoon (Germany/Poland) and in a qualitative way to Curonian Lagoon (Lithuania/Russia).

The semi-quantitative approach, followed the normal procedure and guidelines of the tool. A priori we identified which services were relevant or not for the study area. After that, we defined which indicators could be quantified and which sources of data could be used. Preference was given to observational and crisp data (from datasets and databases), followed by literature-based information, other data (modelling), and lastly using expert judgement.

The qualitative approach was based on expert interviews. This was done both verbally and in written form. We also did a priori identification of relevant ES for the study area. The interviewer explained the concept and tool and asked experts how they perceived changes in service provision over time whether they increased, decreased or remained unchanged. Then we asked the experts to express their assessment of ES changes on a scale from 1 to 5 or − 1 to − 5. In total we interviewed 15 experts from different age and educational backgrounds and covering natural and social sciences. Scientists, municipality, public, tourism association and fisheries representatives gave their expertise representing broad and quite complete view and perception of the lagoon.

Definition of initial and present status for the case studies

Following the EU WFD guidelines, coastal water types in the Baltic Sea are defined by their salinity, depth, mixing, residence time and substratum. According to the typology, the Szczecin Lagoon belongs to type B1, characterized by a salinity < 5 PSU, water retention time > 30 days, depth < 10 m (Schernewski and Wielgat 2004). The German national group responsible for the implementation of the WFD defined the reference ecological conditions of their waters in a time period around 1880s (Schernewski et al. 2015). Following the approach of the WFD described in Schernewski et al. (2015), a good ecological state can be derived from the reference conditions using nutrient concentrations. By adding 50% to the nutrient concentrations from the 1880s it estimates an anthropogenic influence but still good ecological state. In the western Baltic Sea, the corresponding nutrient concentrations were observed, in general in the early 1960s. We then took 5 years, corresponding to the period 1960–1965, and assessed the present status for 5 years (2010–2015) to dilute the interannual variability. For the Curonian Lagoon we took the same time periods for expert evaluation. As the Curonian also belongs to the B1 type, it ensures a comparability with results from the Szczecin Lagoon. Furthermore, in general, experts stated that 1960s correspond also to a good (or better) ecological status in the lagoon.

Results

The results presented comprise the steps 3 and 4 of the MESAT approach, hence not all graphical outputs potentially generated by the tool are presented in this study.

Semi-quantitative assessment of ES in Szczecin Lagoon

A total of 22 out of 31 services were assessed and quantified for the Szczecin Lagoon. Figure 3 (a graphical output from the tool) shows detailed information about the number of indicators, type of data used and proportion of data reliability, for both initial and present status. For the initial and present statuses 32 and 39 indicators were used respectively. Both statuses had "other sources" and "moderate" as predominant data type and reliability score. This is because we used modelling data to assess most of the regulating and maintenance section which we allocate in "other sources" sections and "moderate" reliability.

When assessing the provision section, only the service "Wild animals and their outputs", and its 2 fishery-related indicators, were considered relevant (being used). Table 2 shows the values of the indicators and the category of change across the hierarchical organization of CICES. The overall category of change of "– 3" reveals a decrease of about 40–60% in today's service provision compared to the initial status. More detailed information can be found in Table S3.

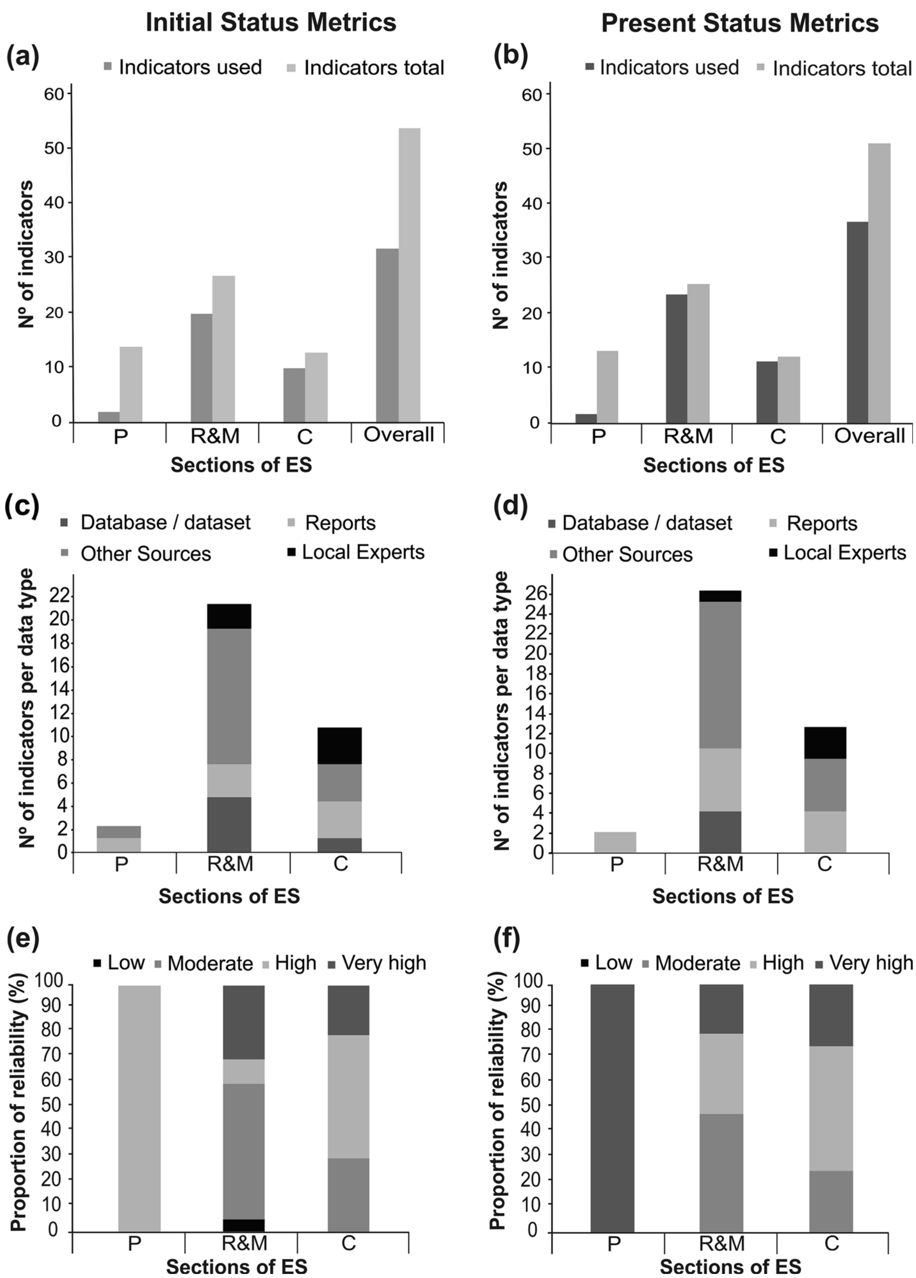

Fig. 3 Metrics regarding the data used for the Szczecin Lagoon assessment. On the left-side results of initial status and on the right-side results of present status. ES Sections: *P* provisioning/*R&M* regulating and maintenance/*C* cultural

This section experienced a strong reduction of services provision. Only 2 out of 14 indicators were considered, which relate to fisheries and follows the sector's trend both globally (FAO 2011), and locally (Stybel et al. 2014). Fish landings have decreased, leading to the indicator classification of "– 1", but more accentuated was the decrease in landings of key market species. While the total fish biomass has decreased only little, there was a shift in market target species. More valuable species such as pikeperch, eel and pike were mainly replaced by low valued species such as roach, perch and bream (Radziejewska and Schernewski 2008; Stybel et al. 2014).

All 11 services of the regulating and maintenance section were considered relevant and assessed by 22 indicators. The results of Table 3 show a decrease of 7 indicators, increase of 4 and 13 remained unchanged. The aggregated category of change suggests an overall decrease of "– 1" or a decrease of today's services provision of about 10–20%. More detailed information can be found in the Table S4.

Most of the regulating and maintenance services and indicators relate directly or indirectly to ecological pro-

Table 2 Assessment of provisioning ES for the Szczecin Lagoon

Classification			Assessment			Aggregation			
Class	Indicator	Units	Initial status	Present status	Category	Class	Group	Division	Section
Wild plants, algae and their outputs	Harvest	ton $year^{-1}$ km^{-2}	N/C					− 3	− 3
	No. of species	No. km^{-2}							
Wild animals and their outputs	Landings	ton $year^{-1}$ km^{-2}	3.937	3.360	− 1	− 3	− 3		
	Landing of key market species	ton $year^{-1}$ km^{-2}	1.082	0.331	− 4				
Animals from in situ aquaculture	Harvest	ton $year^{-1}$ km^{-2}	N/C						
	No. of species	No. km^{-2}							
Plants and algae from in situ aquaculture	Harvest	ton $year^{-1}$ km^{-2}							
	No. of species	No. km^{-2}							
Surface water for drinking purposes	Use of water	m^{-3} km^{-2}					N/C		
Fibres and other materials from plants, algae and animals for direct use or processing	Harvest	ton $year^{-1}$ km^{-2}						N/C	
Materials from plants, algae and animals for agriculture	Harvest	ton $year^{-1}$ km^{-2}							
Surface water for non-drinking purposes	Use of water	m^{-3} km^{-2}							
Plant based resources	Use	ton $year^{-1}$ km^{-2}							
Animal based resources	Use	ton $year^{-1}$ km^{-2}							

On the right-hand side the aggregation based on averages of categories of change for each hierarchical level of the CICES

N/C not considered

cesses and functions. A decrease in this section could point to an impact on the ecosystems ecology and thus its ability to provide services. Kjerfve (1994) relates this phenomenon with increasing anthropogenic environmental problems. The Szczecin Lagoon has experienced a decrease in water quality, an increase in eutrophication events, a decrease in water transparency and a decrease in the overall ecological status (Humborg et al. 2000; Schernewski et al. 2001, 2012b, 2015; Schernewski and Wielgat 2001; Wolnomiejski and Witek 2013). The consequence of this decrease is the influence this section exerts in the regulation of other services and sections (Maes et al. 2015). For example, nowadays there are protected fish nursery areas, which were not in place in 1960, so that the indicator "% of nursery areas which are protected" increased, while potential nursery grounds characterized by a high macrophyte coverage, strongly decreased (Schernewski et al. 2001). Therefore, it may influence the recruitment of fish and therefore fisheries as a service.

Finally, the cultural section is assessed by its 10 services. Table 4 shows that out of 13 indicators 3 remained unchanged and 10 increased. Aggregating the results in the hierarchy the overall category of change for this section is of "3", an increase of 170–250% of today's services provision. More detailed information can be found in the Table S5.

The increase in cultural services provision suggests an increasing usage of cultural, cognitive and emotional outputs connected with the lagoon. Haller et al. (2011) and Schernewski et al. (2012b) estimated per year 33 million overnight stays and 10 million tourists enjoying the German Baltic Sea coast and the Szczecin Lagoon respectively. The increase of other indicators like scientific studies and number of pictures, which reveal cognitive, aesthetic and spiritual connections to the lagoon, can be also explained by the political and social shift between initial and present status. The initial status corresponds historically to the time before the fall of the Iron Curtain, while in the present days the region has more economic and social independence to decide their development plans, including a focussing on investments and touristic development, social wellbeing and other cultural aspects.

Qualitative assessment of ES in Curonian Lagoon

The results in Fig. 4 show the individual contribution of 15 expert valuations for the ES assessment in the Curonian Lagoon. The assessment was done on class level as many experts did not feel comfortable to give their opinion on a specific level as indicators. Each contribution represents a category of change of today's provision relative to the past. In the end we show the average, median and standard deviation of the contributions. No single expert gave scores for all classes of ES. This was especially the case for the regulating and maintenance services where the gap (white cells) appears

Table 3 Assessment of regulating and maintenance ES for the Szczecin Lagoon

Classification			Assessment			Aggregation			
Class	Indicator	Units	Initial status	Present status	Category	Class	Group	Division	Section
Filtration/sequestration/storage/accumulation by ecosystems	N-fixation	kg year^{-1} km^{-2}	0.121	0.063	− 3	− 2	− 1	− 1	− 1
	Burial of P	kg year^{-1} km^{-2}	23.050	17.040	− 2				
	Denitrification	kg year^{-1} km^{-2}	23,634.22	22,755.67	0				
Dilution by atmosphere, freshwater and marine ecosystems	Average of beach closures per year	No. km^{-2}	0	0	0	0			
Mass stabilisation and control of erosion rates	Extent of selected emerged, submerged and intertidal habitats	km^{-2} km^{-2}	0.1	0.039	− 4	− 4	− 2	− 1	
Buffering and attenuation of mass flows	Sediment accumulation rate	cm year^{-1}			0	0			
Flood protection	Shoreline erosion rate	mm year^{-1} km^{-2}			0	− 1	− 1		
	Significant wave height	m	0.185	0.163	0				
	Design-basis flood	m	0.769	0.476	− 3				
Maintaining nursery populations and habitats	Submerged and intertidal habitats diversity	No. km^{-2}	0.006	0.006	0	0	0	− 1	
	Occurrence of bottom oxygen concentration < 6 mg/L	days year^{-1}	0.5	1	0				
	Secchi depth	m	1.100	0.610	− 3				
	Species distribution	km^{-2} km^{-2}			N/C				
	Nursery areas	km^{-2} km^{-2}		0.136	− 4				
	% of nursery areas which are protected	km^{-2} km^{-2}	0	1	5				
Pest and disease control	Harmful algal bloom outbreaks	No. km^{-2}			0	− 2	− 2		
	Presence of alien species	No. km^{-2}			− 4				
Decomposition and fixing processes	Nitrogen removal	%	79	79	0	0	0		
	Water residence time	months	2	2	0				
Chemical condition of salt waters	Nutrients concentration	mg L	0.662	0.760	− 1	− 1	− 1		
	Salinity	PSU	0.900	0.720	− 1				
	Oxygen concentration	mg L	11.300	11.100	0				
Global climate regulation by reduction of greenhouse gas concentrations	C stock	tonC km^{-2}			0	0	0		
	C sequestration	tonC year^{-1} km^{-2}			N/C				
	pH		8.550	8.660	0				
	Net primary production	tonC year^{-1} km^{-2}	0.003	0.004	1				
Micro and regional climate regulation	Evaporation rate	per km^{-2}	513,750.3	528,076.8	0	0			

On the right-hand side the aggregation based on averages of categories of change for each hierarchical level of the CICES
N/C not considered

Table 4 Assessment of cultural ES for the Szczecin Lagoon

Classification		Assessment				Aggregation			
Class	Indicator	Units	Initial status	Present status	Category	Class	Group	Division	Section
Experiential use of plants, animals and land-/seascapes in different environmental settings	No. of visitors taking part in activities related to biota	No. year^{-1} km^{-2}			0	3	3	3	3
Physical use of land-/seascapes in different environmental settings	No. of tourists (within 1 km of coastal zone)	No. km^{-2}	614.113	21,229.85	5	4			
	No. of ship berths in the marinas	No. km^{-2}	0	2.712	4				
	No. of tourist boat	No. * capacity km^{-2}	0	0.123	3				
Scientific and educational	Scientific studies, documentaries, educational publications	No. year^{-1} km^{-2}	0.003	0.114	5	5	4		
	Visits to scientific and artistic exhibits	No. year^{-1}			0				
Heritage, cultural	No. of cultural and heritage sites	No. km^{-2}	0.022	0.063	4	4			
Entertainment	No. of movies and broadcasts about the area	No. km^{-2}	0	0.008	2	2			
Aesthetic	No. of pictures	No. year^{-1} km^{-2}	0.007	0.057	5	5			
Symbolic	No. of red List and iconic species	No. km^{-2}	0.001	0.047	4	4	3	3	
Sacred and/or religious	No. of religious events (within 1 km of coastal zone)	No. km^{-2}	0	0.032	3	3			
Existence	No. of offers for health treatments (within 1 km of coastal zone)	No. * capacity km^{-2}	0		0	0	2		
Bequest	Extent of marine protected areas	km^{-2} km^{-2}	0	1	0	5			

On the right-hand side the aggregation based on averages of categories of change for each hierarchical level of the CICES

N/C not considered

in the middle of the matrix. Experts from different backgrounds than science stated that it would be hard to contribute their knowledge to the assessment of these services or they did not understand the processes which deliver the service well enough to give an opinion.

The results suggest that no changes in services provision occur on an aggregated provisioning section level. This result stems from counteracting movement between individual ES changes. On one side, services related to nutrition decreased over time due to decrease in fisheries (Zolubas et al. 2014) and the abandonment on the usage of plants for food. On the other side, experts pointed an increase in plant and animal-based resources for production of energy, yet it was not possible to find any information about companies or industries exploring these resources.

The overall expert opinion is that provision of regulating and maintenance services has increased. As the lagoon has also suffered from a decrease in water quality and ecological status, it seems inconsistent that a decrease in ecological status would increase the provision of services related to ecological processes and functions, yet only scientists have contributed to this section, and we would assume coherent results.

Finally, the increase in cultural services section was almost unanimous among experts. This was the section where most felt comfortable answering the questions, even if this was not their area of expertise. This might be because cultural services, according to Poe et al. (2014) and Haines-Young and Potschin (2010), are tightly connected to human values. Like the Szczecin Lagoon, political and socio-economic changes between the initial and present status dictates the increase in cultural output demand and provision.

Comparing ES of both lagoons

Figure 5 puts side by side the assessment results of both lagoons. Utilizing the results of the two assessments we can compare, at class level, the changes in services provision. Even though two different approaches were used, the final results are given in the same format allowing for comparison in terms of similarities and dissimilarities.

The first clear dissimilarity is the number of services considered in the assessments, 22 for Szczecin Lagoon and 29 for Curonian Lagoon. This difference at class level, only represents how many services are relevant or explored for each lagoon. However, the difference does not mean that the Szczecin Lagoon has less services, rather that they are not explored or there was no data available to quantify them. Furthermore, in a closer look the difference is mainly because of the provisioning section. The number of services explored in this section is very much connected with socio-economic and cultural background of each study area.

When we are aggregating the results to Section level, the number of services considered do play a role. Fig-

Class of ES	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15	A	M	SD
Wild plants, algae and their outputs						−5	−5	−3	−4	2	−2	−2	−2	0	−2	−2	−2	2
Wild animals and their outputs	−4	−3		−4	−2											−3	−3	1
Animals from in situ aquaculture					−1											−1	−1	0
Plants and algae from in situ aquaculture																		
Surface water for drinking purposes																		
Fibres and other materials from plants (…)				1	5	−3	−3	0	−1	−1	0	−2	2	−3	3	0	0	2
Materials from plants, algae and animals (…)				1		−5	−5	−1	−2	−2	−1	2	−3	−2	−2	−2	−2	2
Surface Water for non-drinking purposes	−1					−4	−4	−2	−2	−1	0	1	3	−2	−4	−1	−2	2
Plant based resources					2											2	2	0
Animal based resources					2											2	2	0
Filtration/sequestration/storage/ (…)				1												1	1	0
Dilution by atmosphere, freshwater (…)	0			1	0											0	0	0
Mass stabilisation and control of erosion rates				1	0											1	1	1
Buffering and attenuation of mass flows				1												1	1	0
Flood Protection	0				0											0	0	0
Maintaining nursery populations and habitats	1	5	2	1	0											2	2	2
Pest and Disease control	3	3	−2	2	−5											0	−1	3
Decomposition and fixing processes	0	−3	−1	1												−1	−1	1
Chemical condition of salt waters	2	3	0	2	−3											1	1	2
Global climate regulation by reduction (…)			1	3	0											1	1	1
Micro and regional climate regulation	1			1	0											1	1	0
Experiential use of plants, animals (…)	3	4	4	1	2	5	5	0	5	5	2	2	3	2	2	3	3	2
Physical use of land-/seascapes in (…)	1	3	3	3	3	5	4	0	1	2	2	3	4	3	0	2	3	1
Scientific and Educational	2	5	3	5	5	4	4	−3	0	0	0	2	2	2	−3	2	2	3
Heritage, cultural	1	3	2	2	5	5	5	4	5	−1	3	3	4	5	3	3	4	2
Entertainment	3	2	2	1	3	1	1	−5	−3	0	1	4	−4	4	2	1	1	3
Aesthetic	5	5	4	5	2	5	5	5	5	5	5	5	5	4	5	5	5	1
Symbolic	0	1	1	2	3	0	0	0	2	3	1	1	2	0	−3	1	1	1
Sacred and/or religious	4	1		2	5	5	5	5	5	0	2	5	4	5	4	4	5	2
Existence	−2	0	4	2	5	5	5	1	5	5	5	5	5	2	5	3	5	2
Bequest	5	5	5	2	5	5	5	1	5	5	5	5	5	2	5	4	5	1

Fig. 4 Expert contributions for the assessment of changes in services provision for the Curonian Lagoon. Negative numbers represent a decrease in services provision, the positive an increase and the number "0" represents no changes. White cells represent no contribution of the expert when assessing the service. *E* expert, *A* average, *SD* standard deviation (color figure online)

ure 6 represent the aggregated results of both lagoons to section level.

For Provisioning the difference is not only in the number of services considered but the overall category of change. The Szczecin show a decrease and the Curonian an unchanged category regarding services provision. Important is to note that one is represented by one service and the other by eight. The practical consequence is that while for the Curonian Lagoon the "no change" is a balance between positive and negative individual changes, for the Szczecin it is only one individual change that represents the whole Section. The Regulating and Maintenance Section also shows differences with a decrease for the Szczecin and an increase for the Curonian. Despite that in both lagoons the ecological status decreased over time, in a quantitative perspective services provision was affected and decreased, while in the qualitative perception it increased. Regarding cultural services both lagoons and approaches were unanimous showing an increase.

Discussion

Methodological considerations

As it was the first test application of the MESAT there are some aspects to take into consideration in terms of the methodological approach. The first aspect to consider is the use of categories of change and not absolute

Classes ES	SL	CL
Wild plants, algae and their outputs		−2
Wild animals and their outputs	−3	−3
Animals from in situ aquaculture		−1
Plants and algae from in situ aquaculture		
Surface water for drinking purposes		
Fibres and other materials from plants, algae and animals for direct use or processing		0
Materials from plants, algae and animals for agriculture		−2
Surface Water for non-drinking purposes		−1
Plant based resources		2
Animal based resources		2
Filtration/sequestration/storage/accumulation by ecosystems	−2	1
Dilution by atmosphere, freshwater and marine ecosystems	0	0
Mass stabilisation and control of erosion rates	−4	1
Buffering and attenuation of mass flows	0	1
Flood Protection	−1	0
Maintaining nursery populations and habitats	0	2
Pest and Disease control	−2	0
Decomposition and fixing processes	0	−1
Chemical condition of salt waters	0	1
Global climate regulation by reduction of greenhouse gas concentrations	0	1
Micro and regional climate regulation	0	1
Experiential use of plants, animals and land -/seascapes in different environmental settings	0	3
Physical use of land-/seascapes in different environmental settings	4	2
Scientific and Educational	5	2
Heritage, cultural	4	3
Entertainment	2	1
Aesthetic	5	5
Symbolic	4	1
Sacred and/or religious	3	4
Existence	0	3
Bequest	5	4

Fig. 5 Comparing ES changes for both lagoons at class level. *SL* Szczecin Lagoon, *CL* Curonian Lagoon. Negative numbers represent a decrease in services provision, the positive an increase and the number "0" represents no changes (color figure online)

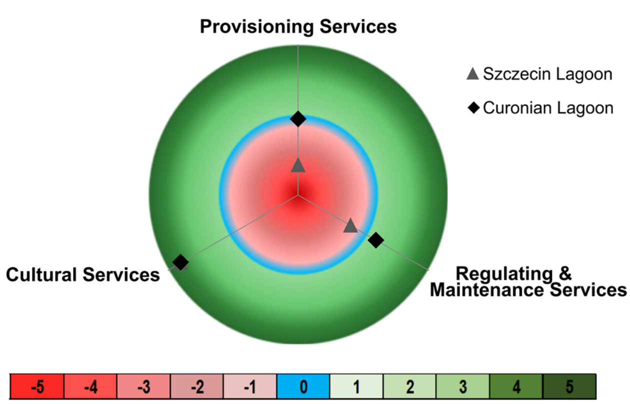

Fig. 6 Aggregated results to sections of ES for both lagoons. Negative numbers represent a decrease in services provision, the positive an increase and the number "0" represents no changes (color figure online)

values of ES, which allows direct comparison not only among services but also between approaches. Figure S2 gives an example of how two indicators as different as "No. of tourists" and "Secchi Depth", are directly compared using categories of change. Having in mind that that the ES concept relates to benefits to humans, means that an increase or decrease of services provision can have positive and negative impacts on human well-being. Therefore, it was necessary to analyse indicator changes against human wellbeing, resulting in a reverted category of change. For example, an increase in the indicator of invasive species occurrence means in most cases negative impacts to the ecosystem and therefore impacting services provision and influencing human wellbeing. Such information is available in the guidelines of the tool and automated in the calculations.

The second aspect to consider is the choice of classification and indicators. However useful, the wording used in this CICES posed some problems, especially in the qualitative context. Haines-Young (2016) analysed CICES users' biggest difficulties in its application, and it was exactly the terminology. This may have been a problem for experts and might also explain the occurred mismatches between expert assessments and other scientific assessments such as on regulating services in the Curonian Lagoon which points to the need for further refinements regarding the qualitative approach. A solution is to simplify the wording and keep the same meaning. We keep to CICES however, the MESAT can easily be adapted and transferred to other state of art or updated classifications. To find optimal indicators to represent services is a hard task and in the MESAT we developed and tried new indicators, which if successful can be used in other studies. Most of the indicators were easy to use, apply and quantify. Yet, problems related to data availability and representativeness made some indicators hard to use. In most cases, indicator failures were due to private data holding and the non-record or data keeping for the initial status, making comparisons hard. Another aspect to take into consideration is the overlap of some indicators with the terrestrial realm (cultural services), where we had to include 1 km coastal zone as many services are generated in water and enjoyed on land (Hein et al. 2006; Syrbe and Walz 2012). Although there is no way to escape from this, what we can do is to improve our indicator set with others used in literature specific for the marine environment (Liquete et al. 2013; Hattam et al. 2015; Sousa et al. 2016).

Another aspect of the MESAT that has to be discussed is the aggregation process. CICES fitted well to our approach as we could aggregate results from lower to higher hierarchical levels of the classification. The aggregation is done via a basic average of categories of change following the CICES classification. For the classes level there is no problem as the aggregated indicators represent only a service. However, this is not true to for higher levels, where there are only one or two services representing a whole section. This is the case of our assessment of provisioning services of the Szczecin Lagoon, where only fishery related services are explored. It seems not reasonable to define a section based only on one service, but in this specific case and according to Newton et al. (2018) provisioning services in lagoons worldwide maybe provide food and materials. In our case fisheries (as food) is representative of provisioning ES. Nevertheless, the aggregation process in the MESAT can be improved. To consider the insertion of a weighting score in the aggregation process, so the results are balanced according to services representability.

A discussion topic recurrently raised around the ES concept is how reliable quantification and assessment of services are (Hamel and Bryant 2017) and how we can improve it. In the MESAT (Table S2) we have tried to go one step in this direction. The content of the table is a subjective perception of data quality, which resulted from a discussion among a group of scientists. It simply, based on scientists' experience, formulates guidelines for each data type to allocate a reliability score. At the moment the reliability scores are not influencing the end results, the guidelines fit to our approach. In future, when introducing a weighting score the guidelines have to be reviewed to follow data quality standards.

It is also important to analyse our own tool against existing ES assessment tools to define points in favour and against. The choice of which tool to use depends on the purpose, technical characteristics and aims (Bagstad et al. 2013; Peh et al. 2013). Tools can be analysed regarding their approach [(semi-)quantitative or qualitative], number of services (holistic, bundles or singular), necessary technical expertise (Excel-based, software or GIS-based), time consumed (days, months, years) and result outputs (assessment, mapping or both). The MESAT is a versatile mixture of these components. It is built in a spreadsheet format, therefore, the technical expertise required is low when compared with software and GIS-based tools, such as "Integration Valuation of Ecosystem Services and Tradeoffs (InVEST)" tool by Tallis et al. (2013) and the "The Multiscale Integrated Model of Ecosystem Services (MIMES)" tool by Boumans et al. (2015). Having low technical expertise needs allows a broader spectrum of users such as municipalities or NGO's, to apply the tool easily. However, besides not being built as a GIS-based tool, the outputs can easily be transferred to GIS using the category of change in a colour scheme. In literature, we find examples of how qualitative and semi-quantitative approaches can be translated to GIS, as in the Matrix by Burkhard et al. (2012) and Depellegrin et al. (2016). What falls short in these approaches is that they assess the actual supply of services without considering the historical background, so there is no information about the sustainable use of ES. In the MESAT as we use a GES we know the state of actual provision which is important in the context of future sustainable development. The time expended is very dependent on data availability and good command of local language. In general, it can take from days (in an expert-based assessment), to several months to a year (in a quantitative assessment) similar to other tools. The versatile nature of the tool to adapt to the needs of users for a specific case study or management practice is a strong point of the MESAT, but the main value added beyond existing tools is the ease in comparing two or more points in time.

Finally, we pin-point strengths and weaknesses as well as opportunities to further develop the tool through a SWOT analysis (Gao and Peng 2011) represented in Table 5.

Comparing assessments and approaches

In both assessments, results are given as categories of change and are therefore comparable among the single services, but also among the different ways of data collection. To have a different number of services assessed does not mean that one lagoon provides more services

Table 5 SWOT analysis for the methodology and tool

SWOT analysis	
Strengths Assessment of multiple ecosystem services Assesses the relative changes in the provision of ES instead of absolute values Builds upon current international mainstream classification and indicators Addresses existing EU Policies Visualization of ES changes and aggregation following classification hierarchy Enables comparison between services Assessment can continually be updated Reliability score aims to reduce uncertainty	*Weaknesses* Requires good access to data sources Requires good knowledge and command of local language No clear separation between land and sea as services enjoyed on land are generated at sea The wording of CICES reveals problems in their understanding Aggregation to section level hamper the effects of individual services changes
Opportunities Fast adaptability to developments in the state of art in classifications and indicators Extension to different spatial scales Integration in GIS Tailormade for a specific case study or management practice analysis Specific guidelines of WFD, can be applied to other coastal systems outside of Europe Transferability across spatial scales	*Threats* Low number of services for a given section Reliability-based on the data quality International need for monetary valuations Indicators can be too general to be applied in a specific habitat

than the other, instead it gives information on similarities and dissimilarities regarding which services are being used and explored as well as the human demand for those services. Comparing both assessments can also provide insights on how both lagoons reacted to the environmental changes, which is important in understanding how ES dynamics and relationship work.

The application of the MESAT to both lagoons was able to demonstrate changes in temporal dynamics of ES provisions. These changes, in an overall perspective, came as a response to multiple drivers influencing the lagoon's ecological and socio-economic systems. In the Szczecin, the decrease of provisioning section, related to fisheries related service, poses a considerable economic problem for communities living on fisheries sector. We conferred the results with local fishermen who acknowledge the situation and related it with environmental impacts such as eutrophication events and low water transparency. In the Curonian Lagoon, the qualitative assessment resulted in no changes in provision for provisioning sections. Evidences of the increasing use of plant and animal-based resources for the production of energy, pointed by experts, were possible to be found. This could be explained by a lack of clarity between the interviewer and the expert or on supply and demand, which can occur in this kind of methodology (Saarikoski et al. 2015).

In both lagoons a decrease in water quality, increase in eutrophication events and overall decrease of ecological status has been observed. In the Szczecin Lagoon, the response to this environmental deterioration is the decrease of services provision for the regulating and maintenance section. In the Curonian Lagoon, despite the environmental deterioration, experts evaluated this section with an increase in provision. Disagreement between experts or the non-understanding of the service could have contributed to this mismatch. For example, the service of ''pest and disease control'' was evaluated with positive and with negative category of change. In the Baltic and in the Curonian Lagoon (Zaiko et al. 2007) the number of invasive species has increased. This would mean that the capacity of this service has decreased and not increased. This reiterates the importance of clarity, where is very important to explain sufficiently the concept and service when interviewing experts.

The increase in cultural section of both lagoons comes as a response to the increasing demand and use of coastal areas as cultural hotspots (Garcia Rodrigues et al. 2017), however it might rather indicate an increase in demand or consumption rather than an increase in supply. Although both lagoons have similar results, for the Curonian Lagoon results are interesting as the score of the experts were directly connected with human values. During the interviews, behind each valuation there was a story, either an episode of childhood or some experience revealed an emotional attachment to nature which unveils the importance of including local/native knowledge into ES assessment (Marie Roué and Zsolt Molnár 2017).

It is also important to analyse the results regarding spatial mismatches of ES provision and socio-economic differences between countries, which are highlighted by Syrbe and Walz (2012) and Milcu et al. (2013). In the assessment of the cross-border Szczecin Lagoon the idea was not to capture cultural and socio-economic differences between countries, but to have a general view of the services provided and used in the lagoon as a whole water body. For further research it makes sense to investigate the how socio-economic differences play a role in cross border systems like coastal lagoons.

Finally, it is also important to analyse how different approaches impact and influence results. Busch et al. (2012) state that both methods have their own merit and can serve different aspects of decision-making. A (semi-) quantitative approach achieves more reliable results as it is based on empirical data, whereas a qualitative approach gives the results based on perceptions and accumulated knowledge and experiences. Both approaches have pros and cons. A quantitative assessment gives more robust and reliable results, if the reliability score of the sources is high. However, it is laborious and consumes more resources, and it is not always possible to assess all services quantitatively. The qualitative expert-based assessment requires fewer resources, is faster and provides a general first impression of services provision, yet the results can be biased or influenced by personal perceptions (Drescher et al. 2013), or potential misunderstandings of categories and indicators as in our case. Also, a problem recurrent of expert assessment is to define the panel size. In our case we chose 15 experts but is this number enough? According to Campagne et al. (2017) there is not an absolute number of experts to be considered enough, only that standard deviation of scores declines with increasing number of experts. Furthermore, difference between 6 and 20 experts is minor. The study by Schernewski et al. (2018) uses a panel size of 8 experts to assess ES applied to coastal management. Although it is preferable to have as many experts involved as possible due to practical reasons it is not always easy to do so. Therefore, with 15 experts we can consider our panel size as sufficient.

In summary, both approaches are applicable within the MESAT and the end-results can be directly compared.

Implications for environmental management

In the marine management, ES knowledge has been integrated into decision-making through different legislation and management strategies such as the Water Framework Directive, Marine Strategy Framework Directive, Marine Spatial Planning, Integrated Coastal Zone Management and Biodiversity Strategy 2020 (Luisetti et al. 2011, 2014; Liquete et al. 2013). O'Higgins and Gilbert (2014) states that the inclusion of ES into MSFD and other policies is important as the inclusion of the integral role of humans into managements helps in the construction of sustainable societies. Such approaches and policies require different levels of needed information from decision makers.

The application of the MESAT can support the implementation of environmental management for different purposes, as different stakeholder needs can be fulfilled by the results from different CICES hierarchical levels. In a worldwide perspective the tool can be used to provides basic information as the number of services explored, which can be compared to other areas as it was done by Newton et al. (2018) showing that a proper management and conservation would contribute to human wellbeing. In a more regional context the tool can be used to deal with management specific questions. Schernewski et al. (2018) uses the tool to understand how potential future management scenarios would influence the provision of services within an area. This information can be then picked up by local stakeholders and discussed to understand which scenario would fit the best for a given objective.

As ES relate to multiple dimensions of human well-being, its assessment can support management approaches and strategies which are developed using the holistic perspective, in achieving more reliable and sustainable management plans. In fact, the inclusion of ES into approaches such ICZM (Elliff and Kikuchi 2015; Marre et al. 2015; Uehara and Mineo 2017) and MSP (Lester et al. 2013; Börger et al. 2014; Hattam et al. 2015; Nahuelhual et al. 2017), has already been address and tested successfully.

A more specific level of knowledge from the MESAT is the information obtained from the temporal dynamics of services provision. As we compare the present state of a water body with the one which refers to the GES, the results directly address the MSFD and the WFD by providing insights of how this future state would look like in terms of ES provision. This level of knowledge can also be related to the Biodiversity 2020 strategy in supporting MS to fulfil the necessary assessments and mapping of ES ensuring that target 2, which aims to restore ecosystems and ES through assessment and mapping in Europe, is achieved.

Other uses of the MESAT within marine environmental management are possible and will be explored in future assessments.

Conclusion

To provide a tool for the assessment of coastal ES, we developed the Ecosystem Services Assessment Tool. It has the capacity and benefit of being able to assess the impact of temporal dynamics and thus compare the current status against a good ecological one as it is required in the WFD and relate them to the provision of ES. The main advantage of the tool is the use of category of change to represent services instead of absolute values, making the comparison between services, data type and study areas possible. The consistently produced and reliable results with a semi-quantitative approach for the Szczecin case study contrasts with some inconsistent qualitative expert assessments, resulting in unexpected results for the Curonian case study, noting the need for further methodological development. With MESAT we provide a ready to use tool for quantitative and semi-quantitative data aided through a self-explanatory spread-sheet that can be applied or ES assessments in the coastal realm, which in turn can inform decisions on sustainable management strategies that ensure a non-declining wellbeing of the coastal population.

Acknowledgements This study was partly funded by The Service of Sediments in German Coastal Seas (SECOS) Syntheses Project, funded by German Federal Ministry of Education and Research (FK: 03F0738A), and BONUS BaltCoast (03F0717A) which has received funding from BONUS (BONUS BaltCoast and BONUS Optimus have received funding from BONUS (Art 185), funded jointly from the European Union's Seventh Programme for research, technological development and demonstration, and from Baltic Sea national funding institutions). Furthermore, the work was also supported by Doctoral Studies Program of Klaipeda University (Lithuania) and Leibniz Institute for Baltic Sea Research Warnemuende (Germany). To all who contributed with data and expertise for the realization of the assessments and development of methodology. To Dr. Nils Droste and Dr. Fatima Aziz, MEDCOAST Foundation and all members "Coastal and Marine Management" group at the Leibniz-Institute for Baltic Sea Research Warnemuende.

References

Bagstad KJ, Semmens DJ, Waage S, Winthrop R (2013) A comparative assessment of decision-support tools for ecosystem services quantification and valuation. Ecosyst Serv 5:27–39. https://doi.org/10.1016/j.ecoser.2013.07.004

Beaumont NJ, Austen MC, Atkins JP et al (2007) Identification, definition and quantification of goods and services provided by marine biodiversity: implications for the ecosystem approach. Mar Pollut Bull 54:253–265. https://doi.org/10.1016/j.marpolbul.2006.12.003

Böhnke-Henrichs A, Baulcomb C, Koss R et al (2013) Typology and indicators of ecosystem services for marine spatial planning and management. J Environ Manag 130:135–145. https://doi.org/10.1016/j.jenvman.2013.08.027

Börger T, Beaumont NJ, Pendleton L et al (2014) Incorporating ecosystem services in marine planning: the role of valuation. Mar Policy 46:161–170. https://doi.org/10.1016/j.marpol.2014.01.019

Boumans R, Roman J, Altman I, Kaufman L (2015) The Multiscale Integrated Model of Ecosystem Services (MIMES): simulating the interactions of coupled human and natural systems. Ecosyst Serv 12:30–41. https://doi.org/10.1016/j.ecoser.2015.01.004

Bouwma I, Schleyer C, Primmer E et al (2016) Adoption of the ecosystem services concept in EU policies. Ecosyst Serv 29:213–222. https://doi.org/10.1016/j.ecoser.2017.02.014

Burkhard B, Kroll F, Nedkov S, Müller F (2012) Mapping ecosystem service supply, demand and budgets. Ecol Indic 21:17–29. https://doi.org/10.1016/j.ecolind.2011.06.019

Busch M, La Notte A, Laporte V, Erhard M (2012) Potentials of quantitative and qualitative approaches to assessing ecosystem services. Ecol Indic 21:89–103. https://doi.org/10.1016/j.ecolind.2011.11.010

Campagne CS, Roche P, Gosselin F et al (2017) Expert-based ecosystem services capacity matrices: dealing with scoring variability. Ecol Indic 79:63–72. https://doi.org/10.1016/j.ecolind.2017.03.043

Čerkasova N, Ertürk A, Zemlys P et al (2016) Curonian Lagoon drainage basin modelling and assessment of climate change impact. Oceanologia 58:90–102. https://doi.org/10.1016/j.oceano.2016.01.003

Chaudhary S, McGregor A, Houston D, Chettri N (2015) The evolution of ecosystem services: a time series and discourse-centered analysis. Environ Sci Policy 54:25–34. https://doi.org/10.1016/j.envsci.2015.04.025

Christian F, Arturas R, Saulius G et al (2008) Hydraulic regime-based zonation scheme of the Curonian Lagoon. Hydrobiologia 611:133–146. https://doi.org/10.1007/s10750-008-9454-5

Costanza R, Arge R, De Groot R et al (1997) The value of the world's ecosystem services and natural capital. Nature 387:253–260. https://doi.org/10.1038/387253a0

De Groot RS, Wilson MA, Boumans RMJ (2002) A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecol Econ 41:393–408. https://doi.org/10.1016/S0921-8009(02)00089-7

Depellegrin D, Pereira P, Misiunė I, Egarter-Vigl L (2016) Mapping ecosystem services potential in Lithuania. Int J Sustain Dev World Ecol 23:441–455. https://doi.org/10.1080/13504509.2016.1146176

Directive 2000/60/EC (2000) Directive 2000/60/EC of the European Parliament: establishing a framework for community action in the field of water policy. Off J Eur Parliam L327:1–82. https://doi.org/10.1039/ap9842100196

Directive 2008/56/EC (2008) Directive 2008/56/EC of the European Parliament and of the Council: establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive). Off J Eur Union 164:19–40

Drescher M, Perera AH, Johnson CJ et al (2013) Toward rigorous use of expert knowledge in ecological research. Ecosphere 4:1–26. https://doi.org/10.1890/ES12-00415.1

Egoh B, Drakou EG, Dunbar MB et al (2012) Indicators for mapping ecosystem services: a review. EU Publications Office, Luxembourg, p 113

Elliff CI, Kikuchi RKP (2015) The ecosystem service approach and its application as a tool for integrated coastal management. Nat Conserv 13:105–111. https://doi.org/10.1016/j.ncon.2015.10.001

European Commission (2000) Common Implementation Strategy for the Water Framework Directive (2000/60/EC): guidance document no. 5—transitional and coastal waters typology, reference conditions and classification systems. European Commission, Brussels

European Commission (2011) European Commission: our life insurance, our natural capital: an EU biodiversity strategy to 2020. European Commission, Brussels

FAO (2011) Review of the state of world marine fishery resources. FAO, Rome

Fleming-Lehtinen V, Andersen JH, Carstensen J et al (2015) Recent developments in assessment methodology reveal that the Baltic Sea eutrophication problem is expanding. Ecol Indic 48:380–388. https://doi.org/10.1016/j.ecolind.2014.08.022

Gao CY, Peng DH (2011) Consolidating SWOT analysis with nonhomogeneous uncertain preference information. Knowl Based Syst 24:796–808. https://doi.org/10.1016/j.knosys.2011.03.001

Garcia Rodrigues J, Conides A, Rivero Rodriguez S et al (2017) Marine and Coastal Cultural Ecosystem Services: knowledge gaps and research priorities. One Ecosyst 2:e12290. https://doi.org/10.3897/oneeco.2.e12290

Gasiūnaitė Z, Daunys D, Olenin S, Razinkovas A (2008) The Curonian Lagoon. In: Schiewer U (ed) Ecology of Baltic Coastal waters. Ecological studies (analysis and synthesis), vol 197. Springer, Berlin

Haines-Young R (2016) Report of Results of a Survey to Assess the Use of CICES, 2016. Support to EEA tasks under the EU MAES Process. Negotiated procedure No EEA/NSS/16/002

Haines-Young R, Potschin M (2010) Proposal for a common international classification of ecosystem goods and services (CICES) for integrated environmental and economic accounting. European Environment Agency, Copenhagen

Haines-Young R, Potschin M (2013) Common International Classification of Ecosystem Services (CICES): consultation on version 4, August–December 2012. EEA Framework Contract No. EEA/IEA/09/003

Haller I, Stybel N, Schumacher S, Mossbauer M (2011) Will beaches be enough? Future changes for coastal tourism at the German Baltic Sea. J Coast Res. https://doi.org/10.2112/SI61-001.68

Hamel P, Bryant BP (2017) Uncertainty assessment in ecosystem services analyses: seven challenges and practical responses. Ecosyst Serv 24:1–15. https://doi.org/10.1016/j.ecoser.2016.12.008

Hattam C, Atkins JP, Beaumont N et al (2015) Marine ecosystem services: linking indicators to their classification. Ecol Indic 49:61–75. https://doi.org/10.1016/j.ecolind.2014.09.026

Hein L, van Koppen K, de Groot RS, van Ierland EC (2006) Spatial scales, stakeholders and the valuation of ecosystem services. Ecol Econ 57:209–228. https://doi.org/10.1016/j.ecolecon.2005.04.005

Hinrichsen D (1998) Coastal waters of the world: trends, threats, and strategies. Island Press, Washington

Hofmann E, Bundy A, Drinkwater K et al (2015) IMBER—research for marine sustainability: synthesis and the way forward. Anthropocene 12:42–53. https://doi.org/10.1016/j.ancene.2015.12.002

Humborg C, Fennel K, Pastuszak M, Fennel W (2000) A box model approach for a long-term assessment of estuarine eutrophication, Szczecin Lagoon, southern Baltic. J Mar Syst 25:387–403. https://doi.org/10.1016/S0924-7963(00)00029-4

Inácio M, Schernewsi G, Nazemtseva Y, Paysen P, Friedland R (2017) Ecosystem services assessment of German Baltic Lagoons. In: Ozhan E (ed) Proceedings of the thirteenth international MEDCOAST congress on coastal and marine sciences, engineering, management and conservation, MEDCOAST 17, 31 Oct–4 Nov, 2017, Mellieha, Malta, vol 1–2. MEDCOAST, Mediterranean Coastal Foundation, Dalyan

Jacobs S, Dendoncker N, Martín-López B et al (2016) A new valuation school: integrating diverse values of nature in resource and land use decisions. Ecosyst Serv 22:213–220. https://doi.org/10.1016/j.ecoser.2016.11.007

Kjerfve B (1994) Coastal lagoons. Elsevier Oceanography Series 60:1–8. https://doi.org/10.1016/S0422-9894(08)70006-0

Lester SE, Costello C, Halpern BS et al (2013) Evaluating tradeoffs among ecosystem services to inform marine spatial planning. Mar Policy 38:80–89. https://doi.org/10.1016/j.marpol.2012.05.022

Liquete C, Piroddi C, Drakou EG et al (2013) Current status and future prospects for the assessment of marine and coastal ecosystem services: a systematic review. PLoS ONE. https://doi.org/10.1371/journal.pone.0067737

Luisetti T, Turner RK, Bateman IJ et al (2011) Coastal and marine ecosystem services valuation for policy and management: managed realignment case studies in England. Ocean Coast Manag 54:212–224. https://doi.org/10.1016/j.ocecoaman.2010.11.003

Luisetti T, Turner RK, Jickells T et al (2014) Coastal zone ecosystem services: from science to values and decision making; a case study. Sci Total Environ 493:682–693. https://doi.org/10.1016/j.scitotenv.2014.05.099

Maes J, Fabrega N, Zulian G et al (2015) Mapping and assessment of ecosystems and their services: trends in ecosystems and ecosystem services in the European Union between 2000 and 2010. Publications Office of the European Union, Luxembourg. https://doi.org/10.2788/341839

Maes J, Liquete C, Teller A et al (2016) An indicator framework for assessing ecosystem services in support of the EU Biodiversity Strategy to 2020. Ecosyst Serv 17:14–23. https://doi.org/10.1016/j.ecoser.2015.10.023

Marre JB, Thebaud O, Pascoe S et al (2015) The use of ecosystem services valuation in Australian coastal zone management. Mar Policy 56:117–124. https://doi.org/10.1016/j.marpol.2015.02.011

Milcu AI, Hanspach J, Abson D, Fischer J (2013) Cultural ecosystem services: a literature review and prospects for future research. Ecol Soc 18(3):44

Millennium Ecosystem Assessment (2005) Ecosystems and human well-being: synthesis. Island Press, Washington, DC

Nahuelhual L, Vergara X, Kusch A et al (2017) Mapping ecosystem services for marine spatial planning: recreation opportunities in Sub-Antarctic Chile. Mar Policy 81:211–218. https://doi.org/10.1016/j.marpol.2017.03.038

Newton A, Icely J, Cristina S et al (2014) An overview of ecological status, vulnerability and future perspectives of European large shallow, semi-enclosed coastal systems, lagoons and transitional waters. Estuar Coast Shelf Sci 140:95–122. https://doi.org/10.1016/j.ecss.2013.05.023

Newton A, Brito AC, Icely JD et al (2018) Assessing, quantifying and valuing the ecosystem services of coastal lagoons. J Nat Conserv. https://doi.org/10.1016/j.jnc.2018.02.009

O'Higgins TG, Gilbert AJ (2014) Embedding ecosystem services into the Marine Strategy Framework Directive: illustrated by eutrophication in the North Sea. Estuar Coast Shelf Sci 140:146–152. https://doi.org/10.1016/j.ecss.2013.10.005

Peh KS-H, Balmford A, Bradbury RB et al (2013) TESSA: a toolkit for rapid assessment of ecosystem services at sites of biodiversity conservation importance. Ecosyst Serv 5:51–57. https://doi.org/10.1016/j.ecoser.2013.06.003

Poe MR, Norman KC, Levin PS (2014) Cultural dimensions of socioecological systems: Key connections and guiding principles for conservation in coastal environments. Conserv Lett 7:166–175. https://doi.org/10.1111/conl.12068

Povilanskas R, Armaitienė A (2014) Marketing of coastal barrier spits as liminal spaces of creativity. Procedia Soc Behav Sci 148:397–403. https://doi.org/10.1016/j.sbspro.2014.07.058

Radziejewska T, Schernewski G (2008) The Szczecin (Oder-) Lagoon. In: Schiewer U (ed) Ecology of Baltic Coastal waters. Springer, Berlin, pp 115–129

Roué M, Molnár Z (eds) (2017) Knowing our lands and resources: indigenous and local knowledge of biodiversity and ecosystem services in Europe and Central Asia. Knowledges of nature, vol 9. UNESCO, Paris

Saarikoski H, Jax K, Harrison PA et al (2015) Exploring operational ecosystem service definitions: the case of boreal forests. Ecosyst Serv 14:144–157. https://doi.org/10.1016/j.ecoser.2015.03.006

Schernewski G, Wielgat M (2001) Eutrophication of the shallow Szczecin Lagoon (Baltic Sea): modelling, management and the impact of weather. In: Brebbia CA (ed) Coastal Engineering V: computer modelling of seas and coastal regions. WITPress, Southampton, Boston, pp 87–98

Schernewski G, Wielgat M (2004) Baltic Sea typology. Warnemünde: EUCC–The Coastal Union; Die Küsten Union Deutschlands e.V. 109 S (Coastline reports; 4)

Schernewski G, Neumann T, Podsetchine V, Siegel H (2001) Spatial impact of the Oder river plume on water quality along the south-western Baltic coast. Int J Hyg Environ Health 204:143–155. https://doi.org/10.1078/1438-4639-00086

Schernewski G, Fischer E, Huttula T et al (2012a) Simulation tools to support bathing water quality management: *Escherichia coli* bacteria in a Baltic lagoon. J Coast Conserv 16:473–488. https://doi.org/10.1007/s11852-012-0202-7

Schernewski G, Stybel N, Neumann T (2012b) Zebra mussel farming in the Szczecin (Oder) Lagoon: water-quality objectives and cost-effectiveness. Ecol Soc. https://doi.org/10.5751/ES-04644-170204

Schernewski G, Friedland R, Carstens M et al (2015) Implementation of European marine policy: new water quality targets for German Baltic waters. Mar Policy 51:305–321. https://doi.org/10.1016/j.marpol.2014.09.002

Schernewski G, Inácio M, Nazemtseva Y (2018) Ecosystem service assessment in coastal and marine planning and management: a Baltic case study. Front Environ Sci 6:1–14. https://doi.org/10.3389/fenvs.2018.00019

Schiewer U (ed.) (2008) Ecology of Baltic Coastal Waters. Ecological studies Studies, vol 197. Springer-Verlag, Berlin, Heidelberg. https://doi.org/10.1007/978-3-540-73524-3

Sousa LP, Sousa AI, Alves FL, Lillebø AI (2016) Ecosystem services provided by a complex coastal region: challenges of classification and mapping. Sci Rep 6:22782. https://doi.org/10.1038/srep22782

Stybel N, Kleissler K, Schulz N, Piotr G (2014) Fisheries management in the Szczecin Lagoon. In: Stybel N, Skor M (eds) Fisheries management in coastal waters of the Baltic Sea—AQUAFIMA results of the Szczecin Lagoon, Vistula Lagoon, Curonian Lagoon and Gulf of Riga. Coastline Reports 22

Syrbe RU, Walz U (2012) Spatial indicators for the assessment of ecosystem services: providing, benefiting and connecting areas and landscape metrics. Ecol Indic 21:80–88. https://doi.org/10.1016/j.ecolind.2012.02.013

Tallis HT, Ricketts T, Guerry AD et al (2013) InVEST 2.5.3 User's Guide. The Natural Capital Project, Stanford

TEEB (2010) The economics of ecosystems and biodiversity: mainstreaming the economics of nature: a synthesis of the approach, conclusions and recommendations of TEEB

Turner K, Schaafsma M, Elliott M et al (2014) UK National Ecosystem Assessment Follow-on. Work package report 4: coastal and marine ecosystem services: principles and practice. LWEC, Swindon

Uehara T, Mineo K (2017) Regional sustainability assessment framework for integrated coastal zone management: Satoumi, ecosystem services approach, and inclusive wealth. Ecol Indic 73:716–725. https://doi.org/10.1016/j.ecolind.2016.10.031

Umgiesser G, Zemlys P, Erturk A et al (2016) Seasonal renewal time variability in the Curonian Lagoon caused by atmospheric and hydrographical forcing. Ocean Sci 12:391–402. https://doi.org/10.5194/os-12-391-2016

UNEP-WCMC (2011) Developing ecosystem service indicators: experiences and lessor learned from sub-global assessments and other initiatives. UNEP-WCMC, Montréal

Vasconcelos RP, Reis-Santos P, Costa MJ, Cabral HN (2011) Connectivity between estuaries and marine environment: integrating metrics to assess estuarine nursery function. Ecol Indic 11:1123–1133. https://doi.org/10.1016/j.ecolind.2010.12.012

Wolnomiejski N, Witek Z (2013) The Szczecin Lagoon Ecosystem: the biotic community of the Great Lagoon and its food web model. Versita, Versita Ltd, London, Great Britain

Zaiko A, Olenin S, Daunys D, Nalepa T (2007) Vulnerability of benthic habitats to the aquatic invasive species. Biol Invasions 9:703–714. https://doi.org/10.1007/s10530-006-9070-0

Žaromskis R (1996) Oceans, seas, estuaries (in Lithuanian). Debesija, Vilnius

Zolubas T, Kontautas A, Shibaev S (2014) Fisheries management in the Curonian Lagoon. In: Stybel N, Skor M (eds) Fisheries management in coastal waters of the Baltic Sea—AQUAFIMA results of the Szczecin Lagoon, Coastline Reports 22, Curonian Lagoon and Gulf of Riga, Vistula Lagoon

Žydelis R, Kontautas A (2008) Piscivorous birds as top predators and fishery competitors in the lagoon ecosystem. Hydrobiologia 611:45–54. https://doi.org/10.1007/s10750-008-9460-7