Journal for Nature Conservation 44 (2018) 50–65

Contents lists available at ScienceDirect

Journal for Nature Conservation

journal homepage: www.elsevier.com/locate/jnc

Assessing, quantifying and valuing the ecosystem services of coastal lagoons

ARTICLE INFO

Keywords:
Coastal lagoons
Ecosystem services
Climate change
Human welfare
Benefits
Wellbeing

ABSTRACT

The natural conservation of coastal lagoons is important not only for their ecological importance, but also because of the valuable ecosystem services they provide for human welfare and wellbeing. Coastal lagoons are shallow semi-enclosed systems that support important habitats such as wetlands, mangroves, salt-marshes and seagrass meadows, as well as a rich biodiversity. Coastal lagoons are also complex social-ecological systems with ecosystem services that provide livelihoods, wellbeing and welfare to humans. This study assessed, quantified and valued the ecosystem services of 32 coastal lagoons. The main findings of the study are: (i) the definitions of ecosystem services are still not generally accepted; (ii) the quantification of ecosystem services is made in many different ways, using different units; (iii) the evaluation in monetary terms of some ecosystem service is problematic, often relying on non-monetary evaluation methods; (iv) when ecosystem services are valued in monetary terms, this may represent very different human benefits; and, (v) different aspects of climate change, including increasing temperature, sea-level rise and changes in rainfall patterns threaten the valuable ecosystem services of coastal lagoons.

1. Introduction

Coastal lagoons occur along 13% of the coastlines of all continents (Barnes, 1980). These areas are important for many biogeochemical processes (Sousa, Lillebø, Gooch, Soares, & Alves, 2013) and they are known for their high productivity. These shallow water bodies support important habitats such as wetlands, mangroves, salt-marshes and seagrass meadows (Basset, Elliott, West, & Wilson, 2013). This typical, mosaic landscape provides support for a rich biodiversity, including vital habitats for bivalves, crustaceans, fish and birds. They provide a physical *refugium* from predation and are used as nursery and feeding areas for some endangered species (Franco et al., 2006). Coastal lagoons are also characterized by harbouring a large part of the human population that may depend directly on these ecosystems (Willaert, 2014). However, these are one of the most threatened ecosystems in the world. Habitat destruction, pollution, water withdrawal, overexploitation and invasive species are the main causes of their degradation (MA - Millennium Ecosystem Assessment, 2005; Barbier, Acreman, & Knowler, 1997). Coastal lagoons are sentinel systems that are very vulnerable to potential impacts associated with climate change (Eisenreich, 2005), particularly, as these systems have a key role in regulating the fluxes of water, nutrients and organisms between land, rivers and the ocean (Brito, Newton, Tett, & Fernandes, 2010; Newton et al., 2014). Sea level rise, increased temperature and changes in precipitation patterns would affect flushing rates, salinity, dissolved oxygen concentration, and biogeochemical properties. These changes could alter the composition and diversity of natural communities, as well as their sensitivity to eutrophication (Anthony et al., 2009), and their capabilities to support goods and services (Cossarini et al. 2008; Melaku Canu et al. 2011).

Lagoons deliver ecosystem goods and services that provide not only livelihoods but also numerous benefits to human health and welfare, which makes them complex social-ecological systems (Newton et al., 2014). The main services provided by coastal systems include food provisioning (mainly fish and shellfish), freshwater storage, hydrological balance, climate regulation, flood protection, water purification, oxygen production, fertility, recreation and ecotourism (Solidoro, Bandelj et al., 2010; Solidoro, Cossarini, Libralalto, & Salon, 2010; Barbier, 2012; Lopes & Videira, 2013). Coastal lagoon ecosystems also support a wide range of human activities, including economic sectors such as fisheries and aquaculture, as well as leisure and tourism (Newton et al., 2014). Therefore, these ecosystem goods and services are not only economically valuable but they also have societal, aesthetic and heritage value due to their contribution to improvements in mental and psychological health (Sandifer, Sutton-Grier, & Ward, 2015). The conservation of coastal lagoons is therefore relevant for their ecological importance, along with the valuable ecosystem services (ES) they provide for human welfare. Holistic management involving economists, ecologists, and environmental scientists that assesses the services of these social-ecological systems is thus required (Barbier et al., 2011; Carpenter et al., 2009; Turner & Daily, 2008).

The discussion about ecosystem services and their categories (De Groot, Wilson, & Boumans, 2002; Costanza, 2008) has been ongoing for more than 20 years, and despite recent efforts, there is no consistent definition or classification. The Millennium Ecosystem Assessment (MA - Millennium Ecosystem Assessment, 2005) was the booster in providing a globally recognized classification for ecosystem services consisting of "*the functions and products of ecosystems that benefit humans, or*

https://doi.org/10.1016/j.jnc.2018.02.009
Received 13 March 2017; Received in revised form 12 February 2018; Accepted 14 February 2018

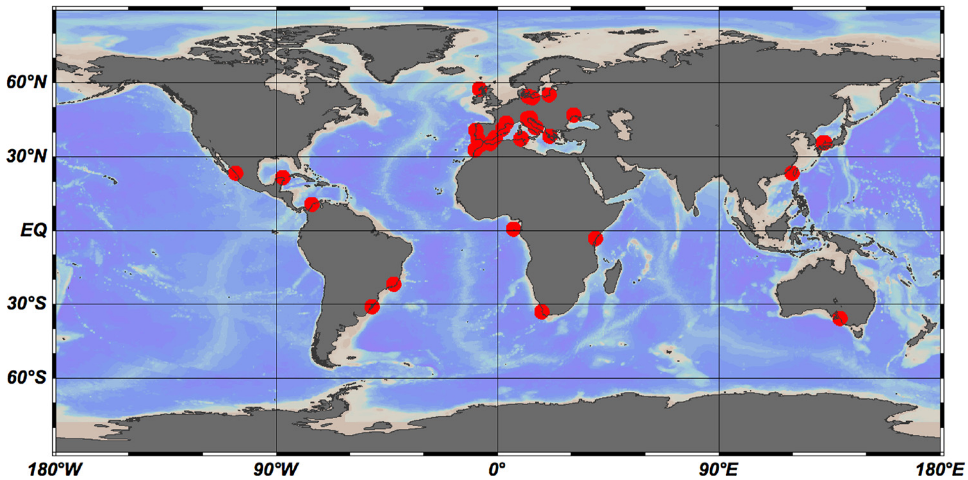

Fig. 1. Geographic location of all the coastal lagoons considered in this study.

yield welfare to society". Nevertheless, the simplicity of this concept can be prone to misinterpretations and lack of consistency across different users. The Economics of Ecosystems and Biodiversity project (TEEB, 2010) was based on the MA and provided an updated classification, which clearly distinguishes services from benefits. Ecosystem services are defined by TEEB as "*the direct and indirect contributions of ecosystems to human well-being*", and it is explicit that services can benefit people in multiple and indirect ways (e.g. food provisioning service have multiple benefits including health, pleasure and sometimes even cultural identity). The Common International Classification of Ecosystem Services (CICES) attempted to be more comprehensive than the MA and TEEB classification and is tailored to environmental and economic accounting. This classification defines ecosystem services as "*the contributions that ecosystems make to human well-being, and arise from the interaction of biotic and abiotic processes*", separating services from ecological phenomena (Haines-Young & Potschin, 2013). CICES focuses on final services or products from ecological systems that people directly consume or use; the welfare gains they generate are classified as benefits.

This issue is particularly important in the case of biodiversity conservation, where effective management towards sustainable development relies on an accurate and widely accepted definition of ecosystem services (Boyd & Banzhaf, 2007; Egoh et al., 2007; Fisher, Turner, & Morling, 2009). Thus, a well-defined unit of services enables their identification, mapping and measurement across different ecosystems, allowing the integration and comparison of different data sources. This assessment of the state of ecosystems and their services at all geographic levels forms the basis for improved environmental policies (Lele, Springate-Baginski, Lakerveld, Deb, & Dash, 2013), e.g. the EU Biodiversity Strategy, that aims to counter the trend of biodiversity loss and ecosystem services degradation. Natural resource decisions are usually based on values humans place on ecosystems and the benefits they provide (Daily et al., 2009; Ingram, Redford, & Watson, 2012). The monetary valuation of ecosystem services allows the translation of their ecological importance into monetary terms to be perceptible for all stakeholders. The economic value is therefore a measure of the well-being provided by the consumption of goods or services, and can be assessed by market and non-market valuation techniques. Although this wide range of valuation methods are very useful for ecosystems' management and decision-making processes, coastal lagoons are under-represented across valuation studies (Barbier et al., 2011). A report by the European Commission (EC, 2017) underlines the importance of correct accounting and valuation of ecosystem services.

The aim of this study is to give an overview of the existing knowledge and gaps about the ecosystem services from coastal lagoons. The objectives are to assess, quantify and value the ecosystem services of coastal lagoons at a global level, to provide and share this information among coastal lagoon scientists in a common framework that could support further, more detailed studies.

Four research questions have been addressed:

1) **Assessment:** What are the ecosystem services that are provided by coastal lagoons?
2) **Quantification:** What are the quantities of the ecosystem services that are provided by coastal lagoons?
3) **Evaluation:** What is the value of the ecosystem services that are provided by coastal lagoons?
4) **Climate change:** How will climate change affect the ecosystem services that are provided by coastal lagoons?

2. Methodological approach

2.1. Location of coastal lagoons in the study

Thirty two coastal lagoons were included in this study, located in five different continents: America, Europe, Africa, Oceania and Asia. The global distribution of the coastal lagoons included in this study is presented in Fig. 1. The names, coordinates and basic data are given in Table 1.

2.2. Historical context

The community of coastal lagoon scientists started to coalesce in the last two decades of the 20th Century. Previously, coastal lagoon scientists had been included in groups such as the Estuarine Research Federation. However, coastal lagoons were never a central topic to these groups. Another factor was the wide range of names applied to coastal lagoons (Newton et al., 2014) that made searching the literature difficult. Even countries with many coastal lagoons, such as Portugal and Italy, had different terms. The European Water Framework Directive (WFD) used the term '*transitional waters*' that included some estuarine coastal lagoons, but not all coastal lagoons fit the salinity condition.

The Italian community of scientists started to coalesce into a network called Lagunet that held meetings and small conferences. This promoted the formation of other national networks in France, Greece, Spain, Portugal, North Africa, Baltic countries and, finally, the formation of EuroMegLag, an international network of coastal lagoon scientists, (http://www.euromedlag.eu/). The community now holds conferences every two years and invites coastal lagoon scientists from all over the world to participate.

Table 1
Location and characteristics of the 32 coastal lagoons in the survey.

Name of coastal lagoon	Adjacent sea/ Ocean	Continent and Country (ies)	Type of Lagoon	Coordinates	Area with permanent water (km^2)	Wetland (km^2)	Mean depth (m)	Salinity range	Climate	Population (within 50 km)	GDP per capita* (Euro)	References
Bizerte Lagoon	Mediterranean Sea	Africa (N), Tunisia	choked	Lat: 37.183°N Lon: 9.850°E	128		7	33.3-36.1	Semi-arid	445072	3770.5	Sakka Hlaili, Grami, Hadj Mabrouk, Gosselin and Hamel (2007), Boukef et al. (2010), Fertouna Bellakhal, Dhib, Béjaoui, Turki and Aleya (2014), Béjaoui, Harzallah, Moussa, Chapelle and Solidoro (2008), Béjaoui et al. (2016)
Cal Tet	Mediterranean Sea	Europe (S), Spain	choked	Lat: 41.302°N Lon: 2.122°E	0.13			2-3	Temperate	3239337	40100	Cañedo-Argüelles and Rieradevall (2011), Roselli et al. (2013)
Cartagena Bay	Caribbean Sea	South America, Colombia	N.A.	Lat: 10.335°N Lon: 75.527°W	84		16	0-37	Equatorial	1 000 000	6000	UNEP – United Nations Environment Programme (1999), Lonin, Parra, Andrade and Yves-Francois (2004), Cardique (2006), Restrepo, Zapata, Díaz, Garzón-Ferreira and García (2006), DANE-Departamento Administrativo (2016)
Coorong	Southern Ocean	Australia	Choked	Lat: 35.933ºS Lon: 139.30ºE	140	490	2		Temperate	30000	33000	Rolf and Dyack (2010), Rolf and Dyack (2011), Clara et al. (2017)
Curonian Lagoon	Baltic Sea	Europe (E), Lithuania/ Russia	restricted	Lat: 55.00ºN Lon: 21.00ºE	1600	1000	3.6		Temperate	800000	12000	Breber, Povilanskas and Armaitiené (2008), Povilanskas, Armaitiené, Breber, Razinkovas-Baziukas and Taminskas (2012), Taminskas, Pileckas, Šimanauskienė and Linkevičienė (2012), Povilanskas, Razinkovas-Baziukas and Jurkus (2014)
Darss-Zingst Bodden	Baltic Sea	Europe (C), Germany	restricted	Lat: 54.383°N Lon: 12.616°E	197		2	0.5-14	Temperate	105500	22800	Winkler (2001), Schiewer (2008), Kruse et al. (2015)
Estero de Urías	Pacific Ocean	North America, Mexico	choked	Lat: 23.193°N Lon: 106.36°W	18		2-12	25.8-38.4	Subtropical	502547	8199.1	Paez-Osuna, Montano-Ley and Bojorquez-Levya (1990), Cardoso-Mohedano et al. (2015a), Cardoso-Mohedano et al. (2015b), Ruiz-Fernández et al. (2016), Ruiz-Fernández et al. (2016)
Etang de Thau	Mediterranean Sea	Europe (S), France	restricted	Lat: 43.40°N Lon: 3.612°E	75	7	4	28-42	Temperate	110000	23566	Souchu et al. (1998), La Jeunesse and Elliott (2004), Mongruel et al. (2013), Loiseau, Roux, Junqua, Maurel and Bellon-Maurel (2014), La Jeunesse et al. (2015), La Jeunesse et al. (2016)
Ichkeul Lake	Mediterranean Sea	Africa (N), Tunisia	choked	Lat: 37.167°N Lon: 9.667°E	155 /78	110	1	5-50	Semi arid	539713	3770.5	Ben Rejeb-Jenhani (1989), Tamisier and Boudouresque (1994), Chaouachi and Ben Hassine (1998) Saied and Elloumi (2007), Trabelsi et al. (2012)
Lagoa de Araruama	South Atlantic	South America, Brazil	choked	Lat: 22.0°S Lon: 42.0°W	210		3	52	Semi arid	200-500 000		

(continued on next page)

Table 1 (*continued*)

Name of coastal lagoon	Adjacent sea/ Ocean	Continent and Country (ies)	Type of Lagoon	Coordinates	Area with permanent water (km²)	Wetland (km²)	Mean depth (m)	Salinity range	Climate	Population (within 50 km)	GDP per capita* (Euro)	References
Lagoa dos Patos	South Atlantic	South America, Brazil	choked	Lat: 31.0S Lon: 51.0°W	10200		5	1-31	Temperate	4 500 000		Kjerfve, Schettini, Knoppers, Lessa and Ferreira (1996), Knopper and Kjerfve (1999), Braga, Vianna and Kjerfve (2003), Souza, Kjerfve, Knoppers, de Souza and Damasceno (2003), Kjerfve and Oliveira (2004) Philomena (1994), Knoppers and Kjerfve (1999), Kjerfve and Knoppers (1999), Odebrecht et al. (2005), Fujita and Odebrecht (2007)
Lake Nakaumi	Sea of Japan	Asia (E), Japan	choked	Lat: 35.452°N Lon: 133.191°E	86.2		5.4	14-30	Temperate	472817	27753	Y, Nakata, Horiguchi and Yamamuro (2000), Yamamuro, Hiratsuka, Ishitobi, Hosokawa and Nakamura (2006), Ishitobi, Kamiya and Yamamuro (2014), Katsuki et al. (2008)
Lake Shinji	Sea of Japan	Asia (E), Japan	lachoked	Lat: 35.450°N Lon: 132.783°E	79.25		4.5	> 3.5	Temperate	476967	28020	Yamamuro et al. (2000), Nakata et al. (2000), Yamamuro et al. (2006), Ishitobi et al. (2014)
Langebaan Lagoon	Atlantic Ocean	Africa (S), South Africa	choked	Lat: 33.153°S Lon: 18.063°E	41.1		4	34.5-35	Temperate	80500	5206	Day (1959), Kerwath et al. (2009), Nel and Branch (2014), AEC (2015), Turpie, Forsythe and Letley (2017)
Lesina lagoon	Mediterranean Sea	Europe (S), Italy	restricted	Lat: 41.90°N Lon: 15.417°E	55		0.7	11-32	Temperate	250000	16000	Manini, Breber, D'Adamo, Spagnoli and Danovaro (2002a), Manini, Breber, D'Adamo, Spagnoli and Danovaro (2005), Roselli et al. (2013), Ferrarin et al. (2010), Cuvata and Di Matteo (2016)
Loch Bi	Atlantic	Europe, Scotland		Lat: 57.372°N Lon: 7.372°W	7.035		< 2	1.68-22.1	Temperate	4703	11919.7	Angus (2016), Angus (2017)
Malanza Lagoon	Atlantic	Africa (W), São Tomé and Principe	choked	Lat: 0.457°N Lon: 6.531°E	0.69	2	1-1.5	0-25	Tropical	170000	3015.3	Pisoni et al. (2015), de Lima et al. (2016), Brito, Silva, Beltrán, Chainho and de Lima (2017), Félix et al. (2017)
Mar Menor	Mediterranean Sea	Europe (S), Spain	restricted	Lat: 37.770°N Lon: 0.786°W	135		3.6	38-51	Temperate	755666	18929	Pérez-Ruzafa, Marcos and Gilabert (2005), De Pascalis, Pérez-Ruzafa, Gilabert, Marcos and Umgiesser (2012), Maynou, Martinez-Banos, Demestre and Franquesa (2014), Marcos, Torres, López-Capel and Pérez-Ruzafa (2015), Velasco, Pérez-Ruzafa, Martínez-Paz and Marcos (2017)
		Europe (S), Italy	restricted		160 /152	7.6	1	30	Temperate	83145	18880	

(*continued on next page*)

Table 1 (*continued*)

Name of coastal lagoon	Adjacent sea/ Ocean	Continent and Country (ies)	Type of Lagoon	Coordinates	Area with permanent water (km^2)	Wetland (km^2)	Mean depth (m)	Salinity range	Climate	Population (within 50 km)	GDP per capita* (Euro)	References
Marano and Grado	Adriatic Sea, Mediterranean Sea			Lat: 45.708°N Lon: 13.352°E								Ferrarin et al. (2010), Bettoso, Acquavita, D'Aletti and Mattassi (2013), Acquavita et al. (2015), Canu, Rosati, Solidoro, Heimbürger and Acquavita (2015), Canu and Rosati (2017)
Messolonghi Central Lagoon	Patraikos Gulf / Mediterranean	Europe (SE), Greece	leaky	Lat: 38.351°N Lon: 21.340°E	285/149.4		1.2	17.3-48.5	Temperate	209029	9300	Katselis, Koutsikopoulos, Dimitriou and Rogdakis (2003), Katselis, Koukou, Dimitriou and Koutsikopoulos (2007), Cabana, Nicolaidou, Sigala and Reizopoulou (2017)
Moulay Bouselham	Atlantic	Africa (NW), Morocco		Lat: 34.846°N Lon: 6.276°W					Temperate			Birks, Birks, Flower, Peglar and Ramdani (2001), Labbardi, Ettahiri, Lazar, Massik and El Antri (2005), Ayache et al. (2009), Thompson and Flower (2009), Maanan et al. (2013)
Nador	Mediaterranean Sea	Africa (N), Morocco	leaky	Lat: 35.166°N Lon: 2.856°W	115		4.8	32.7-40.2	Temperate	248418	9500	Maanan et al. (2015a)
Oualidia	Atlantic	Africa (N), Morocco	choked	Lat: 32.7445°N Lon: 9.03°W	10/3.5		2	22.5-35.9	Semi-Arid	18616	4500	Zourarah et al. (2007), Maanan (2008), Maanan et al. (2014), El Asri, Zidane, Maanan, Tamsouri and Errhif (2015), Maanan et al. (2015b)
Qigu lagoon	South China Sea	Asia (E), Taiwan (W)	leaky	Lat: 23.133°N Lon: 120.067°E	32 /11	32	1	30.65	Tropical	10500	21295.6	Lin et al. (2001), Hsiao et al. (2016)
Ria de Aveiro	N.E. Atlantic	Europe, Portugal (W)	restricted	Lat: 40.633°N Lon: 8.75°W	330/46	90	2	0 -35	Temperate	353 688		Hesse et al. (2015), Lillebø, Stålnacke, and Gooch (2015), Lillebø et al. (2016), Sousa, Sousa, Alves and Lillebø (2016), Clara et al. (2017), Sousa et al. (2017)
Ria Formosa	N.E.Atlantic	Europe (S), Portugal (S)	leaky	Lat: 36.983°N Lon: 7.922°W	111/55	50	1.5	35.5-36.9	Temperate	225901	17786	Mudge and Bebianno (1997), Newton et al. (2003), Ferreira, Dias and Taborda (2008), Brito et al. (2012), Newton et al. (2014)
Szczecin (Oder) Lagoon	Baltic Sea	Europe (C), Germany/ Poland	restricted	Lat: 53.833°N Lon: 14.167°E	687		3.8	0.3-4.5	Temperate	840000	11000	Schernewski and Dolch (2004), Löser and Sekścińska (2005), Radziejewska and Schernewski (2008), Wolnomiejski and Witek (2013), Stybel, Kleissler, Schulz and Piotr (2014)
	Black Sea	Europe (E), Ukraine	choked	Lat: 46.667°N Lon: 31.183°E	221.5/129	18.36	5.4	23-29	Temperate	127800	160	

(*continued on next page*)

Table 1 (*continued*)

Name of coastal lagoon	Adjacent sea/ Ocean	Continent and Country (ies)	Type of Lagoon	Coordinates	Area with permanent water (km^2)	Wetland (km^2)	Mean depth (m)	Salinity range	Climate	Population (within 50 km)	GDP per capita* (Euro)	References
Tyligulskyi Liman lagoon												Tuchkovenko and Loboda (2014), Tuchkovenko, Bogatova and Tuchkovenko (2015a) Tuchkovenko, Kushnir and Loboda (2015b) , Tuchkovenko, Loboda and Khokhlov (2015c) Gubanova, Tuchkovenko, Khokhlov, Stepanenko, and Baggett, 2015
Varano Lagoon	Mediterranean Sea	Europe (S), Italy	restricted	Lat: 41.833°N Lon: 15.750°E	65		3.5	25-32	Temperate	200000	16000	Manini, Breber, D'Adamo, Spagnoli and Danovaro (2002b), Roselli et al. (2013), Cuvata and Matteo (2016)
Venice Lagoon	Adriatic Sea, Mediterranean Sea	Europe (S), Italy	restricted	Lat: 45.436°N Lon: 12.330°E	550/459	47	1.5	8-33	Temperate	262246		Nunes, Rossetto and de Blaeij (2003), Alberini, Rosato, Longo and Zanatta (2005), Alberini, Zanatta and Rosato (2007), Rapaglia et al. (2011), Pranovi, Sarà and Provani et al. (2013b), Salon et al. (2008), Solidoro et al. 2010, Cossarini et al. 2008
Watamu -Mida Creek	Indian Ocean	Africa (E), Kenya	Choked	Lat: 3.35°N Lon: 39.850°E	14.1	17.4	5	33-37	Tropical	500000	1400	Kitheka, Mwashote, Ohowa, and Kamau (1999), Dahdouh-Guebas, Kairo, Koedam, and Mathenge (2000), Kairo, Dahdouh-Guebas, Gwada, Ochieng, and Koedam (2002), Frank et al. (2017), Owuor et al. (2017)
Yalahau Lagoon	Gulf of Mexico, Carabeean Sea	North America, Mexico	choked	Lat: 21.465°N Lon: 87.276°W	275	1526	< 4	36	Tropical	11942	10787	Flores-Verdugo et al. (1990), Tran, Valdes, Euan, Real and Gil (2002), Herrera-Silveira and Morales-Ojeda, 2010, Rubio-Cisneros et al. (2014), Rubio-Cisneros, Aburto-Oropeza and Ezcurra (2016)

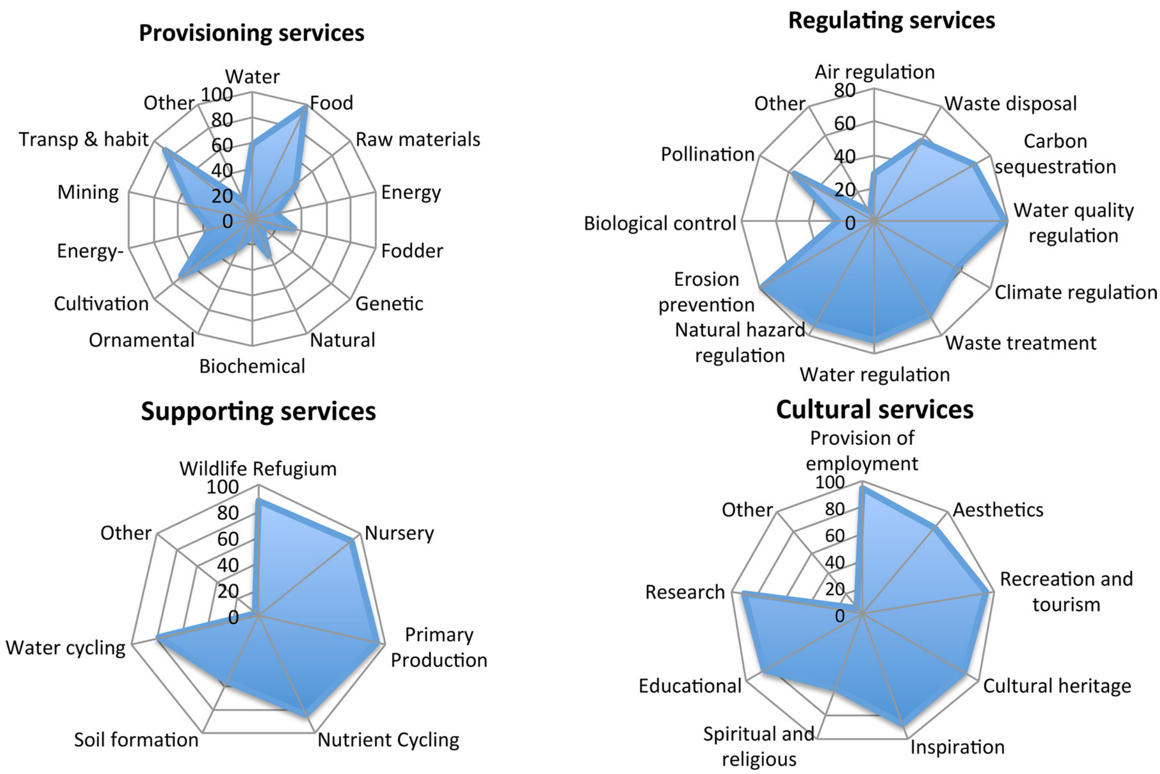

Fig. 2. Percentage of coastal lagoons acknowledged as providing each type of Ecosystem Service (ES). Note that 100% correspond to 32, i.e. the total number of lagoons participating in this study. N = 32.

2.3. Data collection

Coastal lagoon scientists were contacted using the network described in the *Historical context* section above to participate in the survey. Although most of the lagoons in the study are in Europe and the Mediterranean, a concerted effort was made to contact scientists in all continents, apart from Antarctica, see Fig. 1.

The scientists were asked to provide information in a tabular format in 4 steps:

1) Basic information about the coastal lagoon system, such as coordinates and surface area.
   The summary of the results are shown in Table 1.
   The first step also included a list of ecosystem services (ES) provided by the coastal lagoon.
   The summary of the results are shown in Fig. 2.
2) Quantification of the ES provided by the coastal lagoon.
   The summary of the results are shown in Table 2 and Fig. 3.
3) Valuation of the ES provided by the coastal lagoon.
   The summary of the results are shown in Figs. 4–7.
4) An assessment of the effects of climate change on the ES of the lagoon.

Table 2
Quantification of ecosystem services (ES) provided by coastal lagoons. All values represent the average for all coastal lagoons with available data. These ES are only examples taken from the full database. N = 22.

Ecosystem Service	Quantity	Units
Water provisioning	114.01×10^6	m^3
Food provisioning	9.57×10^3	tonnes
Carbon sequestration	0.32×10^6	Mg C
Nursery	67.97×10^6	km^2
Jobs	1.68×10^3	–
Research (number of hits in Google Scholar)	35.23×10^3	–

The summary of the results are shown in Fig. 8.

In some cases, additional processing was required. Data was transformed to obtain comparable datasets. In most cases, this involved calculating annual values from daily means or scaling up the values for the whole lagoon. This was done only when possible. When comparable datasets were not possible to obtain, data were dismissed and not included in the analysis. Please note that valuation data are only indicative, given that for most cases it was not possible to derive comparable values, i.e. taking into consideration the year of the estimate and precise currency exchange rates. Therefore, in this analysis, all values are presented in Euros, converted from the original currency using the European Central Bank exchange rate quoted on 21st February 2017.

3. Results

50 invitations to participate were sent out using mailing lists from EuroMedLag and other mailing lists from other networks and projects. There were 32 respondents (64.0%), who provided the basic information about a coastal lagoon (Table 1). Of these, 15 were from Europe (46.9%), 3 from Asia (9.4%), 8 from Africa (25.0%), 1 from Oceania (3.1%), 2 from N. America (6.3%) and 3 from S. America (9.4%).

32 respondents (64.0%) provided the information listing which ecosystem services were provided by the coastal lagoon (Fig. 2). Almost all coastal lagoons were recognised as important in providing food (96.9% of respondents) and job opportunities (93.8%), as well as allowing its use for recreation and tourism-related activities (93.8%). Research activities were acknowledged by 90.6% of the respondents. Supporting services such as the nursery and primary production functions were also found to be relevant throughout the locations (90.6% and 93.8%, respectively).

22 respondents (68.8%) provided the information quantifying (amounts) the ecosystem services provided by the coastal lagoon (summarised in Table 2 and Fig. 3). Data on food provisioning were

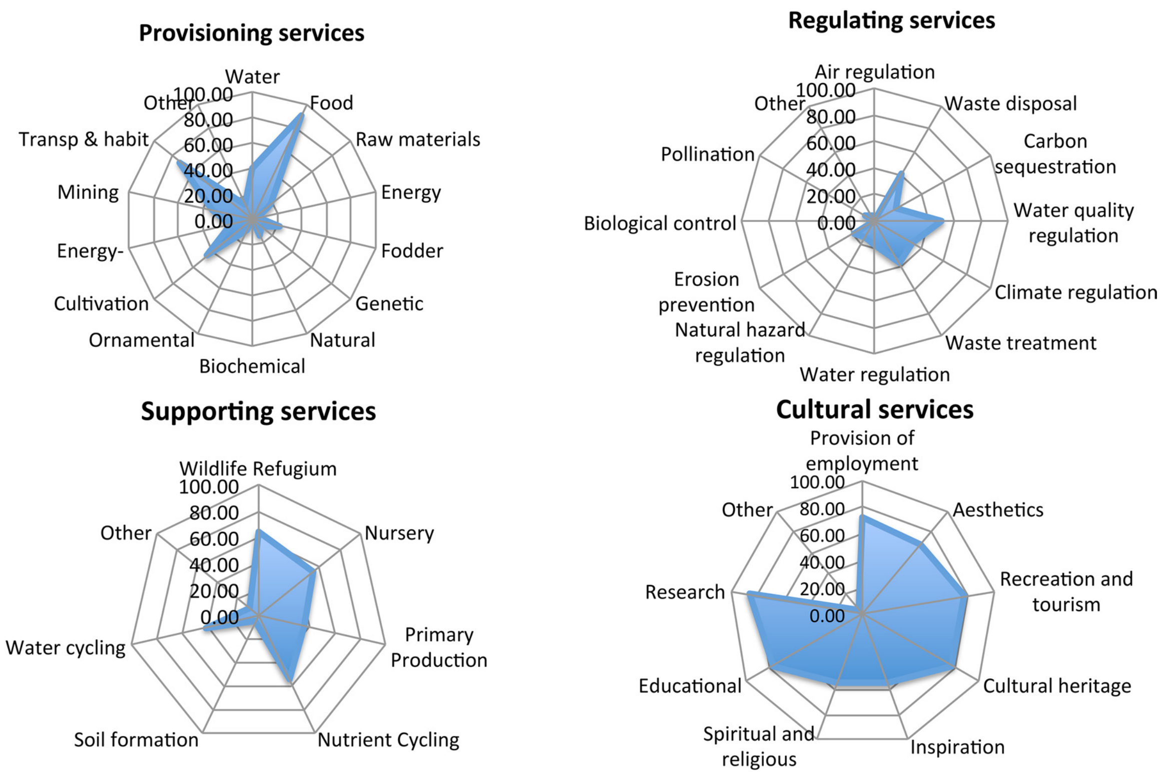

Fig. 3. Percentage of responses for ES quantification. Note that 100% correspond to 22, i.e. the total number of lagoons sending information quantifying the ecosystem services. N = 22.

provided by 90.9% of these (22). A measure of research activities (number of hits in Google Scholar) was also obtained for 86.4% of the lagoons. In general terms, although supporting and regulating services were identified as very relevant (Fig. 2), scientists had difficulties in quantifying those ES. The regulating service with the highest number of responses (50.0%) was the water quality regulation. Most scientists were able to account for the water renewal rate in lagoons. For supporting services, the highest number of responses was obtained for

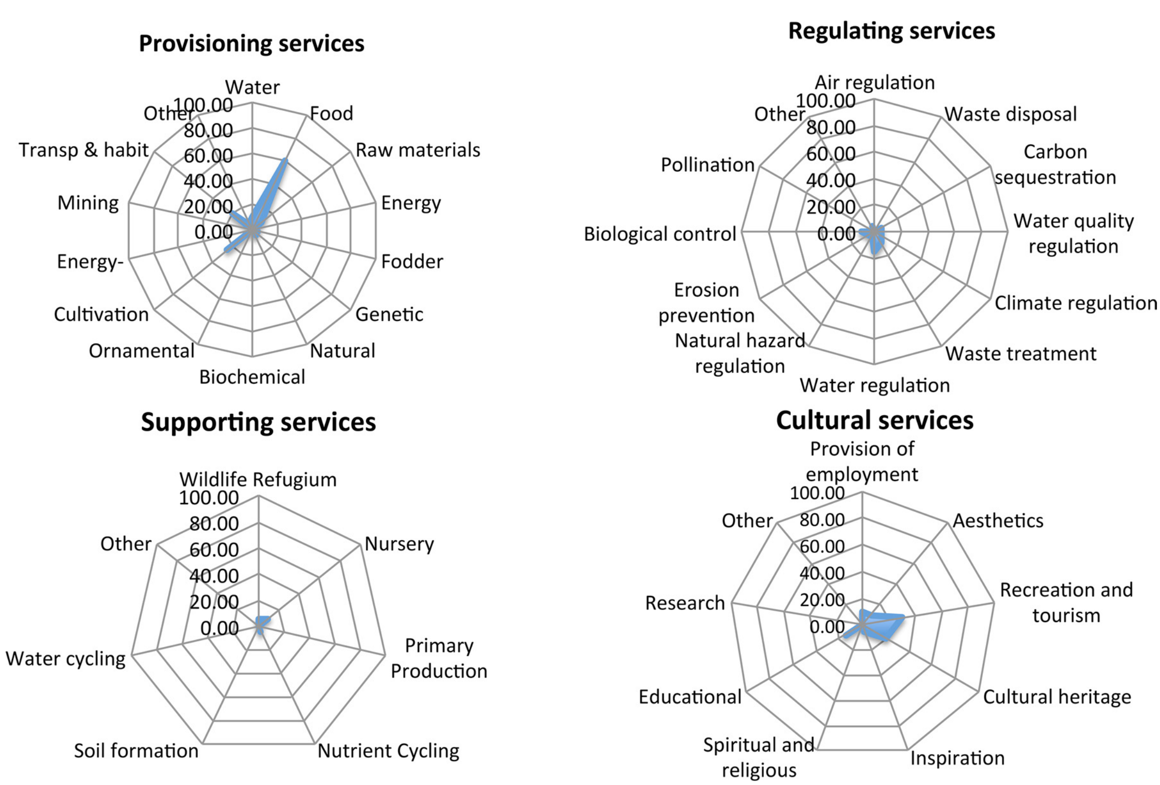

Fig. 4. Percentage of responses for ES valuation. Note that 100% correspond to 20, i.e. the total number of lagoons sending information valuing the ecosystem services. N = 20.

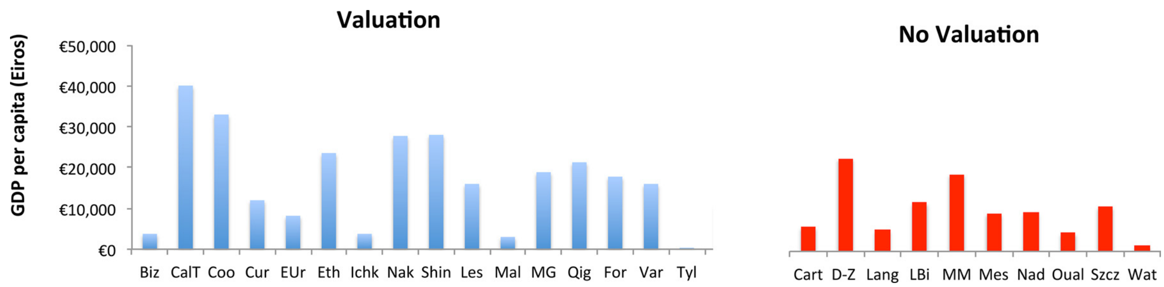

Fig. 5. Gross Domestic Product (GDP) per capita (Euros) reported for each region where lagoons are located. Values are distributed according to the availability of valuation data. If no valuation data exist, they are represented in the right part of the graph. Note that each lagoon region represents one bar. See details of specific GDP values in Table 1. Note that: Biz-Bizerte Lagoon, CalT – Cal Tet, Coo – Coorong, Cur – Curonian, EUr – Estero de Urías, Eth – Ethang de Thau, Ichk – Ichkeul Lake, Nak – Lake Nakumi, Shin – Lake Shinji, Les – Lesina Lagoon, Mal – Malanza Lagoon, MG – Marano and Grado, Qig – Qigu Lagoon, For – Ria Formosa, Var – Varano Lagoon, Tyl – Tyligulskyi Liman Lagoon, Cart – Cartagena Bay, D-Z – Darss-Zingst Bodden, Lang – Langebaan Lagoon, LBi – Loch Bi, MM – Mar Menor, Mes – Messolonghi Central Lagoon, Nad – Nador, Oual – Oualidia, Szcs – Szczecin (Oder) Lagoon, Wat – Watamu-Mida Creek.

wildlife *refugium* (63.6%), accounting for the number of reserves and natural parks, and nutrient cycling (54.6%), accounting for the nutrient inputs into the lagoons.

20 respondents (62.5%) provided the information on the monetary value of ecosystem services provided by coastal lagoons (Fig. 4). Food provisioning was the ES with the highest response rate (60.0%). Valuation figures for cultivation were reported by 25.0% of the respondents. Touristic and recreational, as well as cultural heritage values were also provided by 30.0% and 20.0% of the respondents, respectively. Most valuation figures for these ES were based on market values techniques. Moreover, estimates were obtained both from formal studies and other informal sources, such as newspapers, etc. It is interesting to note the great lack of data for most ES. Thus, although ecosystem services are recognised as existing and important, their value is still largely unknown.

The Gross Domestic Product (GDP) per capita (Euros) reported for each region where the lagoons are located is presented in Fig. 5. The GDP per capita reported for lagoons with no valuation data seems slightly lower than the GDP per capita obtained in lagoons with valuation data. However, the range of variation is high for the lagoons with valuation data.

In general terms, food provisioning and cultural heritage were the services with the highest monetary valuation, representing more than 70 Million Euros per year (Fig. 6). Cultural heritage reached large

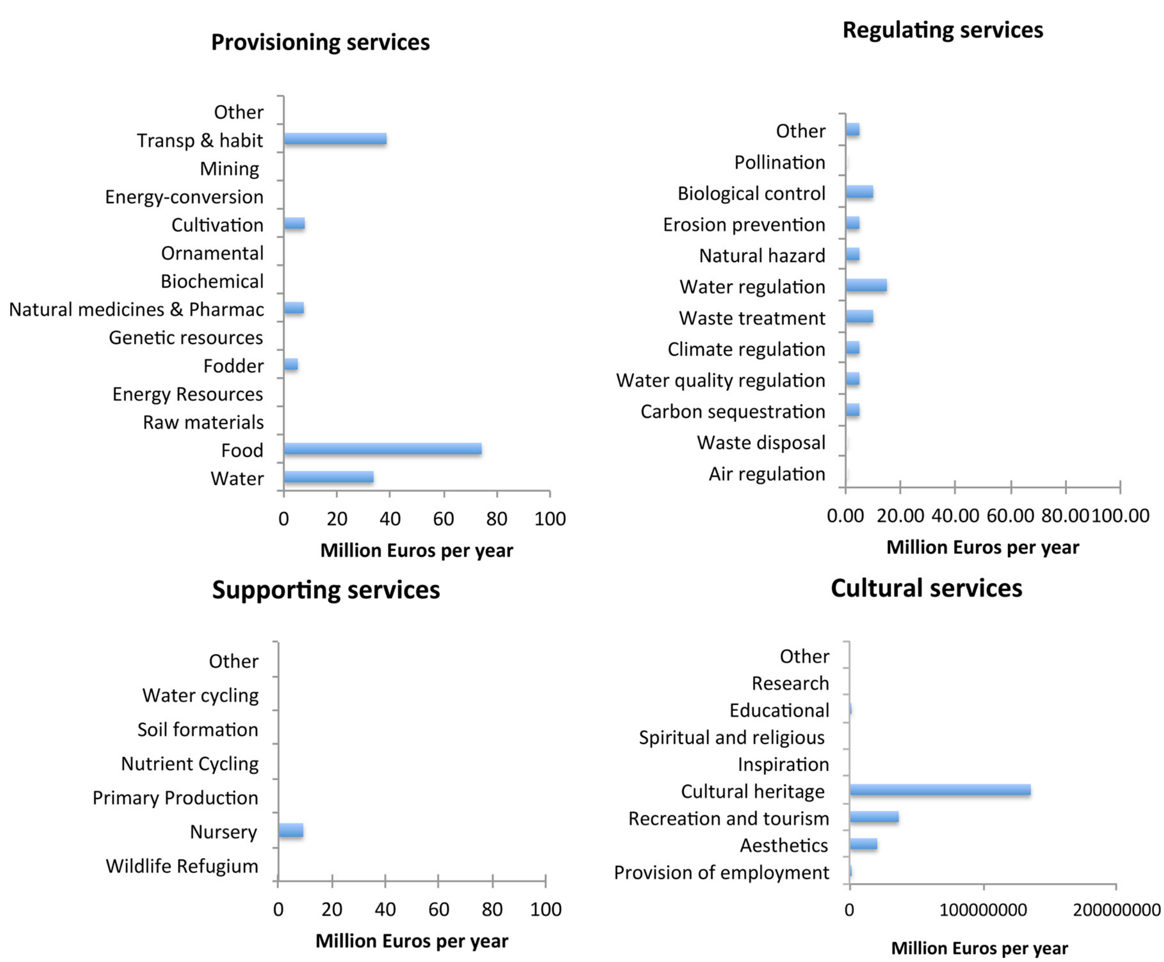

Fig. 6. Valuation of Ecosystem Services (ES) provided by each lagoon. These figures represent average values in Million Euros per year N = 20.

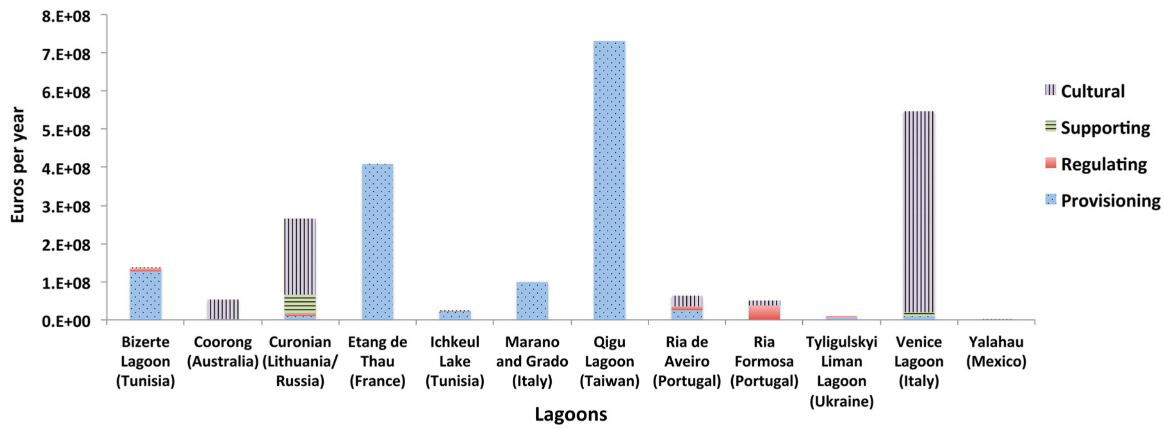

Fig. 7. Valuation estimates of Ecosystem Services (ES) in each lagoon. Please note the distribution of the monetary value by ES groups (provisioning, regulating, supporting and cultural).

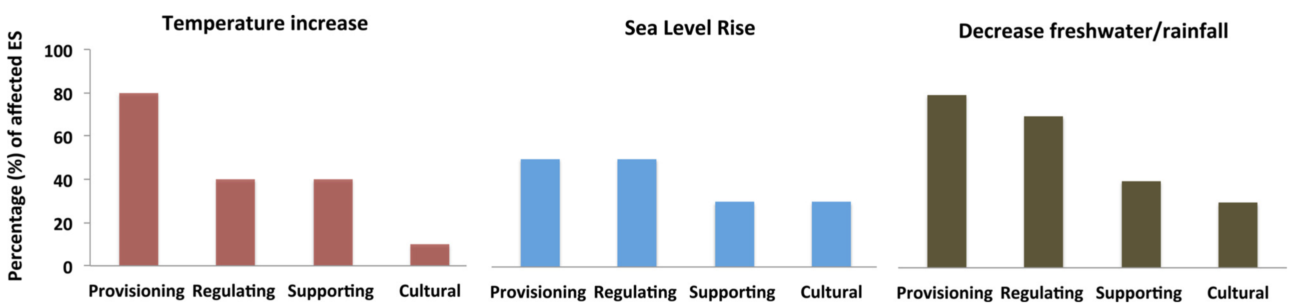

Fig. 8. Percentage of Ecosystem Services (ES) potentially affected by climate change. These represent anticipated effects.

numbers, more than 135 Million Euros per year. Only four lagoons reported values for this ES and this average is strongly dependent on the figures estimated for the Venice lagoon, where this ES reaches 12 Million Euros/km^2 of land (Alberini, Rosato, Longo, & Zanatta, 2005). Water provisioning, transport and habitation were also found as having high monetary values, almost reaching up to 40 Million Euros per year. Note that all currencies were converted to Euros according to 2017's exchange rate (see methods section for details).

Considering the ES valuation data obtained for each lagoon, the relevance of provisioning services that combines all individual ES becomes clearer in most coastal lagoons (Fig. 7). According to the estimates obtained, cultural services represent approximately 5.30×10^8 Euros per year in the Venice lagoon and only 0.01×10^8 Euros per year in the Ichkeul Lagoon. The range of values obtained depends mainly on the availability of data. For example, Clara et al. (2017) reported a valuation estimate of 0.26×10^8 Euros per year in Ria de Aveiro (Portugal), but this number only considers recreational activities, while most lagoons have values for 2–3 cultural services.

Given the importance of these ecosystem services and the current global changes (Eisenreich, 2005), scientists were asked to identify the ES most likely to be affected by changes such as temperature increase, sea level rise, decrease in freshwater inputs and rainfall (Fig. 8). These were the factors identified as the most relevant for coastal lagoons. They were indicated in at least 8 lagoons. Other factors (e.g. extreme events) were indicated only occasionally (once). Provisioning services were identified as the ones at higher risks, indicated at least by 50% of the lagoons. Cultural services were identified as the ones at lower risk ($\leq$30%).

4. Discussion

4.1. There is still confusion about ecosystem services

Several of the respondents had difficulties with the classification of ecosystem services because they were considering different typologies (De Groot et al., 2002; MA - Millennium Ecosystem Assessment, 2005; Costanza, 2008; TEEB, 2010; Haines-Young & Potschin, 2013). During this study it became apparent that most people were familiar with the classification of the Millenium Assessment (MA - Millennium Ecosystem Assessment, 2005) and not with other classifications, such as the one proposed by the Economics of Ecosystems and Biodiversity (TEEB, 2010) or the Common International Classification of Ecosystem Services (CICES; Haines-Young & Potschin, 2013). Data submission templates were left broad enough to allow the maximum response rate but they also indicate the difficulties in using a common approach. The debate about the definition and classification of ecosystem services is important and has been active in the last decades, varying according to the ecological focus or the economic use (Braat & de Groot, 2012). These different approaches have their own strengths and weaknesses. MA was criticized for double counting the benefits from the services. For example, in the case of water-related services, nutrient cycling is a supporting service, water flow regulation is a regulating service and they contribute to several benefits, such as good water quality and recreational services (Fisher et al., 2009). The most recent approaches (e.g. TEEB and CICES) avoid the risk of double counting by distinguishing between intermediate and final services (Hasler et al., 2016). Nonetheless, the integration of the two visions, environmental and economic, in one simple approach can make the difference in managing activities and developing policies. More and more, environmental problems are framed in an economic context and cost-benefit analyses are performed to make decisions. The monetary figures tend to have high impact and empower scientists and policy makers. Adequate communication and understanding between all partners from different backgrounds (ecology, economy and policy) is therefore key to facilitate the process of adaptive management and the ecosystem approach.

4.2. Coastal lagoons provide a wide range of ES

This study revealed a high number of ES that are considered as important in most coastal lagoons located worldwide. In particular, the provision of food and tourism recreation (> 95%) are important for lagoons. This result was somehow anticipated, as these are some of the most productive marine ecosystems, being the perfect location for nature-based and aquatic activities (e.g. Kjerfve, 1994; Anthony et al., 2009). This is also in line with what has been reported for other coastal ecosystems (e.g. Barbier et al., 2011; Brander et al., 2012; Vo, Kuenzer, Vo, Moder, & Oppelt, 2012), such as mangroves and estuaries. Moreover, more than 85% of the scientists also highlighted transport and habitation, and other supporting services such as its role as a wildlife *refugium*, nursery, etc. Lagoons also regulate water and water quality, climate, erosion and natural hazards as well as carbon sequestration. The range of ES provided is wide and there is the need to develop common approaches to quantify these ES using a comparable methodology.

4.3. Coastal lagoons provide a large quantity of ES

Coastal lagoons are highly productive, are in high demand for recreational activities, and integrate complex biogeochemical processes that contribute to the regulation of water cycles, climate, and carbon sequestration (Chmura, Anisfeld, Cahoon, & Lynch, 2003). Quantification data for food provisioning, tourism and recreational activities were obtained for approximately 80% of the lagoons. In these productive systems, food provisioning can be key in the regional economy. For example, the Ria Formosa in Portugal provided up to 90% of the national production of clams (Newton et al., 2003). In a review study, Boerema, Geerts, Oosterlee, Temmerman and Meire (2016) indicated that food production and climate regulation are the ES with the highest number of quantification studies. However, it is interesting to highlight that climate regulation data was obtained only for 23.3% of the lagoons included in this study, suggesting the difficulty in evaluating this service for these systems.

How can we quantify all these ES? How accurate are the quantification estimates available in the literature? Boerema et al. (2016) reported an important lack of consensus on what constitutes an ES and a variety of measures to quantify ES, leading to low quality estimates. In fact, the data obtained in this study are not always comparable because: 1) different entities are reported, e.g. some report the aquaculture production of the most important fish species and others do not identify the organisms or do not describe if those quantities are from aquaculture or catches; 2) different units to express similar entities are used, i.e. data may be given in tonnes per annum or in tonnes per hectare or tonnes per farm, which requires additional information, such as the area considered for the production or the number of farms actively operating, which is not generally available. Scientists reported what is available. One of the problems is that this information is obtained from governmental studies and statistical reports that often have different formats. Again, a common framework to guide the process of data collection and estimation would reduce these differences.

It seems even more difficult to quantify those ES that have a critical functional role in the ecosystem, such as water regulation and carbon sequestration. Only 15% or less of the respondents provided quantification data for these roles. In these cases, estimates were almost entirely derived from scientific approaches with final outcomes that were comparable between them (Mg C/annum; e.g. Lin, Hung, Shao, & Kuo, 2001; Sousa et al., 2017). For carbon sequestration ES, one of the first steps is to estimate the carbon stock and then the flux, i.e. the amount of carbon that is effectively taken up from the environment in a specific time. This is an example of the level of detail and difficulty in directly quantifying ES.

Both the ecological and sociological characteristics of coastal lagoons are dynamic. Changes in the way people use coastal lagoons are expected, as well as changes in the ES provided by lagoons. It is important to find strategies to incorporate this dynamic nature in the methodologies used to evaluate ES. For example, the geomorphology of a coastal lagoon may change due to sediment movement and prevent temporary or permanent ship navigation. In addition, large ships can also contribute to the erosion of the lagoon due to increased turbulence (Rapaglia, Zaggia, Ricklefs, Gelinas, & Bokuniewicz, 2011). Another example of a change in ES provided by a lagoon can be shown for the Ria de Aveiro, where aquatic vegetation (*moliço*) was collected using traditional boats (*Moliceiros)*. The harvested vegetation was used as fertilizer and supported important agricultural activities in the fields in the vicinity of the lagoon. Nowadays, this biomass is no longer used as a natural fertilizer and the *Moliceiros* have been converted to a different activity and are now used by guided tour operators. While this may be considered as cultural erosion, it may also be considered to be a form of cultural adaptation. Another example is the gondoliers of Venice, who adhere to strong traditions, but they are now mainly used by tourists, rather than Venetian residents.

4.4. Coastal lagoons provide valuable ES

Although the ES discussion has been going on for more than 20 years, it was only in the last decade that scientists and technical officers have really started to focus on the quantification and valuation of those services. In a review study, Torres, Catalina, and Hanley, 2016 have reported 8 valuation studies on coastal areas (capes, peninsulas, barrier islands, etc.) and 37 valuation studies on coastal waters (bays, gulfs, sounds, fjords, inland seas, etc.). Little is known about the valuation of ES in coastal lagoons and only few studies were available in the literature (e.g. Rolf & Dyack, 2010; De Wit, Rey-Valette, Balavoine, Ouisse, & Lifran, 2015).

Coastal lagoons are amongst the most used and valuable ecosystems on earth. TEEB (2010) estimated that two-thirds of the ecosystem services that make up the planet's natural capital are derived from ocean and coastal biomes. In practical terms, some ES are easier to assign a monetary value than others, for example recreation and tourism have been receiving attention in the past years especially in areas as coastal lagoons due to their attractiveness for recreational activities (e.g. Rolf & Dyack, 2010; Clara et al., 2017). However, there are other services such as erosion or pollution control, that have been neglected because they are difficult to estimate, there is a lack of available data, or it is difficult to conceive and transmit an economic value for these types of services (Barbier et al., 2011, 1997).

Even for the same ES, there are several valuation techniques that can be used. Non-market valuation techniques can be divided in two distinct types: revealed preference methods (estimates of people's preferences based on their behavioural choices) and stated preference methods (based on asking people their preferences). They have very different ways of achieving estimates and for some ES both methods can be used which can cause some confusion when comparing the results. Problems for the comparison of estimates of the valuation can also arise from the different survey approaches (the way questions are posed in questionnaires) and even different statistical analysis used (different modelling choices).

4.5. Climate change will affect the ES of coastal lagoons

The level, rate and effects of climatic changes across the globe are expected to vary from region to region (IPCC, 2014). Increase in temperature, sea level and storminess or extreme events are the main changes that are likely to affect coastal lagoons. Coastal lagoons are generally shallow, and therefore are prone to the effects of temperature increase (Lloret, Marin, & Marin-Guirao, 2008; Brito, Newton, Tett, & Fernandes, 2012; Chapman, 2012). Temperature is one of the most important parameters for biological processes, influencing the functioning of the ecosystem, from basic chemical reactions to the timing (phenology) of lagoon processes, affecting reproduction, migrations, etc. Additionally, increased water temperature causes a decrease in dissolved oxygen, essential for aerobic organisms. Provisioning services provided by coastal lagoons are therefore likely to be at risk by temperature increase. This was acknowledged by 80% of the scientists participating in this study. Sea level rise is also likely to cause relevant impacts in the services provided by lagoons. Lloret et al. (2008) and Brito et al. (2012) have already discussed how light reduction in the bottom may lead to the decay of benthic primary producers and alter the whole structure of the food web, with obvious effects on the trophic state. Benthic primary producers have a key functional role in these systems, being involved in several processes that constitute the basis for supporting and regulating services. The increase in the frequency and intensity of extreme weather events is also likely to happen. Some regions across the globe are expected to experience precipitation decreases while others may receive increases (IPCC, 2014). In the latter regions, increased precipitation and storminess can augment watershed runoff and erosion resulting in a greater flux of terrestrial sediments and pollutants to the coast during runoff events (Anthony et al., 2009). Meanwhile, in regions with reduced precipitation, the decrease in freshwater input was also identified as an important change in coastal lagoons, as it can cause extreme changes in the salinity regime, especially during warmer seasons, as well as changes to a lagoon's water circulation and flushing rate (Lee & Park, 2013). Changes in precipitation regimes will also affect freshwater and nutrients inputs carried by the rivers, with cascading effects on lagoon biogeochemistry (Cossarini et al., 2008; Solidoro, Cossarini et al., 2010) and provisional services (Melaku Canu et al., 2011).

5. Conclusion

The assessment exercise showed that there is a high awareness in the scientific community about the ecosystem services of coastal lagoons. However, there are important challenges and knowledge gaps that have been revealed in this survey that could provide the basis for further research. In particular, the following were identified:

1) The definitions of Ecosystem Services are still not generally accepted. This makes comparative studies difficult. The recommendation is that the researchers use a commonly agreed typology for ES.
2) The quantification of ES is made in many different ways, using different units. This makes comparison and in some cases calculations difficult. The recommendation is that standard units should be used, for example yield (kg) per area (meter sq.) per annum (year). Further information about the lagoon, such as total area, is also important for the result to be useful.
3) The evaluation of ES is even more problematic. Some ES are difficult to value in monetary terms, for example coastal aesthetics and different approaches to valuation are used. The recommendation is that the non-monetary evaluation methods should be standardized, so that the results can be compared.
4) The valuation of ES is also problematic. When ES are valued in monetary terms, what this represents in terms of human benefits and livelihoods is very variable. It may depend on whether it is a developing country or a developed country, the basic wage or salary of the local population and the percentage of income spent on food. For example, a coastal lagoon may provide a high value good, e.g. high value bivalves such as oysters or clams. However, these may be too expensive for the local population to afford and are exported to another country. Values in terms of Gross Domestic Product may not reflect this, especially in countries where there is a large GINI coefficient or index. The recommendation is that valuation should be given in context of the local economy, not just in absolute terms.
5) Another problem for comparison are fluctuations in exchange rates and value of goods. In the case of exchange rates, this can be overcome by quoting the original currency and the date of exchange calculation. However, prices may also vary for different reasons, for example the collapse of a bivalve aquaculture due to disease in one country may affect the prices in neighbouring countries. Once more, dates are important for monetary values to be useful.
6) Different aspects of climate change, including increasing temperature, sea-level rise and decreased rainfall and changes in precipitation regime threaten the valuable ES of coastal lagoons.
7) The conservation of coastal lagoons is important not only for their ecological importance, but also because of the valuable ES they provide for human welfare and wellbeing.

Acknowledgements

Alice Newton's work was supported by the DEVOTES project, funded from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement n° 308392. The author also acknowledges the help and support from the networks and communities of Eurolag, Future Earth Coasts and SCOR. Ana C. Brito was funded by Fundação para a Ciência e a Tecnologia (FCT) Investigador Programme (IF/00331/2013). This study also received support from Fundação para a Ciência e a Tecnologia (UID/MAR/04292/2013). Ana I. Lillebø and Ana I. Sousa were supported through CESAM by FCT/MEC national funds (PIDDAC) (UID/AMB/50017/2013 - POCI-01-0145-FEDER-007638), co-funded by FEDER, within the PT2020 Partnership Agreement and Compete 2020. Ana I. Lillebø research was supported by the European Commission, under the 7th Framework Programme through the collaborative research project LAGOONS (contract n° 283157); and Ana I. Sousa and Ricardo F. de Lima by FCT through the Post-Doc grants SFRH/BPD/107823/2015 and SFRH/BPD/91494/2012, respectively.

References

Acquavita, A., Aleffi, I. F., Benci, C., Bettoso, N., Crevatin, E., Milani, L., ... Mattassi, G. (2015). Annual characterization of the nutrients and trophic state in a Mediterranean coastal lagoon: The Marano and Grado lagoon (northern Adriatic Sea). *Regional Studies in Marine Science, 2*, 132–144. http://dx.doi.org/10.1016/j.rsma.2015.08.017http://www.journals.elsevier.com/regional-studies-in-marine-science/.

AEC (Anchor Environmental Consultants) (2015). *The state of Saldanha Bay and Langebaan Lagoon 2014/2015. Technical report September 2015. Prepared for the Saldanha Bay water quality forum trust*Cape Town.

Alberini, A., Rosato, P., Longo, A., & Zanatta, V. (2005). Information and willingness to pay in a contingent valuation study: The value of S. Erasmo in the Lagoon of Venice. *Journal Of Environmental Planning and Management, 48*(2).

Alberini, A., Zanatta, V., & Rosato, P. (2007). Combining actual and contingent behaviour to estimate the value of sports fishing in the Lagoon of Venice. *Ecological Economics, 61*(2-3), 530–541.

Angus, S. (2016). Monitoring and surveillance of a highly variable habitat: The challenge posed by Scottish saline lagoons. *Regional Studies in Marine Science, 8*, 20–26.

Angus, S. (2017). Scottish saline lagoons: Impacts and challenges of climate change. *Estuarine, Coastal and Shelf Science, 198*, 626–635.

Anthony, A., Atwood, J., August, P., Byron, C., Cobb, S., Foster, C., ... Vinhateiro, N. (2009). Coastal lagoons and climate change: Ecological and social ramifications in U.S. Atlantic and Gulf Coast ecosystems. *Ecology and Society, 14*, 8.

Ayache, F., Thompson, J. R., Flower, R. J., Boujarra, A., Rouatbi, F., & Makina, H. (2009). Environmental characteristics, landscape history and pressures on three coastal lagoons in the Southern Mediterranean Region: Merja Zerga (Morocco), Ghar El Melh (Tunisia) and Lake Manzala (Egypt). *Hydrobiologia, 622*, 15–43. http://dx.doi.org/10.1007/s10750-008-9676-6.

Barbier, E. B. (2012). A spatial model of coastal ecosystem services. *Ecological Economics, 78*, 70–79.

Barbier, E. B., Acreman, M. C., & Knowler, D. (1997). *Economic valuation of wetlands: A guide for policy makers and planners.* Gland, Switzerland: Ramsar Convention Bureau.

Barbier, E. B., Hacker, S. D., Kennedy, C., Koch, e. Q., Stier, A. C., & Silliman, B. R. (2011). The value of estuarine and coastal ecosystem services. *Ecological Monographs, 81*, 169–193.

Barnes, R. S. K. (1980). *Coastal lagoons.* Cambridge, UK: Cambridge University Press.

Basset, A., Elliott, M., West, R. J., & Wilson, J. G. (2013). Estuarine and lagoon biodiversity and their natural goods and services. *Estuarine, Coastal and Shelf Science, 132*, 1–4. http://dx.doi.org/10.1016/j.ecss.2013.05.018.

Béjaoui, B., Harzallah, A., Moussa, M., Chapelle, A., & Solidoro, C. (2008). Analysis of hydrobiological pattern in the Bizerte lagoon (Tunisia). *Estuarine, Coastal and Shelf Science, 80*, 121–129.

Béjaoui, B., Solidoro, C., Harzallah, A., Chevalier, C., Chapelle, A., Zaaboub, N., ... Aleya,

L. (2016). 3D modeling of phytoplankton seasonal variation and nutrient budget in a southern Mediterranean Lagoon. *Marine Pollution Bulletin, 114*, 962–976. http://dx.doi.org/10.1016/j.marpolbul.2016.11.001.
Ben Rejeb-Jenhani, A. (1989). Le Lac Ichkeul: Conditions de milieu, peuplements et biomasses phytoplanctoniques. *Thèse de doctorat Faculté des Sciences de Tunis,* 221.
Bettoso, N., Acquavita, A., D'Aletti, A., & Mattassi, G. (2013). The Marano and Grado Lagoon: A brief synopsis on the aquatic fauna and fisheries resources. *Annales Series Historia Naturalis,* 135–142 23/21013/2.
Birks, H. H., Birks, H. J. B., Flower, R. J., Peglar, S. M., & Ramdani, M. (2001). Recent ecosystem dynamics in nine North African lakes in the CASSARINA project. *Aquatic Ecology, 35*, 461–478.
Boerema, A., Geerts, L., Oosterlee, L., Temmerman, S., & Meire, P. (2016). Ecosystem service delivery in restoration projects: The effect of ecological succession on the benefits of tidal marsh restoration. *Ecology and Society, 21*(2), 10. http://dx.doi.org/10.5751/ES-08372-210210.
Boukef, I., El Bour, M., Got, P., Mejri, S., Elbahri, O., Troussellier, M., ... Boudabous, A. (2010). Survival of *Escherichia coli* strains in Mediterranean brackish water (Bizerte lagoon, Northern Tunisia). *Water Environment Research, 82*, 2249–2257. http://dx.doi.org/10.2175/106143010X12609736967161.
Boyd, J., & Banzhaf, S. (2007). What are ecosystem services? *Ecological Economics, 63*(2–3), 616–626.
Braat, L., & de Groot, R. (2012). The ecosystem services agenda: Bridging the worlds of natural science and economics, conservation and development, and public and private policy. *Ecosystem Services, 1*, 4–15.
Braga, C. Z. F., Vianna, M. L., & Kjerfve, B. (2003). Environmental characterization of a hypersaline coastal lagoon from landsat-5 TM data. *International Journal of Remote Sensing, 24*(16), 3219–3234.
Brander, L., Wagtendonk, A. J., Hussain, S. S., McVittie, A., Verburg, P. H., de Groot, R., ... van der Ploeg, S. (2012). Ecosystem service values for mangroves in Southeast Asia: A meta-analysis and value transfer application. *Ecosystem Services, 1*, 62–69.
Breber, P., Povilanskas, R., & Armaitienė, A. (2008). Recent evolution of fishery and land reclamation in Curonian and Lesina lagoons. *Hydrobiologia, 611*, 105–114.
Brito, A. C., Newton, A., Tett, P., & Fernandes, T. F. (2010). Sediment and water nutrients and microalgae in a coastal shallow lagoon, Ria Formosa (Portugal): Implications for the water framework directive. *Journal of Environmental Monitoring, 12*, 318–328.
Brito, A. C., Newton, A., Tett, P., & Fernandes, T. F. (2012). How will shallow coastal lagoons respond to climate change? A modelling investigation. *Estuarine, Coastal and Shelf Science, 112*, 98–104. http://dx.doi.org/10.1016/j.ecss.2011.09.002.
Brito, A. C., Silva, T., Beltrán, C., Chainho, P., & de Lima, R. F. (2017). Phytoplankton in two tropical mangroves of São Tomé Island (Gulf of Guinea): A contribution to water quality assessment and management. *Regional Studies in Marine Science, 9*, 89–96.
Cabana, D., Nicolaidou, A., Sigala, K., & Reizopoulou, S. (2017). Multi-scale functional and taxonomic β-diversity of the macroinvertebrate communities in a Mediterranean coastal lagoon. *Mediterranean Marine Science, 18*, 121–133. http://dx.doi.org/10.12681/mms.1844.
Cañedo-Argüelles, M., & Rieradevall, M. (2011). Early succession of the macroinvertebrate community in a shallow lake: Response to changes in the habitat condition. *Limnologica-Ecology and Management of Inland Waters, 41*(4), 363–370. http://dx.doi.org/10.1016/j.limno.2011.04.001.
Canu, D. M., & Rosati, G. (2017). Long-term scenarios of mercury budgeting and exports for a Mediterranean hot spot (Marano-Grado Lagoon, Adriatic Sea). *Estuarine, Coastal and Shelf Science, 198*, 518–528. http://dx.doi.org/10.1016/j.ecss.2016.12.005.
Canu, D. M., Rosati, G., Solidoro, C., Heimbürger, L.-E., & Acquavita, A. (2015). A comprehensive assessment of the mercury budget in the Maranoe Grado Lagoon (Adriatic Sea) using a combined observational modeling approach. *Marine Chemistry, 177*, 742–752. http://dx.doi.org/10.1016/j.marchem.2015.10.013.
Cardique, A. G. D. (2006). *Registro de las actividades de desarrollo de la franja costera de la parte continental de la Bahía de Cartagena - Departamento de Bolívar. Corporación Autónoma Regional del Canal del Dique (Cardique) & Fundación Alta Gestión Para el Desarrollo (AGD). Informe Final. Cartagena de Indias* 204 pp.
Cardoso-Mohedano, J. G., Bernardello, R., Sanchez-Cabeza, J. A., Molino-Minero-Re, E., Ruiz-Fernández, A. C., & Cruzado, A. (2015a). Accumulation of conservative substances in a sub-tropical coastal lagoon Estuarine. *Coastal and Shelf Science, 164*, 1–9. http://dx.doi.org/10.1016/j.ecss.2015.06.022.
Cardoso-Mohedano, J. G., Bernardello, R., Sanchez-Cabeza, J. A., Ruiz-Fernández, A. C., Alonso-Rodriguez, R., & Cruzado, A. (2015b). Thermal impact from a thermoelectric power plant on a tropical coastal lagoon. *Water Air and Soil Pollution, 226*, 2202. http://dx.doi.org/10.1007/s11270-014-2202-8.
Carpenter, S. R., Mooney, H. A., Agard, J., Capistrano, D., Defries, R. S., Díaz, S., Dietz, T., Duraiappah, A. K., Oteng-Yeboah, A., Pereira, H. M., Perrings, C., Reid, W. V., Sarukhan, J., Scholes, R. J., & Whyte, A. (2009). Science for managing ecosystem services: Beyond the millennium ecosystem assessment. *Proceedings of the National Academy of Sciences, 106*(5), 1305–1312.
Cavuta, G., & Di Matteo, D. (2016). Landscapes protection and eco-development: The case study of Gargano National Park, Italy. *GeoJournal of Tourism and Geosites, 17*, 95–111. Available at: http://gtg.webhost.uoradea.ro/PDF/GTG-1-2016/194_Cavuta.pdf.
Chaouachi, B., & Ben Hassine, O. K. (1998). The status of fish biodiversity in Ichkeul lagoon (Tunisia). *Italian Journal of Zoology, 65*(Suppl), 303–304.
Chapman, P. M. (2012). Management of coastal lagoons under climate change. *Estuarine, Coastal and Shelf Science, 110*, 32–35.
Chmura, G. L., Anisfeld, S. C., Cahoon, D. R., & Lynch, J. C. (2003). Global carbon sequestration in tidal, saline wetland soils. *Global Biogeochemical Cycles, 17*, 1111. http://dx.doi.org/10.1029/2002GB001917.4.
Clara, I., Dyack, B., Rolfe, J., Newton, A., Borg, D., Povilanskas, R., ... Brito, A. C. (2017). The value of coastal lagoons: Case study of recreation at Ria de Aveiro, Portugal in comparison to the Coorong, Australia. *Journal of Nature Conservation*. http://dx.doi.org/10.1016/j.jnc.2017.10.012 in press.
Cossarini, G., Libralato, S., Salon, S., Gao, X., Giorgi, F., & Solidoro, C. (2008). Downscaling experiment for the Venice lagoon. II. Effects of changes in precipitation on biogeochemical properties. *Climate Research, 38*(1), 43–59.
Costanza, R. (2008). Ecosystem services: Multiple classification systems are needed. *Biological Conservation, 141*, 350–352.
Dahdouh-Guebas, F., Kairo, J. G., Koedam, N., & Mathenge, C. (2000). Utilization of mangrove wood products around Mida Creek (Kenya) amongst subsistence and commercial users. *Economic Botany, 54*(4), 513–527. http://dx.doi.org/10.1007/BF02866549.
Daily, G. C., Polasky, S., Goldstein, J., Kareiva, P., Mooney, H. A., Pejchar, L., ... Shallenberger, R. (2009). Ecosystem services in decision making: Time to deliver. *Frontiers in Ecology and the Environment, 7*(1), 21–28.
DANE - Departamento Administrativo (2016). *Nacional de Estadística Estimaciones de población 1985–2005, proyecciones de población 2005–2020 y producto interno bruto (PIB).* Accessed 21 February 2017 http://www.dane.gov.co/.
Day, J. H. (1959). The biology of Langebaan Lagoon: A study of the effect of shelter from wave action. *Transactions of the Royal Society of South Africa, 35*, 475–547.
De Groot, R. S., Wilson, M. A., & Boumans, R. M. (2002). A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics, 41*(3), 393–408.
De Pascalis, F., Pérez-Ruzafa, A., Gilabert, J., Marcos, C., & Umgiesser, G. (2012). Climate change response of the Mar Menor coastal lagoon (Spain) using a hydrodynamic finite element model. *Estuarine, Coastal and Shelf Science, 114*, 118–129. http://dx.doi.org/10.1016/j.ecss.2011.12.002.
De Wit, R., Rey-Valette, H., Balavoine, J., Ouisse, V., & Lifran, R. (2015). Restoration ecology of coastal lagoons: New methods for the prediction of ecological trajectories and economic valuation. *Aquatic Conservation: Marine and Freshwater Ecosystems, 27*, 137–157.
EC (2017). *Science for Environment Policy. Taking stock: Progress in natural capital accounting. Report 16*. Bristol: European Commission, DG Environment, Science Communication Unit, UWEhttp://dx.doi.org/10.2779/304410. 52 pp http://ec.europa.eu/science-environment-policy.
Egoh, B., Rouget, M., Reyers, B., Knight, A. T., Cowling, R. M., Jaarsveld, A. S., ... Welz, A. (2007). Integrating ecosystem services into conservation assessments: A review. *Ecological Economics, 63*, 714–721.
Eisenreich, S. J. (Ed.). (2005). *Climate change and the European water dimension. EU report no. 21553*. Ispra, Italy: European Communities, Joint Research Centre, European Commission.
El Asri, F., Zidane, H., Maanan, M., Tamsouri, M., & Errhif, A. (2015). Taxonomic diversity and structure of the molluscan fauna in Oualidia Lagoon (Moroccan Atlantic Coast). *Environmental Monitoring and Assessment, 187*, 545–554.
Félix, P. M., Chainho, P., de Lima, R. F., Costa, J. L., Almeida, A. J., Domingos, I., & Brito, A. C. (2017). Mangrove fish of São Tomé Island (Gulf of Guinea): New occurrences and habitat usage. *Freshwater and Marine Research, 68*, 123–130.
Ferrarin, C., Umgiesser, G., Bajo, M., Bellafiore, D., De Pascalis, F., Ghezzo, M., ... Scroccaro, I. (2010). Hydraulic zonation of the lagoons of Marano and Grado, Italy. A modelling approach. *Estuarine, Coastal and Shelf Science, 87*, 561–572.
Ferreira, O., Dias, J. A., & Taborda, R. (2008). Implications of sea-level rise for Continental Portugal. *Journal of Coastal Research, 24*(2), 317–324. http://dx.doi.org/10.2112/07A-0006.1.
Fertouna-Bellakhal, M., Dhib, A., Béjaoui, B., Turki, S., & Aleya, L. (2014). Driving factors behind the distribution of dinocyst composition and abundance in surface sediments in a western Mediterranean coastal lagoon: Report from a high resolution mapping study. *Marine Pollution Bulletin, 84*, 347–362. http://dx.doi.org/10.1016/j.marpolbul.2014.04.041.
Fisher, B., Turner, R. K., & Morling, P. (2009). Defining and classifying ecosystem services for decision making. *Ecological Economics, 68*(3), 643–653.
Flores-Verdugo, F., González-Farías, F., Ramírez-Flores, O., Amezcua-Linares, F., Yáñez-Arancibia, A., Alvarez-Rubio, M., ... Day, J. W. (1990). Mangrove ecology, aquatic primary productivity, and fish community dynamics in the Teacapán-Agua Brava lagoon-estuarine system (Mexican Pacific). *Estuaries, 13*(2), 219–230.
Franco, A., Franzoi, P., Malavasi, S., Riccato, F., Torricelli, P., & Mainardi, D. (2006). Use of shallow water habitats by fish assemblages in a Mediterranean coastal lagoon. *Estuarine Coastal and Shelf Science, 66*, 67–83.
Frank, C., Kairo, J., Mohamed, M., Bosire, J., Dahdouh-Guebas, F., & Koedam, N. (2017). Involvement, knowledge and perception in a natural reserve under participatory management: Mida Creek, Kenya. *Ocean and Coastal Management, 142*, 28–36.
Fujita, C. C., & Odebrecht, C. (2007). Short term variability of chlorophyll a and phytoplankton composition in a shallow area of the Patos Lagoon estuary (Southern Brazil). *Atlântica, 29*, 93–106.
Gubanova, O., Tuchkovenko, Y., Khokhlov, V., Stepanenko, V., & Baggett, S. (2015). The management story of Tyligulskyi Liman Lagoon. In A. I. Lillebø, P. Stålnacke, & G. D. Gooch (Eds.). *Coastal Lagoons in Europe: Integrated water resource strategies* (pp. 87–96). London: IWA Publishing.
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.
Hasler, B., Ahtiainem, H., Hasselstrom, L., Heiskanen, A.-S., Soutukorva, A., & Martinsen, L. (2016). *Marine ecosystem services in Nordic marine waters and the Baltic Sea- possibilities for valuation.* Nordic Council of Ministers 159pp.
Herrera-Silveira, J., & Morales-Ojeda, S. (2010). Subtropical karstic coastal lagoon assessment, southeast Mexico. In M. Kennish, & H. Paerl (Eds.). *Coastal lagoons critical habitats of environmental change* (pp. 307–333). Boca Raton: Taylor & Francis.
Hesse, C., Bielecka, M., Stefanova, A., Robakiewicz, M., Staroszczyk, R., Zalewski, M., Khokhlov, V., Tuchkovenko, Y., Lloret, J., Lencart e Silva, J., Dias, J. M., Lillebø, A. I.,

Chubarenko, B., & Krysanova, V. (2015). Impacts of potential climate change on lagoons and their catchments (chapter 13) In A. L. Lillebø, P. Stålnacke, & G. D. Gooch (Eds.). *Coastal lagoons in Europe: Integrated water resource strategies* (pp. 115–131). IWA), UK: International Water Association Chapter 13.

Hsiao, S. T., Chuang, S. C., Chen, K. S., Ho, P. H., Wu, C. L., & Chen, C. A. (2016). DNA barcoding reveals that the common cupped oyster in Taiwan is the Portuguese oyster *Crassostrea angulata* (Ostreoida; Ostreidae), not *C. gigas*. *Scientific Reports, 6*, 1–11. http://dx.doi.org/10.1038/srep34057.

Ingram, J. C., Redford, K. H., & Watson, J. E. M. (2012). Applying ecosystem services approaches for biodiversity conservation: Benefits and challenges. *Surveys and Perspectives Integrating Environment and Society, 5*(1).

IPCC (2014). Climate change 2014: Synthesis report. In Core Writing Team, R. K. Pachauri, & L. A. Meyer (Eds.). *Contribution of working groups I, II and III to the fifth assessment report of the intergovernmental panel on climate change*. Geneva, Switzerland: IPCC.

Ishitobi, Y., Kamiya, H., & Yamamuro, M. (2014). *Science of Lakes Nakaumi and Shinji - hydrology, water chemistry and ecosystem.* Matsue: Harvest Publishing (In Japanese).

Kairo, J. G., Dahdouh-Guebas, F., Gwada, P. O., Ochieng, C., & Koedam, N. (2002). Regeneration status of mangrove forests in Mida Creek, Kenya: A compromised or secured future? *Ambio, 31*(7–8), 562–568. http://dx.doi.org/10.1579/0044-7447-31.7.562.

Katselis, G., Koutsikopoulos, C., Dimitriou, E., & Rogdakis, Y. (2003). Spatial patterns and temporal trends in the fishery landings of the Messolonghi-Etoliko lagoon system (western Greek coast). *Scientia Marina, 67*, 501–511.

Katselis, G., Koukou, K., Dimitriou, E., & Koutsikopoulos, C. (2007). Short-term seaward fish migration in the MessolonghieEtoliko lagoons (Western Greek coast) in relation to climatic variables and the lunar cycle. *Estuarine, Coastal and Shelf Science, 73*, 571–582.

Katsuki, K., Miyamoto, Y., Yamada, K., Takata, H., Yamaguchi, K., Nakayama, D., ... Khim, B.-K. (2008). Eutrophication-induced changes in Lake Nakaumi, southwest Japan. *Journal of Paleolimnology, 40*, 1115–1125.

Kerwath, S. E., Thorstad, E. B., Næsje, T. F., Attwood, C. G., Cowley, P. D., Økland, F., ... Wilke, C. (2009). Crossing invisible boundaries: The effectiveness of The Langebaan Lagoon marine protected area as a harvest refuge for a migratory fish species in South Africa. *Conservation Biology, 23*(3), 653–661.

Kitheka, J., Mwashote, B., Ohowa, & Kamau (1999). Water circulation, groundwater outflow and nutrient dynamics in Mida Creek, Kenya. *Mangroves and Saltmarshes, 3*, 135–146. http://dx.doi.org/10.1023/A:10099121214709.

Kjerfve, B. (1994). *Coastal lagoon processes.* Amsterdam, The Netherlands: Elsevier.

Kjerfve, B., & Knoppers, B. (1999). Physical characteristics of lagoons of the east fluminense coast, state of Rio de Janeiro, Brazil. In B. Knoppers, E. D. Bidone, & J. J. Abrão (Eds.). *Environmental geochemistry of coastal lagoon systems*. Rio de Janeiro: Série Geoquímica Amb.

Kjerfve, B., & Oliveira, A. M. (2004). Modelling of circulation and water exchange in a hypersaline coastal lagoon: Lagoa de Araruama, Brazil. In Lacerda L.D, Santelli R.E, Duursma E, & J. J. Abrão (Eds.). *Environmental geochemistry in tropical and subtropical environments* (pp. 235–251). Berlin: Springer Verlag.

Kjerfve, B., Schettini, C., Knoppers, B., Lessa, G., & Ferreira, H. O. (1996). Hydrology and salt balance in a large, hypersaline coastal lagoon: Lagoa de Araruama, Brazil. *Estuarine, Coastal and Shelf Science, 42*, 701–725.

Knoppers, B., & Kjerfve, B. (1999). Coastal lagoons of southeastern Brazil: Physical and biogeochemical characteristics. In G. M. E. Perillo, M. C. Piccolo, & M. Pino (Eds.). *Estuaries of South America* (pp. 25–66). Heidelberg: Springer Verlag.

Kruse, M., Benkenstein, M., & Müller, F. (2015). Ein Konzept zur Bewertung von Ökosystemleistungen in der Darß-Zingster Boddenkette – qualitative Analyse und Vorstellung des Mengengerüsts zur Quantifizierung. *Rostocker Meeresbiologische Beiträge, 25*, 133–157.

La Jeunesse, I., & Elliott, M. (2004). Anthropogenic regulation of the phosphorus balance in the Thau catchment-coastal lagoon system (Mediterraean Sea, France) over 24 years. *Marine Pollution. Bulletin, 48*, 679–687. http://dx.doi.org/10.1016/j.marpolbul.2003.10.011.

La Jeunesse, I., Cirelli, C., Sellami, H., Aubin, D., Deidda, R., & Baghdadi, N. (2015). Is the governance of the Thau coastal lagoon ready to face climate change impacts? *Ocean & Coastal Management, 118*, 234–246. http://dx.doi.org/10.1016/j.ocecoaman.2015.05.014.

La Jeunesse, I., Cirelli, C., Larrue, C., Aubin, D., Sellami, H., Afifi, S., ... Soddu, A. (2016). Is climate change a threat for water uses in the Mediterranean region? Results from a survey at local scale. *Science of the Total Environment, 543*, 981–996. http://dx.doi.org/10.1016/j.scitotenv.2015.04.062.

Labbardi, H., Ettahiri, O., Lazar, S., Massik, Z., & El Antri, S. (2005). Étude de la variation spatio-temporelle des paramètres physico-chimiques caractérisant la qualité des eaux d'une lagune côtière et ses zonations écologiques: cas de Moulay Bousselham, Maroc. *Comptes Rendus Geoscience, 337*(5), 505–514. http://dx.doi.org/10.1016/j.crte.2005.01.009.

Lee, H. W., & Park, S. S. (2013). A hydrodynamic modeling study to estimate the flushing rate in a large coastal embayment. *Journal of Environmental Management, 115*, 278–286.

Lele, S., Springate-Baginski, O., Lakerveld, R., Deb, D., & Dash, P. (2013). Ecosystem services : Origins, contributions, pitfalls, and alternatives. *Conservation and Society, 11*(4), 343–358.

Lillebø, A. I., Stålnacke, P., & Gooch, G. D. (Eds.). (2015). *Coastal lagoons in Europe: Integrated water resource strategies*London Water: Water Research Series IWA publishinghttp://wio.iwaponline.com/content/ppiwawio/14/9781780406299.full.pdf.

Lillebø, A. I., Somma, F., Norén, K., Gonçalves, J., Alves, M. F., Ballarini, E., ... Zaucha, J. (2016). Assessment of marine ecosystem services indicators: Experiences and lessons learned from 14 European case studies. *Integrated Environmental Assessment and Management, 12*(4), 726–734. http://dx.doi.org/10.1002/ieam.1782.

de Lima, R. F., Chainho, P., Félix, P., Costa, J. L., Almeida, A., Domingos, I., ... Brito, A. C. (2016). Mangroves of São Tomé Island: A preliminary assessment. *Archipelago - Life and Marine Sciences,* (Suppl. 9), 422–423.

Lin, H. J., Hung, J. J., Shao, K. T., & Kuo, F. (2001). Trophic functioning and nutrient flux in a highly productive tropical lagoon. *Oecologia, 129*, 395–406. http://dx.doi.org/10.1007/s004420100730.

Lloret, J., Marin, A., & Marin-Guirao, L. (2008). Is coastal lagoon eutrophication likely to be aggravated by global climate change? *Estuarine Coastal and Shelf Science, 78*, 403–412.

Loiseau, E., Roux, P., Junqua, G., Maurel, P., & Bellon-Maurel, V. (2014). Implementation of an adapted LCA framework to environmental assessment of a territory: Important learning points from a French Mediterranean case study. *Journal of Cleaner Production, 80*, 17–29. http://dx.doi.org/10.1016/j.jclepro.2014.05.059.

Lonin, S., Parra, C., Andrade, C., & Yves-Francois, T. (2004). Patrones de la pluma turbia del Canal del Dique en la Bahía de Cartagena. *Boletín Científico CIOH, 22*, 77–89.

Lopes, R., & Videira, N. (2013). Valuing marine and coastal ecosystem services: An integrated participatory framework. *Ocean & Coastal Management, 84*, 153–162. http://dx.doi.org/10.1016/j.ocecoaman.2013.08.001.

Löser, N., & Sekścińska, A. (2005). *Integriertes Küste-Flusseinzugsgebiets-Management an der Oder/Odra: Hintergrundbericht [integrated coastal area – River basin management at the Oder/Odra: Background report; German with extended Polish and English abstracts]. IKZMOder Berichte 14*http://databases.eucc-d.de/files/documents/00000033_IKZM_Oder_Berichte14.pdf.

MA - Millennium Ecosystem Assessment (2005). *Ecosystem services and human well-being.* Washington, DC: Island Press.

Maanan, M. (2008). Trace metal contamination of marine organisms from the Moroccan North Atlantic coastal environments. *Environmental Pollution, 153*(1), 176–183.

Maanan, M., Landesman, C., Maanan, M., Zourarah, B., Fattal, F., & Sahabi, M. (2013). Evaluation of the anthropogenic influx of metal and metalloid contaminants into the Moulay Bousselham lagoon, Morocco, using chemometric methods coupled to geographical information systems. *Environmental Science and Pollution Research, 20*(7), 4720–4741. http://dx.doi.org/10.1007/s11356-012-1399-6.

Maanan, M., Ruiz-Fernández, A.-C., Maanan, M., Sahabi, M., Fattal, P., & Zourarah, B. (2014). A long-term record of land use change impacts on lagoonal sediments (Oualidia lagoon, Morocco). *International Journal of Sediment Research, 29*, 1–10.

Maanan, M., Saddik, M., Maanan, M., Chaibi, M., Assobhei, O., & Zourarah, B. (2015a). Environmental and ecological risk assessment of heavy metals in sediments of Nador lagoon, Morocco. *Ecological Indicators, 48*, 616–626.

Maanan, M., Zourarah, B., Sahabi, M., Maanan, M., Le Roy, P., Mehdi, K., ... Salhi, F. (2015b). Environmental risk assessment of the Moroccan Atlantic continental shelf: The role of the industrial and urban area. *Science of the Total Environment, 511*, 407–415.

Manini, E., Breber, P., D'Adamo, R., Spagnoli, R., & Danovaro, R. (2002a). Lagoon of Lesina. Final report of the LaguNet workshop land–ocean interactions in the coastal zone (LOICZ). In G. Giordani, P. Viaroli, D. P. Swaney, C. N. Murray, J. M. Zaldìvar, & J. I. Marshall Crossland (Eds.). *Nutrient fluxes in transitional zones of the Italian coast* (pp. 49–54). LOICZ Reports and Studies.

Manini, E., Breber, P., D'Adamo, R., Spagnoli, R., & Danovaro, R. (2002b). Lagoon of Varano. Final report of the LaguNet workshop land–ocean interactions in the coastal zone (LOICZ). In G. Giordani, P. Viaroli, D. P. Swaney, C. N. Murray, J. M. Zaldìvar, & J. I. Marshall Crossland (Eds.). *Nutrient fluxes in transitional zones of the Italian coast* (pp. 55–58). LOICZ Reports and Studies.

Manini, E., Breber, P., D'Adamo, R., Spagnoli, F., & Danovaro, R. (2005). *Lagoon of Lesina. Nutrient fluxes in transitional zones of the Italian coast28*, LOICZ Reports and Studies49–54.

Marcos, C., Torres, I., López-Capel, A., & Pérez-Ruzafa, A. (2015). Long term evolution of fisheries in a coastal lagoon related to changes in lagoon ecology and human pressures. *Reviews in Fish Biology and Fisheries, 25*, 689–713. http://dx.doi.org/10.1007/s11160-015-9397-7.

Maynou, F., Martinez-Banos, P., Demestre, M., & Franquesa, R. (2014). Bio-economic analysis of the Mar Menor (Murcia, SE Spain) small-scale lagoon fishery. *Journal of Applied Ichthyology, 30*(5), 978–985. http://dx.doi.org/10.1111/jai.12460.

Melaku Canu, D., Campostrini, P., Dalla Riva, S., Pastre, R., Pizzo, L., Rossetto, L., & Solidoro, C. (2011). Addessing sustainability of clam farming in the Venice Lagoon. *Ecology and Society, 16*(3), http://dx.doi.org/10.5751/ES-04263-169326.

Mongruel, R., Vanhoutte-Brunier, A., Fiandrino, A., Valette, F., Ballé-Béganton, J., Pérez Agúndez, J. A., ... Laugier, T. (2013). Why, how, and how far should microbiological contamination in a coastal zone be mitigated? An application of the systems approach to the Thau lagoon (France). *Journal of Environmental Management, 118*, 55–71.

Mudge, S. M., & Bebianno, M. J. (1997). Sewage contamination following an accidental spillage in the Ria Formosa, Portugal. *Marine Pollution Bulletin, 34*(3), 163–170.

Nakata, K., Horiguchi, F., & Yamamuro, M. (2000). Model study of Lakes Shinji and Nakaumi – a coupled coastal lagoon system. *Journal of Marine Systems, 26*, 145–169.

Nel, P., & Branch, G. M. (2014). The effect of bait collectors on stocks of *Callichirus kraussi* and *Upogebia* species in Langebaan Lagoon. *African Zoology, 49*(1).

Newton, A., Icely, J. D., Falcão, M., Nobre, A., Nunes, J. P., Ferreira, J. G., ... Vale, C. (2003). Evaluation of eutrophication in the Ria Formosa coastal lagoon, Portugal. *Continental Shelf Research, 23*, 1945–1961. http://dx.doi.org/10.1016/j.csr.2003.06.008.

Newton, A., Icely, J. D., Cristina, S., Brito, A., Cardoso, A. C., Colijn, F., ... Zaldívar, J. M. (2014). An overview of ecological status, vulnerability and future perspectives of European large shallow, semi-enclosed coastal systems, lagoons and transitional waters. *Estuarine, Coastal and Shelf Science, 140*, 95–122. http://dx.doi.org/10.1016/j.ecss.2013.05.023.

Nunes, P. A. L. D., Rossetto, L., & de Blaeij, A. (2003). Monetary value assessment of clam

fishing management practices in the Venice lagoon: Results from a stated choice exercise. *FEEM NOTA DI LAVORO, 67*http://www.feem.it/Feem/Pub/Publications/WPapers/default.html.
Odebrecht, C., Abreu, P. C., Moller, O., Nienchski, L. F., Proença, L., & Torgan, L. C. (2005). Drought effects on pelagic properties in shallow and turbid Patos Lagoon, Brazil. *Estuaries, 28*, 675–685.
Owuor, M., Icely, J., Newton, A., Nyunja, J., Otieno, P., Tuda, A., ... Oduor, N. (2017). Mapping of ecosystem services flow in Mida Creek, Kenya. *Ocean and Coastal Management, 140*, 11–21. http://dx.doi.org/10.1016/j.ocecoaman.2017.02.013.
Paez-Osuna, F., Montano-Ley, J., & Bojorquez-Levya, H. (1990). Intercambio de agua, fosforo y material suspendido entre el sistema lagunar del puerto de mazatlan y las aguas costeras adyacentes. *Revista Internacional de Contaminación Ambiental, 6*, 19–32. Available in: http://www.redalyc.org/articulo.oa?id=37060102.
Pérez-Ruzafa, A., Marcos, C., & Gilabert, J. (2005). The ecology of the Mar Menor coastal lagoon: A fast-changing ecosystem under human pressure. In Gönenç I.E, & J. P. Wolflin (Eds.). *Coastal Lagoons: Ecosystem processes and modeling for sustainable use and development* (pp. 392–422). Boca Ratón, Florida: CRC Press.
Philomena, A. L. (1994). Money and energy analysis of coastal lagoon resources. In B. Kjerfve (Ed.). *Coastal Lagoon processes* (pp. 535–551). Elsevier.
Pisoni, T., de Lima, R., Brito, A. C., Chainho, P., Félix, P. M., Caçador, I., ... Carvalho, A. (2015). *Plano de gestão participativa para dois sítios de mangal na ilha de S. tomé: Praia das conchas e malanza. Abordagem ecossistémica integrada para a conversação e gestão da biodiversidade na zona tampão dos parques naturais obô de são tomé e príncipe.* 79pp.
Povilanskas, R., Armaitienė, A., Breber, P., Razinkovas-Baziukas, A., & Taminskas, J. (2012). Integrity of linear littoral habitats of Lesina and Curonian Lagoons. *Hydrobiologia, 699*, 99–110.
Povilanskas, R., Razinkovas-Baziukas, A., & Jurkus, E. (2014). Integrated environmental management of transboundary transitional waters: Curonian Lagoon case study. *Ocean and Coastal Management, 101*, 14–23.
Pranovi, F., Sarà, G., & Franzoi, P. (2013a). Valuing the unmarketable: An ecological approach to the externalities estimate in fishing activities. *Sustainability, 5*, 643–653. http://dx.doi.org/10.3390/su5020643.
Pranovi, F., Caccin, A., Franzoi, P., Malavasi, S., Zucchetta, M., & Torricelli, P. (2013b). Vulnerability of artisanal fisheries to climate change in the Venice lagoon. *Journal of Fish Biology, 83*, 847–863. http://dx.doi.org/10.1111/jfb.12124.
Radziejewska, T., & Schernewski, G. (2008). The Szczecin (Oder-) Lagoon. In U. Schiewer (Vol. Ed.), *Ecology of Baltic coastal waters series. Ecological studies: 197*, (pp. 115–129). Berlin: Springer. http://dx.doi.org/10.1007/978-3-540-73524-3_5.
Rapaglia, J., Zaggia, L., Ricklefs, K., Gelinas, M., & Bokuniewicz, H. (2011). Characteristics of ship's depression waves and associated sediment resuspension in Venice Lagoon, Italy. *Journal of Marine Systems, 85*(1), 45–56.
Restrepo, J. D., Zapata, P., Díaz, J., Garzón-Ferreira, J., & García, C. (2006). Fluvial fluxes into the Caribbean Sea and their impact on coastal ecosystems: The Magdalena River, Colombia. *Global and Planetary Change, 50*(1), 33–49.
Rolf, J., & Dyack, B. (2010). Testing for convergent validity between travel cost and contigent valuation estimates of recreation values in the Coorong, Australia. *Australian Journal of Agricultural and Resource Economics, 54*, 583–599. http://dx.doi.org/10.1111/j.1467-8489.2010.00513.x.
Rolf, J., & Dyack, B. (2011). Valuing recreation in the Coorong, Australia, with travel cost and contingent behaviour models. *Economic Record, 87*, 282–293. http://dx.doi.org/10.1111/j.1475-4932.2010.00683.x.
Roselli, L., Cañedo-Argüelles, M., Costa Goela, M. P., Cristina, S., Rieradevall, M., D'Adamo, R., ... Newton, A. (2013). Do physiography and hydrology determine the physico-chemical properties and trophic status of coastal lagoons? A comparative approach. *Estuarine, Coastal and Shelf Science, 117*, 29–36. http://dx.doi.org/10.1016/j.ecss.2012.09.014.
Rubio-Cisneros, N. T., Aburto-Oropeza, O. M., Murray, J., Gonzalez-Abraham, C. E., Jackson, J., & Ezcurra, E. (2014). Transnational ecosystem services: The potential of habitat conservation for waterfowl through recreational hunting activities. *Human Dimensions of Wildlife, 19*, 1–16. http://dx.doi.org/10.1080/10871209.2013.819536.
Rubio-Cisneros, N. T., Aburto-Oropeza, O., & Ezcurra, E. (2016). Small-scale fisheries of lagoon estuarine complexes in Northwest Mexico. *Tropical Conservation Science, 9*(1), 78–134. http://dx.doi.org/10.1177/194008291600900106.
Ruiz-Fernández, A. C., Sanchez-Cabeza, J. A., Serrato de la Peña, J. L., Perez-Bernal, L. H., Cearreta, A., Flores-Verdugo, F., ... Diaz-Asencio, M. (2016). Accretion rates in coastal wetlands of the southeastern Gulf of California and their relationship with sea level rise. *The Holocene, 26*(7), 1126–1137. http://dx.doi.org/10.1177/0959683616632882.
Saied, M., & Elloumi, M. J. (2007). *Prise en compte des besoins écologiques de l'Ichkeul dans la Gestion de l'eau en Tunisie. Gestion de la demande en eau en Méditerranée, progrès et politiques*.
Sakka Hlaili, A., Grami, B., Hadj Mabrouk, H., Gosselin, M., & Hamel, D. (2007). Phytoplancton growth and microzooplanton grazing rates in a restricted Mediterranean lagoon (Bizerte lagoon, Tunisia). *Marine Biology, 151*, 767–783. http://dx.doi.org/10.1007/s00227-006-0522-y.
Salon, S., Cossarini, G., Libralato, S., Gao, X., Solidoro, C., & Giorgi, F. (2008). Downscaling experiment for the Venice lagoon. I. Validation of the present-day precipitation climatology. *Climate Research, 38*(1), 31–41.
Sandifer, P. A., Sutton-Grier, A. E., & Ward, B. P. (2015). Exploring connections among nature, biodiversity, ecosystem services, and human health and well-being: Opportunities to enhance health and biodiversity conservation. *Ecosystem Services, 12*, 1–15.
Schernewski, G., & Dolch, T. (Eds.). (2004). *The Oder Estuary against the background of the European water framework directive* (pp. 302). Warnemün: Institut für Ostseeforschung.
Schiewer, U. (2008). Darss-Zingst Bodden, Noorthern Rügener Bodden and Schlei. In U. Schiewer (Vol. Ed.), *Ecology of Baltic coastal waters series. Ecological studies: 197*, (pp. 35–81). Berlin: Springer. http://dx.doi.org/10.1007/978-3-540-73524-3_5.
Solidoro, C., Bandelj, V., Bernardi Aubry, F., Camatti, E., Ciavatta, S., Cossarini, G., ... Torricelli, P. (2010). Response of Venice lagoon ecosystem to natural and anthropogenic pressures over the last 50 years. In H. Paerl, & M. Kennish (Eds.). *Coastal Lagoons: Systems of natural and anthropogenic change. Marine science book series* (pp. 483). Taylor and Francis CRC press.
Solidoro, C., Cossarini, G., Libralalto, S., & Salon, S. (2010). Remarks on the redefinition of system boundaries and model parametrization for downscaling experiments. *Progress in Oceanography, 84*, 134–137.
Souchu, P., Gasc, A., Collos, Y., Vaquer, A., Tournier, H., Bibent, B., ... Deslous-Paoli, J.-M. (1998). Biogeochemical aspects of bottom anoxia in a Mediterranean lagoon (Thau, France). *Marine Ecological Progress Series, 164*, 135–146. http://dx.doi.org/10.3354/meps164135.
Sousa, L. P., Lillebø, A. I., Gooch, G. D., Soares, J. A., & Alves, F. L. (2013). Incorporation of local knowledge in the identification of Ria de Aveiro Lagoon ecosystem services (Portugal). *Journal of Coastal Research, 65*, 1051–1056.
Sousa, L. P., Sousa, A. I., Alves, F. L., & Lillebø, A. I. (2016). Ecosystem services provided by a complex coastal region: Challenges of classification and mapping. *Scientific Reports, 6*, 22782. http://dx.doi.org/10.1038/srep22782.
Sousa, A. I., Santos, D. B., Ferreira da Silva, E., Sousa, L. P., Cleary, D. F. R., Soares, A. M. V. M., ... Lillebø, A. I. (2017). 'Blue Carbon' and nutrient stocks of salt marshes at a temperate coastal lagoon (Ria De Aveiro, Portugal). *Scientific Reports, 7*, 41225. http://dx.doi.org/10.1038/srep41225.
Souza, M., Kjerfve, B., Knoppers, B., de Souza, W., & Damasceno, R. (2003). Nutrient budgets and trophic state in a hypersaline coastal lagoon: Lagoa de Araruama, Brazil. *Estuarine, Coastal and Shelf Science, 57*, 843–858.
Stybel, N., Kleissler, K., Schulz, N., & Piotr, G. (2014). Fisheries management in the Szczecin Lagoon. In N. Stybel, & M. Skor (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.
Taminskas, J., Pileckas, M., Šimanauskienė, R., & Linkevičienė, R. (2012). Wetland classification and inventory in Lithuania. *Baltica, 25*, 33–44.
Tamisier, A., & Boudouresque, C. (1994). Aquatic bird populations as possible indicators of seasonal nutrient flow at Ichkeul Lake, Tunisia. In J. J. Kerekes (Vol. Ed.), *Aquatic birds in the trophic web of lakes. Hydrobiologia: 279/280*, (pp. 149–156). Belgium: Kluwer. http://dx.doi.org/10.1007/BF00027849.
TEEB - Economics of Ecosystems and Biodiversity (2010). *Mainstreaming the economics of nature: A synthesis of the approach, conclusions and recommendations of TEEB.* London and Washington: Earthscan.
Thompson, J. R., & Flower, R. J. (2009). Environmental science and management of coastal lagoons in the Southern Mediterranean Region: Key issues revealed by the MELMARINA project. *Hydrobiologia, 622*, 221–232. http://dx.doi.org/10.1007/s10750-008-9675-7.
Torres, F., Catalina, M., & Hanley, N. (2016). *Economic valuation of coastal and marine ecosystem services in the 21st century: An overview from a management perspective. No 2016-01. Discussion papers in environment and development economics*. University of St. Andrews, School of Geography and Sustainable Developmenthttps://EconPapers.repec.org/RePEcsss:wpaper:2016-01.
Trabelsi, Y., Gharbi, F., El Ghali, A., Oueslati, M., Samaali, M., Abdelli, W., ... Abril José, M. (2012). Recent sedimentation rates in Garaet El Ichkeul Lake, NW Tunisia, as affected by the construction of dams and a regulatory sluice. *Journal of Soils and Sediments, 12*, 784–796. http://dx.doi.org/10.1007/s11368-012-0496-y.
Tran, K. C., Valdes, D., Euan, J., Real, E., & Gil, E. (2002). Status of water quality at Holbox Island, Quintana Roo State, Mexico. *Aquatic Ecosystem Health & Management, 5*(2), 173–189. http://dx.doi.org/10.1080/14634980290031875.
Tuchkovenko, Y. S., Bogatova, Y. I., & Tuchkovenko, O. A. (2015a). Hydrochemical regime of Tyligulskiy Liman in modern period. *Vìsn. Odes. Derž. Ekol. Unìv, 19*, 126–133. (in Russian) http://bulletin.odeku.edu.ua/en/category/2015-en-2/19-en/.
Tuchkovenko, Y. S., Kushnir, D. V., & Loboda, N. S. (2015b). Estimation of the influence of water exchange with the sea conditions on the water level and salinity variability in the Tyligulskyi Liman lagoon. *Ukr. Gydrometeorol. Ž. 16*, 232–241. (in Russian) http://uhmj.odeku.edu.ua/en/category/2015-en/16-en/.
Tuchkovenko, Y., Loboda, N., & Khokhlov, V. (2015c). The physio-geographical background and ecology of Tyligulskyi Liman Lagoon. In A. I. Lillebø, P. Stålnacke, & G. D. Gooch (Eds.). *Coastal Lagoons in Europe: Integrated water resource strategies* (pp. 77–85). London: IWA Publishing.
Tuchkovenko, Y. S., & Loboda, N. S. (Eds.). (2014). *Water resources and hydroecological conditions of the Tyligulskyi Liman Lagoon*Odessa: Odessa State Environmental University.
Turner, R. K., & Daily, G. C. (2008). The ecosystem services framework and natural capital conservation. *Environmental and Resource Economics, 39*(1), 25–35.
Turpie, J. K., Forsythe, K., & Letley, G. (2017). *Classification of and resource quality objectives for the water resources of the Berg Water Management. Component 4: Socio-economics. Report to Aurecon on behalf of the Department and Water Sanitation* Republic of South Africa.
UNEP – United Nations Environment Programme (1999). *Planning and management of heavily contaminated bays and coastal areas in the wider Caribbean. Final report. GEF-UNEP-UNOPS regional project RLA/93/G41, 104*, pp.
Velasco, A. M., Pérez-Ruzafa, A., Martínez-Paz, J. M., & Marcos, C. (2017). Ecosystem services and main environmental risks in a coastal lagoon (Mar Menor, Murcia, se Spain): The perception of stakeholders. *Journal for Nature Conservation* in press.
Vo, Q. T., Kuenzer, C., Vo, Q. M., Moder, F., & Oppelt, N. (2012). Review of valuation methods for mangrove ecosystem services. *Ecological Indicators, 23*, 431–446.
Willaert, T. O. M. (2014). *Valuation of marine and coastal ecosystems: The role of ecological-economic modeling*.

Winkler, H. (2001). Fischgemeinschaften und Fischerei in den Darß-Zingster Bodden. In H. Benke (Ed.). *Die Darß-Zingster Bodden. Monographie einer einzigartigen küstenlandschaft. Meer und Museum. Bd 16* (pp. 76–84). Stralsund: Deutsches Meeresmuseum.

Wolnomiejski, N., & Witek, Z. (2013). The Szczecin Lagoon ecosystem: The biotic community of the Great Lagoon and its food web model. *Versita London*. http://dx.doi.org/10.2478/9788376560502.

Yamamuro, M. (2000). Chemical tracers of sediment organic matter origins in two coastal lagoons. *Journal of Marine Systems, 26*, 127–134.

Yamamuro, M., Hiratsuka, J.-I., Ishitobi, Y., Hosokawa, S., & Nakamura, Y. (2006). Ecosystem shift resulting from loss of eelgrass and other submerged aquatic vegetation in two estuarine lagoons, Lake Nakaumi and Lake Shinji, Japan. *Journal of Oceanography, 62*, 551–558.

Zourarah, B., Maanan, M., Carruesco, C., Aajjane, A., Mehdi, K., & Conceição Freitas, M. (2007). Fifty-year sedimentary record of heavy metal pollution in the lagoon of Oualidia (Moroccan Atlantic coast. *Estuarine, Coastal and Shelf Sciences, 72*, 359–369.

Alice Newton[a,b,*], Ana C. Brito[c,d], John D. Icely[b,t], Valérie Derolez[e], Inês Clara[c,d], Stewart Angus[f], Gerald Schernewski[g,h], Miguel Inácio[g,h], Ana I. Lillebø[i], Ana I. Sousa[i], Béchir Béjaoui[j], Cosimo Solidoro[k], Marko Tosic[l], Miguel Cañedo-Argüelles[m,n], Masumi Yamamuro[o], Sofia Reizopoulou[p], Hsiao-Chun Tseng[b,q], Donata Canu[k], Leonilde Roselli[r], Mohamed Maanan[s], Sónia Cristina[b,t], Ana Carolina Ruiz-Fernández[u], Ricardo F. de Lima[v], Björn Kjerfve[w], Nadia Rubio-Cisneros[x], Angel Pérez-Ruzafa[y], Concepción Marcos[y], Roberto Pastres[z], Fabio Pranovi[z], Maria Snoussi[A], Jane Turpie[B], Yurii Tuchkovenko[C], Brenda Dyack[D], Justin Brookes[E], Ramunas Povilanskas[h], Valeriy Khokhlov[C]

[a] *NILU – IMPACT, Box 100, 2027, Kjeller, Norway*
[b] *CIMA – Centro de Investigação Marinha e Ambiental, Universidade do Algarve, Campus de Gambelas, 8005-139, Faro, Portugal*
[c] *Departamento de Biologia Vegetal, Faculdade de Ciências, Universidade de Lisboa, Campo Grande, 1749-016, Lisboa, Portugal*
[d] *MARE – Centro de Ciências do Mar e do Ambiente, Faculdade de Ciências, Universidade de Lisboa, 1749-016, Lisboa, Portugal*
[e] *Ifremer – Laboratoire Environnement Ressources du Languedoc-Roussillon/MARBEC, Avenue Jean Monnet – CS, 30171 - 34203, Sète cedex, France*
[f] *Scottish Natural Heritage, Great Glen House, Leachkin Road, Inverness, IV3 8NW, United Kingdom*
[g] *Leibniz Institute for Baltic Sea Research Warnemünde (IOW), Seestrasse 15, D-18119, Rostock, Germany*
[h] *Klaipėda University, Herkaus Manto str., LT-92294, Klaipėda, Lithuania*
[i] *Department of Biology & CESAM – Centre for Environmental and Marine Studies, University of Aveiro, Campus Universitário de Santiago, 3810-193, Aveiro, Portugal*
[j] *Institut National des Sciences et Technologie de la Mer (INSTM), 28 rue 2 mars 1934, Carthage Salammbô 2025, Tunisie*
[k] *Istituto Nazionale di Oceanografia e di Geofisica Sperimentale – OGS, Borgo Grotta Gigante 42/c Sgonico, Italy*
[l] *EAFIT University, School of Sciences, Department of Earth Sciences, Carrera 49, #7S-50, A.A.3300, Medellín, Colombia*
[m] *Grup de Recerca Freshwater Ecology and Management (FEM), Departament d'Ecologia, Facultat de Biologia, Universitat de Barcelona (UB), Diagonal 643, 08028, Barcelona, Catalonia, Spain*
[n] *Aquatic Ecology Group, BETA Tecnio Centre, University of Vic, Central University of Catalonia, Vic, Catalonia, Spain*
[o] *Graduate School of Frontier Sciences, The University of Tokyo Environment Bldg 562, 5-1-5 Kashiwanoha, Kashiwa, 277-8563, Japan*
[p] *Hellenic Centre for Marine Research, Institute of Oceanography, Anavyssos 19013, Attiki, Greece*
[q] *UNESCO UNITWIN/WiCop, Physical Chemistry Department, Faculty of Marine and Environmental Sciences, Polígono río San Pedro s/n, University of Cadiz, 11519, Puerto Real, Cadiz, Spain*
[r] *Environmental Protection Agency of Puglia Region, Department of Lecce 73100 Lecce, Italy*
[s] *Laboratory of Littoral, Environment, Remote Sensing and Geomatic – Institute of Geography and Planning – University Nantes, France*
[t] *Sagremarisco, Apt 21, 8650-999, Vila do Bispo, Portugal*
[u] *Unidad Académica Mazatlán, Instituto de Ciencias del Mar y Limnología, Universidad Nacional Autónoma de México, Mazatlán, Sinaloa, Mexico*
[v] *Centre for Ecology and Environmental Changes and Departmento de Biologia Animal, Faculdade de Ciências, Universidade de Lisboa, Campo Grande, 1749-016, Lisboa, Portugal*
[w] *American University of Sharjah, University City, Sharjah, United Arab Emirates*
[x] *Centro de Investigación y de Estudios Avanzados (CINESTAV), Unidad Merida km 6 Antigua carretera a Progreso Apdo. 73, Cordemex, 97310, Mérida, Yucatán, Mexico*
[y] *Department of Ecology and Hydrology, University of Murcia, 30100, Murcia, Spain*
[z] *Ca' Foscari Unversity of Venic Campus Scientifico, via Torino 155, Venice, 30170, Italy*
[A] *Université Mohammed V, Faculté des Sciences, Rabat, Morocco*
[B] *Environmental-Economics Policy Research Unit, School of Economics, University of Cape Town, Private Bag, Rondebosch, Cape Town, 7700, South Africa*
[C] *Department of Oceanology and Marine Nature Management, Lvivska str. 15, 65016, Odessa State Environmental University, Odessa, Ukraine*
[D] *Institute for Applied Ecology, University of Canberra, Canberra, ACT, 2617, Australia*
[E] *Department of Ecology and Environmental Science, The University of Adelaide, Australia*
E-mail address: anewton@ualg.pt

* Corresponding author at: NILU-IMPACT, Box 100, 2027 Kjeller, Norway.