Journal of Ocean and Coastal Economics

Volume 10 | Issue 1 Article 2

June 2023

Ecosystem Service Valuation of Blue Carbon Habitats: A Review for Saltmarshes and Seagrasses

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Recommended Citation

Doolan, Geraldine and Hynes, Stephen (2023) "Ecosystem Service Valuation of Blue Carbon Habitats: A Review for Saltmarshes and Seagrasses," *Journal of Ocean and Coastal Economics*: Vol. 10: Iss. 1, Article 2.
DOI: https://doi.org/10.15351/2373-8456.1174

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Acknowledgments

This research is an output of the BlueC project which is carried out with the support of the Marine Institute and the Environmental Protection Agency, funded by the Irish Government.

1. INTRODUCTION

In the past 150 years, atmospheric CO_2 concentrations have risen to levels that have not been experienced in at least 2 million years (Arias *et al*. 2021). Along with increasing concentrations of other greenhouse gases, this has led to significant increases in global mean temperatures (Dusenge *et al*. 2019). This human-induced climate change has been observed to cause widespread loss and damage to nature and people (Arias *et al*. 2021). Adverse socio-economic impacts are broad ranging and include reduced agricultural yields and economic production, increased risk of violent conflict and crime, and higher mortality rates (Carleton and Hsiang 2016). Recognition of the risks posed by climate change is reflected by the Paris Climate Agreement commitment to hold "the increase in the global average temperature to well below 2°C above pre-industrial levels" (UNFCCC 2015). This requires not only reducing emissions from human activities, but also large-scale CO_2 removal methods (Smith *et al*. 2016).

Improved land and ocean stewardship is the most mature and relatively low cost means of CO_2 removal, and provides co-benefits of improving habitat quality and biodiversity (Field and Mach 2017). These methods include reforestation, afforestation, and coastal restoration . Marine and coastal restoration is less developed relative to terrestrial restoration (Saunders *et al*. 2020), yet oceans and coastal marine ecosystems play a significant role in the global carbon cycle as a long-term carbon sink. Vegetated coastal habitats such as seagrass, saltmarsh and mangroves are estimated to account for 50% of carbon storage in marine sediments, despite occupying less than 2% of the ocean (Duarte *et al*. 2005). However, these ecosystems are being degraded 5-10 times faster than rainforests (Nellemann and Corcoran 2009). This not only compromises their ability to act as carbon sinks but can result in carbon being released back into the atmosphere (Cott *et al*. 2021).

"Blue carbon" is a term that was introduced by the United Nations Environment Programme (UNEP) and the International Union for Conservation of Nature (IUCN) in 2009 to describe the carbon stored in these ecosystems (Nellemann and Corcoran 2009). The specific definition of "blue carbon ecosystems" refers to mangrove forests, saltmarsh, seagrass meadows and tidal freshwater forests (Blue Carbon Initiative 2015). International policy mechanisms such as the Convention on Biological Diversity (Aichi Target 11 and 15); the UN Sustainable Development

Goals (SDGs 13 and 14); the European Green Deal and the EU Biodiversity Strategy 2030 all increase pressure to appropriately manage these ecosystems.

Blue carbon habitats are not only valuable for their carbon storage capabilities, but also for the range of ecosystem services they provide, including coastal protection and improving coastal water quality. However, restoring these ecosystems can be costly and will entail trade-offs with economic activity. To make effective and appropriate management decisions, these costs must be compared with the benefits provided by these ecosystems. Ecosystem services provided by blue carbon ecosystems (BCEs) should therefore be defined and quantified in order to understand their socio-economic value and to inform policy decisions in relation to carbon emission reduction policies and environmental conservation and restoration efforts. The BlueC project, supported by the Marine Institute and the Environemental Protection Agency of Ireland, specifically aims to advance understanding of two particular BCEs; saltmarsh and seagrass. With that in mind this research carries out a global review of the literature of ecosystem service valuation related to saltmarsh and seagrass habitats.

1.1 Ecosystem Service Valuation

The modern use of the term ecosystem services (ES) began in the 1970s (Gómez-Baggethun *et al*. 2010), and was originally intended as a metaphor to communicate the benefits that humans receive from nature (Norgaard 2010). What we now refer to as ES have always existed, the term is simply a new way to describe the relationship between humans and nature. The concept gained recognition at the turn of the century with the publication of Costanza *et al.*'s global valuation of the world's ecosystems and natural capital (1997), and the Millennium Ecosystem Assessment (MEA) (MEA 2005). Since then, the ES literature has grown exponentially (Fisher *et al*. 2009). In the ES framework, the ecosystem is conceptualized as a fund or a stock of natural capital from which a range of services are drawn (Bateman *et al*. 2011; Farley 2012). It is often depicted as a cascade, and the services link the environmental system to the social and economic system (Haines-Young and Potschin 2010) (Figure 1). They are commonly split into four branches, called provisioning, regulating, cultural (or information) and supporting services (de Groot *et al*. 2002; MEA 2005). Provisioning services are often traded in markets, examples include timber and fish that are harvested from the forests and

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DOI: 10.15351/2373-8456.1174

seas. Regulating global temperatures through carbon sequestration or providing flood defense by slowing water flows are two examples of regulating services, which refer to the ways in which ecosystems moderate or mediate the environment that benefit humans. Cultural services are outputs that allow us to have a relationship with nature in recreational, spiritual, aesthetic or educational ways. Finally, supporting services are the processes that underpin the other services. Primary production and soil formation are examples. Provisioning, regulating and cultural services are known as final ES, while supporting can also be known as intermediate. As this framework only accounts for the ways in which nature impacts human well-being, it is inherently anthropocentric (Bateman *et al*. 2011). While nature can and does have an intrinsic value apart from the value associated with the impact on human well-being, impact on well-being is measurable in economic terms and the ES framework only addresses these values.

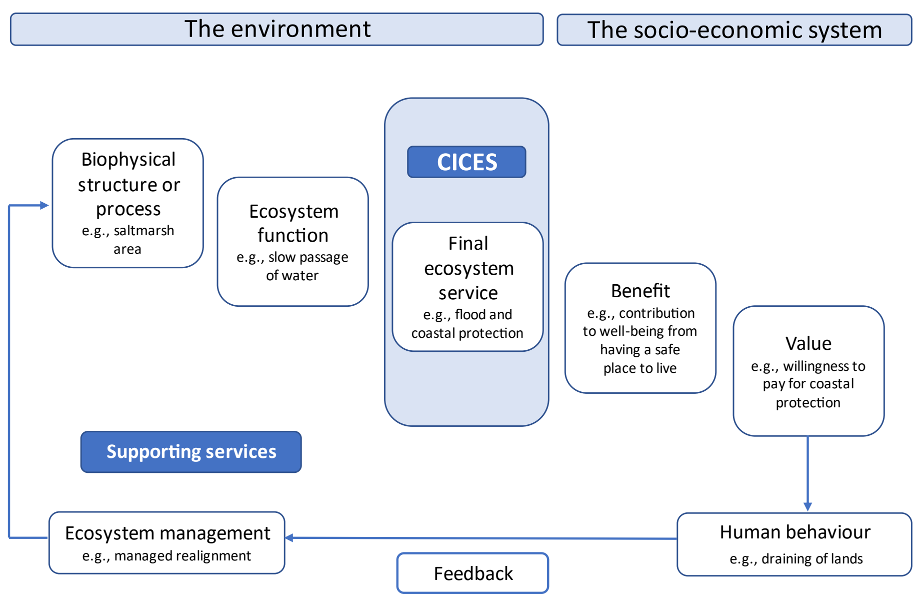

Figure 1. The Ecosystem Services Cascade, adapted from Potschin and Haines-Young (2016)

A common classification system is necessary to be able to meaningfully discuss and compare ES. The classification developed by The Economics of Ecosystems and Biodiversity (TEEB) is an early example of this (Van der Ploeg *et al*. 2010). A more recent system is the Common International Classification of Ecosystem Services (CICES). It was developed as part of work on the System of Environmental-Economic Accounting (SEEA) led by the United Nations Statistical Division (Haines-Young and Potschin 2018). The system is endorsed by the European Commission (Campagne *et al*. 2015) and will be used to classify ES here. The first version was published in 2013. Version 5.1. is the latest iteration and it was published in 2018 (Haines-Young and Potschin 2018). While earlier works such as the MEA described ES as the benefits people receive from ecosystems (MEA 2005), CICES defines them as the contributions ecosystems make to human well-being, distinct from the goods and benefits that are derived from them (Haines-Young and Potschin 2018). For example, seagrasses purify coastal waters – the contribution – which leads to reduced risk of illness or disease – the benefit. Therefore, in this classification, services are defined in terms of "what ecosystems do" (Haines-Young and Potschin 2018). In CICES and commonly in valuations to avoid double counting, only provisioning, regulating and cultural services are included (Haines-Young and Potschin 2018). As supporting services form the building blocks for all final services, including them in valuations would lead to inflated figures.

Since the publication of the MEA, the focus in the literature has increasingly fallen on the economic valuation of ES – or ecosystem service valuation (ESV) (Fisher *et al*. 2009; Gómez-Baggethun and Ruiz-Pérez 2011). Valuations of entire ecosystems can be an important tool in natural capital accounting and sustainable development, as maintaining natural capital stocks is essential for sustainable development and ensuring future provision of ES (Guerry *et al*. 2015) . However, as ES are flows, ESV should assess how marginal changes in service provision (flows) impact human well-being. This requires ecological understanding of how external changes will affect ecosystems, and how these changes in stock will vary the level of ES provision (Bateman *et al*. 2011) . Provisioning services are often traded in markets, so assigning a value to these services can be less complex. However, regulating and cultural services provide non-market benefits, and thus require non-market valuation.

ESV and non-market valuation has become a requirement in some policy areas (Hanley *et al*. 2015). As an example, the EU Water Framework Directive (WFD) allows states to extend the deadline for achieving good ecological status if it is "disproportionately expensive" (European Commission 2000). This is also the case for the European Marine Strategy Framework Directive and the Maritime Spatial

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Planning Directive (Milon and Alvarez 2019). Good ecological status is not something that can be bought and sold on the market, so to ascertain whether achieving it is too costly, non-market valuation of the benefits associated with good ecological status is required (Hanley *et al*. 2015). Although ESV rhetoric is present in policy, the extent to which it has an influencing role rather than an informing one is questionable (Milon and Alvarez 2019). Part of the reason for this may be the observed gap between academic ESV research and policy applicable data and results (Olander *et al*. 2017). Non-market valuation methods have been in existence since the 1970s (Hanley *et al*. 2015), and commonly used methods for ESV can be found in Table 1. It has been noted that these methods, while established in academia, can be resource and data intensive and not always understood by stakeholders, which can limit their applicability in the policy-making realm (Olander *et al*. 2017).

Table 1. Common methods used for ecosystem service valuation

Method	Overview	BCE ES that can be valued
Adjusted market prices	Market prices adjusted for distortions	Contribution of saltmarsh to agriculture through grazing, e.g., saltmarsh-fed lamb (CICES 1.1.3.1 animals reared for nutritional purposes)
Production function	Estimates of production functions to isolate the impact of the ES as an input	Contribution of seagrass and saltmarsh to commercial fisheries (CICES 1.1.6.1 wild animals used for nutritional purposes)
Damage cost avoided	Costs avoided by the presence of ecosystems	Role of saltmarsh in coastal protection (CICES 2.2.1.3 hydrological cycle and water flow regulation)
Replacement cost	Cost of artificial substitutes for environmental goods or services	Contribution of seagrass to bio-remediation of coastal waters (CICES 2.1.1.1 bio-remediation by micro-organisms, algae, plants and animals)
Revealed preference	Examines expenditure on ecosystem related goods, e.g., travel costs for recreation, hedonic modelling with house prices for aesthetic properties	Birdwatching on saltmarshes (CICES 3.1.1.1 characteristics of living systems that enable activities promoting health, recuperation or enjoyment through active or immersive interactions)
Stated preference	Contingent valuation or choice modelling, using surveys to	Non-use or use value of seagrass and saltmarsh (CICES 3.1.2.3

	estimate willingness to pay (WTP) or willingness to accept (WTA) changes in ES provision	characteristics of living systems that are resonant in terms of culture and heritage)

Adapted from Barbier 1997, Bateman 2011.

The ES approach is not without its criticisms. The lack of ecological data and understanding of the link between ecosystem functions and services, especially for marine and coastal ecosystems, has been cited as an impediment to producing meaningful valuations (Hanley *et al*. 2015; Norgaard 2010). Safe ecological thresholds are often unknown, and there can be disagreement between ecologists about what will trigger tipping points such as species extinction (Norgaard 2010). The ability to predict smaller changes is not guaranteed, yet it is often what is required of valuation studies which attempt to value marginal changes. In the face of ecological thresholds and the possible existence of some level of critical natural capital below which human welfare will be drastically reduced, there is a question to be answered about whether such incremental analysis is appropriate (Farley 2012). At the other end of the cascade, some concerns have been raised that well-being in the ES framework does not reflect the more holistic concepts of well-being that have been developed in recent years, as the focus remains on monetary units and number of beneficiaries (Rendón *et al*. 2019).

A further concern is that ESV is a step that may lead to the commodification of nature by incorporating ecosystem services into the market through monetization, appropriation – which often means privatization – and commercialization (Gómez-Baggethun and Ruiz-Pérez 2011). Practitioners have maintained that ESV is not intended to commodify nature, rather to make transparent the implicit trade-offs that humans already make in terms of ecosystem services (Costanza *et al*. 2014; de Groot *et al*. 2012). However, the prevailing socio-political processes and institutions in place since the 1980s and the enthusiasm for market-based solutions will influence how these valuations are used (Gómez-Baggethun *et al*. 2010; Gómez-Baggethun and Ruiz-Pérez 2011).

Ethical arguments aside, other critiques have focused on the policy relevance of ESV. Firstly, the uncertainty inherent in ESV and the range of possible values and valuation approaches may weaken arguments for conservation policies against developments with certain monetary benefits (D. King 1998). Secondly, even when links between function and service are known, studies are often based on a small site and selection of services, which can make application to broader policy

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impractical (Milon and Alvarez 2019). Publication pressures may incentivize novelty and precision, resulting in papers that may be of little benefit to decision-makers due to their complexity and scale (Olander *et al*. 2017). The complexities of ESV are too extensive to discuss in their entirety here, for further information on the debates surrounding ESV, see Farley (2012), Gómez-Baggethun *et al*. (2010) and Norgaard (2010), and for a discussion on the current state of ESV in marine policymaking, see Hanley *et al*. (2015) and Tinch *et al*. (2021).

1.2 Blue Carbon Ecosystems

Oceans and coastal ecosystems play a significant role in the global carbon cycle, as marine living organisms capture over half of the carbon that is sequestered globally (Nellemann and Corcoran 2009). "Blue carbon" describes the carbon that is captured and stored by the oceans and, in particular, stored by vegetated coastal habitats (Nellemann and Corcoran 2009). Blue carbon ecosystems (BCEs) such as seagrasses, saltmarshes and mangroves cover less than 0.5% of the seabed, yet may account for up to 71% of all carbon storage in ocean sediments (Nellemann and Corcoran 2009). The capacity of BCEs to act as a carbon sink is however being threatened by degradation (Cott *et al*. 2021; Nellemann and Corcoran 2009). Research and management strategies are urgently needed to conserve these resources globally to combat both climate change and the biodiversity crisis.

1.2.1 Seagrasses

Seagrasses are marine flowering plants (angiosperms) found in shallow coastal waters on all continents expect Antarctica (Short and Green 2003). Modelled estimates of the global extent of seagrass range from 300,000 km^2 (Duarte *et al*. 2005) to 1,646,788 km^2 (Jayathilake and Costello 2018). A 2020 study stated that between 160,387 km^2 and 212,562 km^2 of seagrass were mapped globally (McKenzie *et al*.). Difficulties with mapping and a paucity of data for bioregions in the developing world make estimates of their true extent challenging (McKenzie *et al*. 2020).

Seagrasses can sequester carbon and store significant amounts in the sediment and soils beneath them (de los Santos *et al*. 2020; Duarte 2017; Fourqurean *et al*. 2012). They are also an important nursery habitat, which contributes to commercial and recreational fisheries (Nordlund *et al*. 2018). Through dampening wave movement (wave attenuation) and sediment stabilization, they protect the coast (Newell and Koch 2004; Paul and Amos 2011). Seagrasses remove nutrients and pollutants from the water by filtering, cycling, and storing them (de los Santos *et al*. 2020), which is one of their most valuable services (Costanza *et al*. 1997). Seagrass is often used in research and especially as a bioindicator (Govers *et al*. 2014), and there is potential to use seagrass wrack as a source of bioenergy (Balata and Tola 2018). Historically, it has been used as an insulation material, as medicine, and as a fertilizer (de la Torre-Castro and Ronnback 2004; Fernández *et al*. 2022; Wyllie-Echeverria and Cox 1999). In Europe, seagrass was harvested for use as a fertilizer up until the late 20th century (Santos and Duarte 1991), and there continues to be interest in the use of seagrass as an organic fertilizer around the world (Grassi *et al*. 2015; Emadodin *et al*. 2020)

Despite providing valuable services that impact human well-being, seagrasses are still threatened by water quality degradation, coastal development, and eutrophication (Duarte 2002; Dunic *et al*. 2021). These and other human associated impacts can alter food webs and contribute to further degradation (Fredriksen *et al*. 2004). As a result, seagrasses are in decline globally. It is estimated that 29% of seagrass coverage has been lost since the first known mapping (de los Santos *et al*. 2019). Previously it was found that seagrasses were disappearing at a rate of 110 km^2 per year since 1980 (Waycott *et al*. 2009), while a more recent study found that declining trends have stabilized and are recovering in some bioregions (Dunic *et al*. 2021). However, persistent declines of around 1-2% were still found in individual meadows, which raises concerns about the long-term viability of these ecosystems (Dunic *et al*. 2021). The most recent study measuring seagrass trends in Europe found that decadal loss peaked in the 1970s and has since been declining (de los Santos *et al*. 2019).

Alarm bells and calls for increased monitoring, modelling and education efforts for seagrass have been sounding since the early 2000s (Duarte 2002; Orth *et al*. 2006). A Web of Science search for publications that refer to seagrass returns over 14,000 results, 62% of which have been published in since 2010, indicating that research is increasing (Figure 2). However, difficulties remain. Large areas of seagrass remain unmapped, hindering monitoring efforts (McKenzie *et al*. 2020). Models are improving, yet there is still a lack of knowledge about the dynamics of their most well-known service – blue carbon (Unsworth *et al*. 2022). There have been efforts in Europe to educate the public about seagrass - see Barracosa *et al*.

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(2019); Portugal (2018) - yet public perception of seagrass services is assumed to be low, and has been found to be so even among frequent users of these ecosystems (Barañano *et al*. 2022; Losciale *et al*. 2022).

1.2.2 Saltmarshes

Saltmarshes are coastal ecosystems found in the intertidal zone that are regularly flooded with salt or brackish water (Weis *et al*. 2016). They are found on every continent except for Antarctica, and are more commonly situated in middle to high latitudes (Weis *et al*. 2016). It has been estimated that they occupy 22,000 – 400,000 km^2 around the globe (Pendleton *et al*. 2012), yet a 2017 study puts the total global mapped saltmarsh area at 54,950 km^2 across 99 countries (McOwen *et al*.). Saltmarshes are highly productive ecosystems (Deegan *et al*. 2012; Gedan *et al*. 2009; Wilson and Koutsagiannopolou 2014), characterized by the presence of salt-tolerant plants, herbs and low shrubs (Weis *et al*. 2016).

Saltmarshes are a key BCE, acting as significant carbon sinks and providing sequestration services (Ribeiro *et al*. 2010; Weis *et al*. 2016). While blue carbon has recently been the focus of saltmarsh research efforts (Burke *et al*. 2021; Penk and Perrin 2022; McMahon *et al*. 2023), they also provide many other services. Saltmarsh edges are an important nursery habitat, which contributes to the health of recreational and commercial fisheries (Voltaire *et al*. 2017; Wilson and Koutsagiannopolou 2014). Saltmarshes protect the coast from hydrological disturbances and erosion (Gedan *et al*. 2010; S.E. King and Lester 1995; Liu *et al*. 2019; Weis *et al*. 2016). The creation and restoration of saltmarshes by inundation of previously dry or reclaimed land - a process known as managed realignment in the UK - is seen as a sustainable coastal defense option (Jones *et al*. 2011; Luisetti *et al*. 2011). They also regulate nitrogen levels (Alldred and Baines 2016; S.C.L. Watson *et al*. 2020), thereby controlling water quality (Breaux *et al*. 1995; Kazmierczak 2001). They are sites of recreational hunting, fishing, birdwatching and walking (Jones *et al*. 2011; Lewis 2019; McKinley *et al*. 2022). Traditionally and to the present day they have been used as grazing sites for ruminants (Curtis 2003; Davidson *et al*. 2017; McKinley *et al*. 2022). Historically, saltmarsh plants have been used as a raw material for insulation, fertilizers, and ornamental uses (Curtis 2003; Gedan *et al*. 2009).

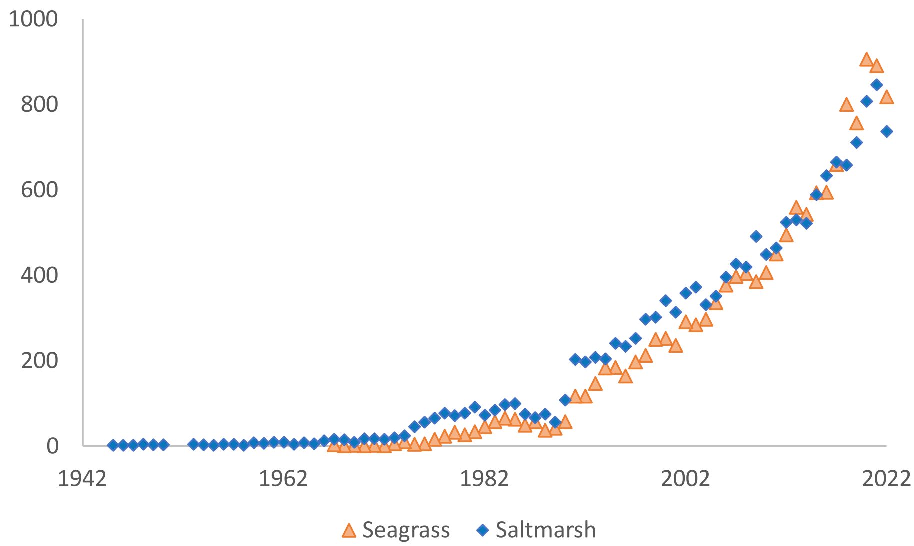

Figure 2: Number of references to saltmarsh and seagrass in web of science publications

As with many coastal ecosystems, saltmarshes are in decline, at an estimated rate of 1 - 2% per annum (McLeod *et al*. 2011). Large swathes of saltmarshes have been lost in previous centuries as the land was converted for agricultural or urban use (Gedan *et al*. 2009). In the southeast of Ireland for example, embankment and agricultural reclamation reduced much of the original saltmarsh area (Curtis and Sheehy Skeffington 1998). Where saltmarshes are used as grazing sites, inefficient grazing regimes can reduce the level of associated services (Curtis and Sheehy Skeffington 1998; Davidson *et al*. 2017). Land reclamation and dredging, particularly for coastal development, remains a threat (Gedan *et al*. 2009; Weis *et al*. 2016). Other human associated threats include eutrophication, hydromodification and sea level rise (Horton *et al*. 2018; Weis *et al*. 2016). Research on saltmarshes began earlier than seagrasses. The first publication referencing saltmarshes on the Web of Science is from 1945, and there are over 16,000 studies referencing saltmarsh since then (Figure 2). However, in recent years, the number of references to seagrass has been slightly higher.

2. LITERATURE REVIEW METHODOLOGY

A review of existing literature on seagrass and saltmarsh ESV was conducted following the systematic method described in Pickering and Byrne (2014) and the

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literature selection guidelines in Moher *et al*. (2010). A database of economic valuation studies of saltmarsh and seagrass ES was constructed. Both primary studies and those using benefit transfer methods were included. Meta-analyses on their own were not included, but when they were identified in the search, the literature incorporated into the analyses was extracted and considered for inclusion.

Searches with variations of the terms: "valuation," "seagrass" and "saltmarsh" were conducted in Science Direct, Ebsco and Google Scholar. This returned 3,567 studies. Abstracts and key words were scanned to narrow the selection, which reduced the total to 294. Global ESV databases have previously been developed, and these were also consulted. The TEEB database was published in 2010 and contains 1,310 value estimates from 267 studies (Van der Ploeg *et al*. 2010). This contributed to the Ecosystem Services Valuation Database (ESVD), by the Foundation for Sustainable Development, which is being continuously updated. Currently it contains 6,700 value records from over 950 studies (Foundation for Sustainable Development 2021). The Canadian Government maintains the Environmental Valuation Reference Inventory (EVRI), which collates studies of the economic values of environmental assets (Environment and Climate Change Canada 2022). After papers from the systematic review and the existing databases were gathered, duplicates were removed, and the full text was accessed and assessed for inclusion in the final database (Figure 3).

For each study, the full reference, location, socio-economic status of country, study area, geographical coordinates, condition, protected status, type of ecosystem, service valued, original value (including currency and year), method of valuation, and data type and source were added to the database. When the geographical coordinates were not included in the study, they were estimated using the place names with Google Maps. The socio-economic status of the country followed the classification of the UN World Economic Situations and Prospects Report (UN 2022). Study area, condition and protected status were not always included in the original paper. The services were classified according to the CICES class definition.

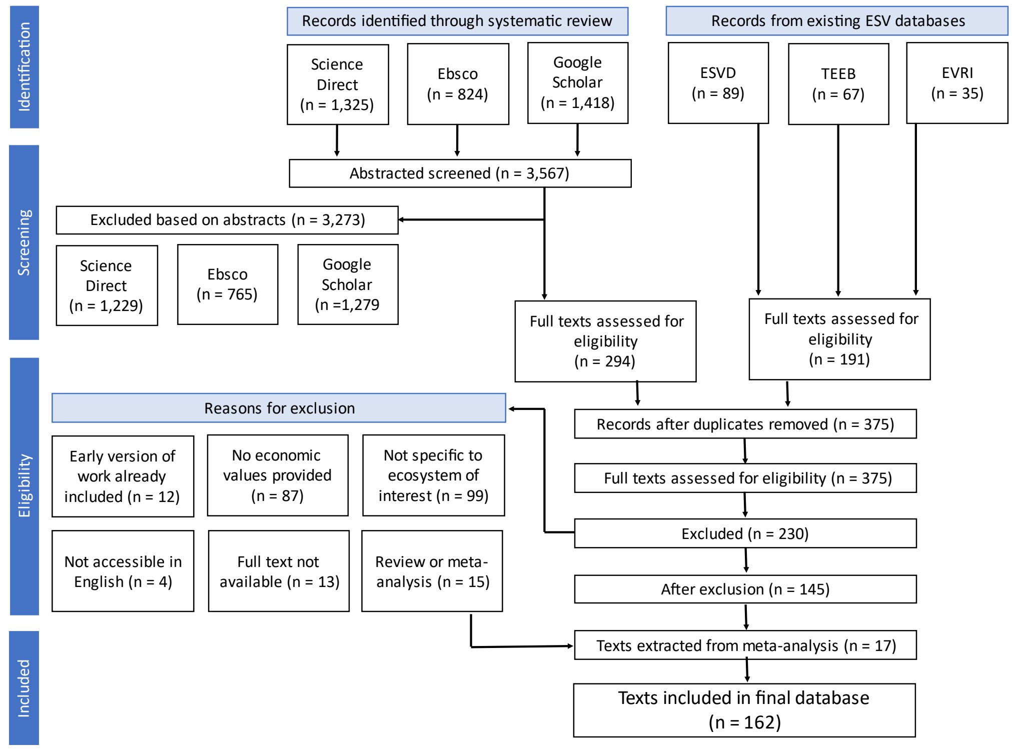

Figure 3. Literature collection following modified version of PRISMA (Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement) (Moher *et al*. 2010)

To enable comparison between values, monetary figures were standardized to 2018 international dollars by adjusting for purchasing power parity (PPP) and inflation, following Ghermandi *et al*. (2010). PPP indices and GDP deflators from the World Bank were used. The year 2018 was chosen as it was the year with the most studies published that was removed from influence of the distortion caused by COVID-19 and the inflation that has followed. When the currency year was not specified in the paper, it was presumed to be the year prior to publication, or the year of data collection in stated preference studies. If the original values were provided in a foreign currency, they were first converted to the currency of the country, unless they had already been adjusted for PPP. When exchange rates were provided in the paper, these were used to convert the values to the original currency, and where they weren't provided historical exchange rates from the World Bank were used. Some studies provided global values, or values for entire regions such as Europe. These values were not corrected for PPP as they were not country

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specific. GDP deflators at this scale are not available from the World Bank, but real and nominal GDP figures are available. These were used to construct global and regional GDP deflators.

Where possible, values were presented in a per hectare format, to allow for comparison. Some studies calculated marginal values, but many present average values per hectare. This implies a linear relationship between ecosystem extent and service provision, which may not always be the case (Milon and Alvarez 2019). Thus, while the per hectare values are presented for comparison, the original values are also available in the database. Values for stated preference studies could be presented in per hectare format if information was available on the extent of the ecosystem valued and the size of the population in question but this was not always provided in the study. Studies that undertook scenario analysis and provided net present values were standardized to present values in the same way as other figures. In most cases it was not possible to convert these values to an annual per hectare value, as the assumptions and prices applied in the scenarios changed year on year, and information on the original condition (extent especially) of the ecosystem was not always provided.

Standardizing the values to a common year and currency enables comparison across studies, but most of these values are specific to a time and place. While PPP and inflation have been accounted for, changes in the ecosystem extent and condition have not. For example, the per hectare value for nutrient cycling on a Louisiana saltmarsh may have been calculated in 1990. The 2018 international dollar value does not represent the present-day value of that service at that site, as in the intervening years, the value may have increased as service provision becomes scarce, or collapsed entirely if the saltmarsh has been degraded to an extent where it can no longer filter nutrients.

3. RESULTS

The final database included 162 studies with 736 associated value observations. Over half of the studies were retrieved through the systematic review searches. Many studies in the existing ESV databases had already been collected through the systematic review search, so fewer studies were added in this way. The most studies were found for seagrasses, which had 80 entries, compared to 58 for saltmarsh and 24 for studies valuing both seagrass and saltmarsh. Of the total studies, 81% were peer reviewed articles. The grey literature included government and consultancy reports, conference papers, four masters' theses, and one book. Peer reviewed articles made up 86% of the seagrass studies, 78% of the saltmarsh studies and 84% of the studies that valued seagrass and saltmarsh. The articles were published in 59 journals. *Ecosystem Services*, *Ocean and Coastal Management* and *Marine Pollution Bulletin* published the most seagrass articles, with six each. For saltmarsh studies, *Ecological Economics* and the *Journal of Environmental Management* published the most articles.

Table 2. Seagrass and saltmarsh valuation studies

	Seagrass	**Saltmarsh**	**Seagrass and Saltmarsh**	**Total**
Systematic Review	51	30	17	98
ESVD	14	6	0	20
EVRI	4	5	2	11
TEEB	4	12	0	16
Meta-analysis	7	5	5	17
Total	80	58	24	162

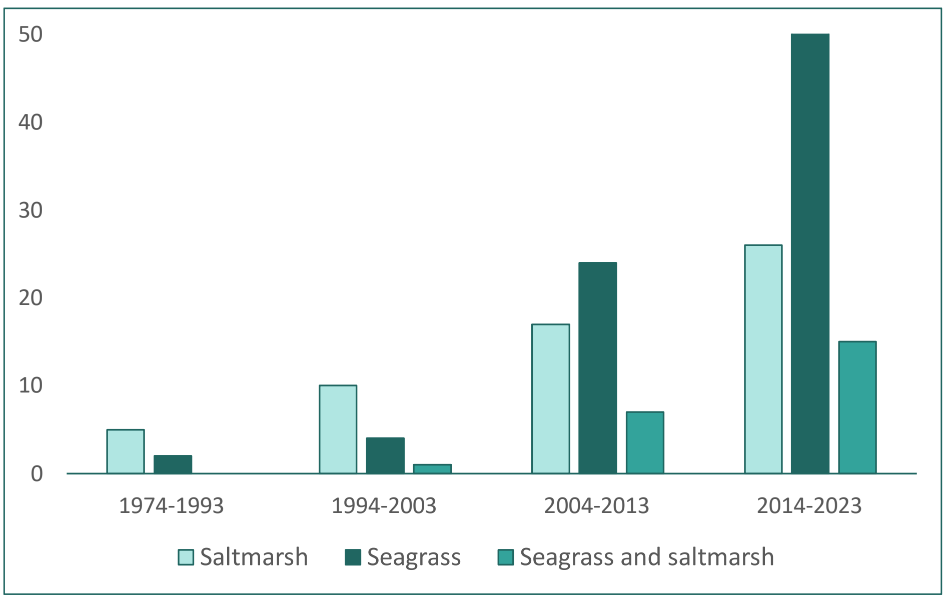

Figure 4. Number of valuation studies published over the years

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DOI: 10.15351/2373-8456.1174

The first seagrass valuation in this database is from 1989, although this is an outlier as only three more studies were published until the turn of the century. Most of the seagrass valuations (73%) were published from 2013 onwards. This is in line with the increase in scientific literature on seagrasses in the last decade referred to earlier. In order to value an ES, there needs to be sufficient ecological knowledge to estimate the impacts of a change in function of service provision (Bateman *et al*. 2011; Norgaard 2010). The first saltmarsh valuation was published in 1974, but only nine more were published up to the year 2000. The number of saltmarsh valuation studies has been steadily rising but has not increased as rapidly as seagrass studies have in the last 10 years. Over 60% of the ESV studies for both seagrass and saltmarsh have been published in the last 10 years.

3.1 Geographical Distribution

Figures 5 and 6 illustrate the location of seagrass and saltmarsh ES values found in this review. Some studies provided values for more than one location, and these are entered in the map separately. Data points that are inland represent studies that estimated values on a state-wide basis. Seagrass valuations are mainly located in Europe, Asia, and Oceania. Australia is the site of 20 studies. The United States follows with 8 valuations, yet Europe and Asia are the regions with the majority of seagrass valuation studies. The earliest Australian seagrass valuation study was published in 1993, but most of the studies are from after 2010. Australia is home to 31% of the worlds known mapped seagrass (McKenzie *et al*. 2020), which may explain the concentration of valuation studies there. Central and South America are underrepresented in the seagrass valuation literature, with the only study from Colombia (Zarate-Barrera and Maldonado 2015). This may be result of the studies being restricted to those published in the English language, but as there is a known lack of data on seagrass extent in this area (McKenzie *et al*. 2020), it is likely to be a further significant research gap. Africa is the site of seven seagrass studies. There is a known link across the continent between seagrass and coastal fisheries (de la Torre-Castro and Ronnback 2004; Musembi *et al*. 2019; Ochieng and Erftemeijer 2003), and two studies attempt to qualify this. One ambitious study attempted to quantify benefits for the nine large marine ecosystems on the continent (Trégarot *et al*. 2020).

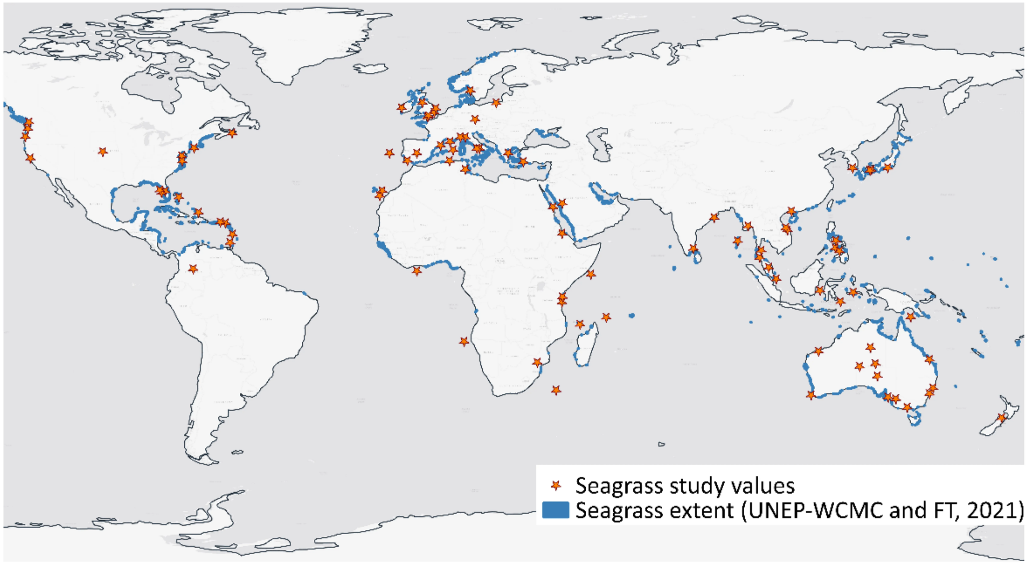

Figure 5. Geographical distribution of seagrass valuation studies. Data points inland indicate national or regional studies.

Saltmarsh valuations are overwhelmingly concentrated in the United States and the United Kingdom, with approximately 70% of the valuations found there. This is likely due to early recognition of the importance of coastal wetlands (Gosselink *et al*. 1974), and the national “No Net Loss” policy for wetlands in the US (Bauer *et al*. 2004). This policy requires that any development of wetlands must be offset by compensatory mitigation, i.e., the creation of new wetlands (Bauer *et al*. 2004). Economic values are often required to justify such developments (D. King 1998). These factors combined may be associated with the predominance of saltmarsh valuation studies in the US. In the UK, policy focus on managed realignment (Tinch and Ledoux 2006) may have stimulated interest in quantifying the benefits generated by saltmarshes. Africa and South America are not represented in the saltmarsh valuation literature. Similar to seagrass, mapping of saltmarsh extent in these regions is patchy and known to be missing large data points (McOwen *et al*. 2017), which likely contributes to the lack of saltmarsh valuations. It may also be the case that mangroves are more important wetland habitats in these regions as opposed to the North Atlantic region which is home to some of the largest areas of saltmarsh (McOwen *et al*. 2017).

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DOI: 10.15351/2373-8456.1174

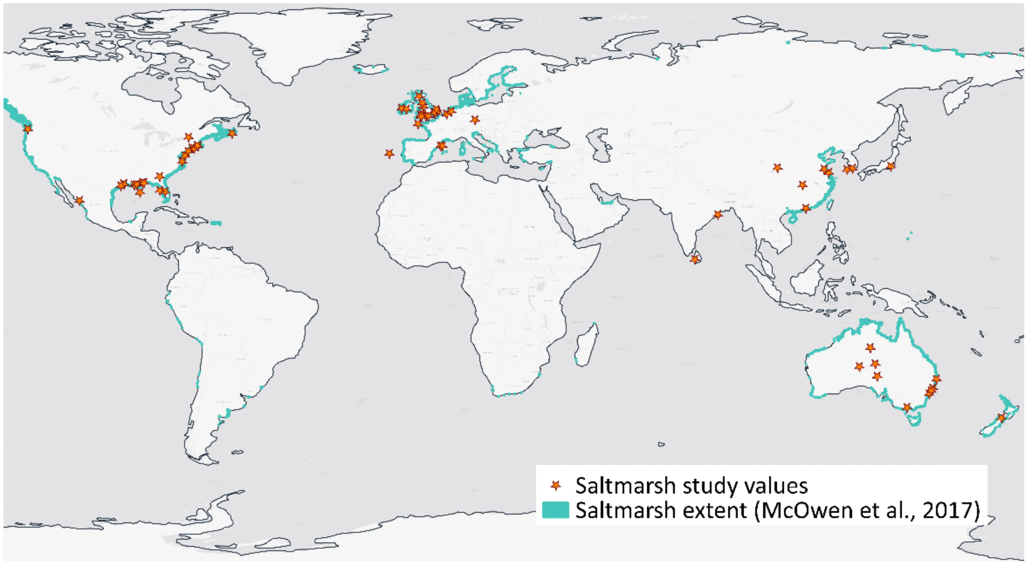

Figure 6. Geographical distribution of saltmarsh valuation studies. Data points inland indicate national or regional studies.

3.2 Blue Carbon

Regulation of the chemical composition of the atmosphere and oceans (CICES code 2.1.6.1; hereafter this ecosystem service will be referred to by numerical code alone) is the service associated with blue carbon and climate regulation. This is the most commonly studied service for seagrass, with 29 associated studies. A further 14 studies valued climate regulation for seagrass and saltmarsh habitats, and 14 for just saltmarsh. A summary of climate regulation values for saltmarsh and seagrass can be found in the Supplementary Materials, in Tables S1 and S2, respectively.

The most common way to measure the value of this service was to estimate rates of carbon sequestration and storage at a site and combine this with carbon prices. In some studies field samples of carbon were taken (Beaumont *et al*. 2014; Carnell *et al*. 2019; Ganguly *et al*. 2018; Green *et al*. 2018; Lavery *et al*. 2013; Luisetti *et al*. 2019), but in most cases sequestration rates were taken from the literature. The price used to value carbon varied from study to study, with most studies using estimates based on the Social Cost of Carbon (SCC) or market prices. The SCC is the discounted cost of future damages associated with emitting a ton of carbon today (Nordhaus 2017; Tol 2005). Carbon is also traded in markets, notably under the European Union Emissions Trading Scheme (EU ETS), and 12 studies used carbon market prices. Studies based in the UK often used the non-traded carbon values published by the UK Department of Business, Energy and Industrial Strategy (formerly published by the Department of Energy and Climate Change). These values are based on the cost of abatement and estimates are provided for up to the year 2100 (DECC 2011). Outside of the UK, other studies also based their prices on policy recommendations or national carbon tax rates, for example Campagne *et al*. (2015); Hynes, Norton, *et al*. (2013) and Wawo *et al*. (2014). In the papers found in this review, the lowest price used was US$2.93 tC^{-1} – based on the assumption that India's share of the global SCC is 9% - (Ganguly *et al*. 2018) and the highest was $312 tC^{-1} - presented as part of a range of values (Luisetti *et al*. 2013). Some studies presented a range of estimates based on different carbon prices (Luisetti *et al*. 2013; Luisetti *et al*. 2019; McHarg *et al*. 2022).

While sequestration rates are commonly used to value this service, using carbon stock as an indicator is also an option. Measuring carbon stocks can be seen as an overly simplistic proxy for the climate regulation service (Boerema *et al*. 2017), yet knowing the original value of the stock is important for calculating the loss of future benefits of carbon storage if habitat is destroyed. The value of the stock was presented in the context of these analyses in González-García *et al*. (2022); dos Santos (2018); Luisetti *et al*. (2013) and Montero-Hidalgo *et al*. (2023) yet it was also presented as a value for the climate regulation service on its own in Bañolas *et al*. (2020); de los Santos *et al*. (2020); Praisankul and Nabangchang-Srisawalak (2016) and Wawo *et al*. (2014). This can be misleading, as the value of the stock doesn't account for the continual benefits brought by sequestration. This was an issue observed in seagrass studies but not as often in saltmarsh studies. Most studies reported annual values for carbon sequestration, which showed variation as well. The range of values reported in the papers is found in Table 3. The value of carbon sequestration and storage depends not only on the price used, but also on site- and species-specific conditions.

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Table 3. Range of values for climate regulation

	Min	Max	Median	Mean
	Carbon storage			
Seagrass	29 ha^{-1} [a]	91,919 ha^{-1} [b]	654 ha^{-1}	14,841 ha^{-1}
Saltmarsh	22 ha^{-1} [c]	1,246 ha^{-1} [d]	240 ha^{-1}	503 ha^{-1}
	Carbon sequestration			
Seagrass	8 $ha^{-1} y^{-1}$ [e]	1,146 $ha^{-1} y^{-1}$ [f]	107 $ha^{-1} y^{-1}$	218 $ha^{-1} y^{-1}$
Saltmarsh	3 $ha^{-1} y^{-1}$ [g]	1,540 $ha^{-1} y^{-1}$ [h]	122 $ha^{-1} y^{-1}$	271 $ha^{-1} y^{-1}$

Source: [a] Ganguly *et al*. (2018) [b] González-García *et al*. (2022) [c] (Luisetti *et al*. 2013) [d] Schmidt *et al*. (2014) [e] Sangha *et al*. (2019) [f] Bann and Başak (2013) [g] Dhivya *et al*. (2023) [h] (S.C.L. Watson *et al*. 2022). Median and mean values authors own calculations.

3.3. Seagrass

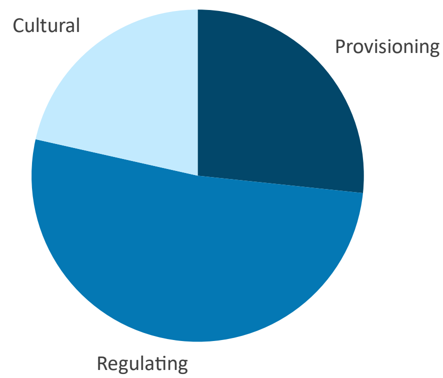

Figure 7. Valuation studies for seagrass ES according to CICES category

Seagrasses provide as many as 27 ES, provision of which varies according to region and species (Nordlund *et al*. 2016). A comprehensive study identified these services through expert elicitation and literature review and categorized them according to TEEB's classification system (Nordlund *et al*. 2016). Some of these services have no corresponding valuations in the literature. Seagrasses used as food for humans (1.1.5.1) was only identified in the tropical Indo-Pacific bioregion by experts , and reference to use as food in the literature was historical (Prendergast 2002), or concentrated in small traditional communities (Ochieng and Erftemeijer 2003). This explains the lack of valuations for this service.

Table 4. Studies valuing seagrass ES and location.

Services	**No. of Studies**[1]	**Location of primary studies**
Provisioning		
Aquaculture (1.1.4.1)	2	CHN, SWE
Materials from wild plants (1.1.5.2)	4 (2)	TUS, VNM
Food from wild animals (1.1.6.1)	33 (5)	AUS, CHN, ESP, FRA, IDN, MLT, MOZ, PHL, PRT, SAU, SWE, THA, TUS, TZA, USA
Regulating		
Decomposing wastes (2.1.1.1)	5 (3)	FRA
Filtering wastes (2.1.1.2)	17 (12)	AUS, GBR, POL, USA
Controlling erosion rates (2.2.1.1)	5 (3)	FRA
Regulating flows of water (2.2.1.3)	7 (2)	FRA, TUS, USA,
Providing habitats (2.2.2.3)	21 (6)	AUS, ESP, FRA, JPN, PRT, USA
Seawater quality (2.2.5.2)	8	AUS, FRA, JPN, POL
Climate regulation (2.2.6.1)	43 (6)	AUS, CHN, COL, ESP, FRA, GBR, IDN, IND, KEN, KOR, PRT, SWE, THA, TUR, USA
Cultural		
Active recreation (3.1.1.1)	16 (3)	AUS, FRA, GBR, IDN, JPN, MLT, POL
Passive recreation (3.1.1.2)	5 (1)	AUS, FRA, IDN, MLT
Researching nature (3.1.2.1)	5 (2)	FRA, IDN, JPN
Aesthetic value (3.1.2.4)	1	IDN
Existence value (3.2.2.1)	13 (2)	AUS, FRA, GRC, KOR, PHL, THA, USA

[1]Number of which benefit transfer studies in brackets

Seagrasses as a source of genetic material (1.2.1.1) was not mentioned by experts and only one paper was found to refer to it (Sinclair *et al*. 2013). The limited ecological knowledge about the use of seagrasses as a source of genetic material is likely a reason for the lack of valuations of this service. Cultural ES were the least frequently studied services (Figure 7). Recreation was the most frequently valued cultural service for seagrass. No primary valuations were found for the symbolic meaning of seagrass (3.2.1.1) or being significant in terms of culture and heritage

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(3.1.2.3) – these services were only valued as part of a bundle of cultural services in two benefit transfer studies (Cole *et al*, 2014; Brenner *et al.*, 2010). Table S3 provides an overview of seagrass services and values that have been found for them in the literature.

3.3.1. Seagrass Provisioning Services

Thirty-six studies valued the provisioning services of seagrass, with the vast majority valuing their contribution to commercial fishery activity. Two studies valued the contribution of seagrass to animals reared by in-situ aquaculture (1.1.4.1) (S.G. Cole and Moksnes 2016; Han *et al*. 2008). One primary study used market prices to estimate the net benefit of the use of seagrass plants for direct use and processing (1.1.5.2), in the Tam Giang–Cau Hai lagoon complex in Vietnam (Tuan *et al*. 2009). Another looked at the value lost to fertilizer production due to the decline in seagrass beds (El Zrelli *et al*. 2023).

The contribution of seagrasses to commercial fisheries – wild animals used for nutritional purposes (1.1.6.1) had 33 associated studies. Seagrasses contribute to commercial fisheries through providing juvenile and adult habitat, as a food source, and through their regulating services (Nordlund *et al*. 2018). When studies provided values for the contribution of seagrass to commercial fisheries without naming explicitly which service they aimed to value, the CICES class was assumed to be 1.1.6.1. This can be an attractive service to study due to the availability of market data.

Most studies use market prices to value this service. The prices are adjusted to isolate the contribution of seagrass, but not adjusted for any market distortions. A common method is to estimate fish biomass in a seagrass area and combine this with market prices (Carnell *et al*. 2019; Erzini *et al*. 2022; Tuya *et al*. 2014; Unsworth *et al*. 2010). These values are often based on specific commercially targeted fish species. Average values using this method ranged from \$20 ha^{-1} y^{-1} (Carnell *et al*. 2019) to \$1,415 ha^{-1} y^{-1} (Tuya *et al*. 2014). Another method involves developing a seagrass residency index to weigh the importance of seagrass to the abundance of fish species. This index was applied to landed values for each species to give a monetary value for the seagrass contribution. This ranged from \$14 ha^{-1} y^{-1} in the Mediterranean (Jackson *et al*. 2015) to \$143 ha^{-1} y^{-1} in Southern Australia (McArthur and Boland 2006). Three Australian studies used stable isotope analysis, which traces the nutritional value of seagrass in fish diets to assign part of the market value to seagrass. According to this method, the gross value of product associated with seagrass in Wallis Lake, New South Wales was \$43 $ha^{-1} y^{-1}$ (Raoult *et al*. 2022), and in the Richmond River estuary, \$70,753 of annual estuary caught commercial catch value could be attributed seagrass (Jänes, Macreadie, *et al*. 2021). The average value of commercial fish catch attributable to seagrass across Australia was \$ 9 $ha^{-1} y^{-1}$ (Jänes *et al*. 2020). Some studies attributed a percentage of catch value to seagrass based on expert opinion or the literature (Han *et al*. 2008; Hughes 2015; Interwies and Görlitz 2013). Other studies, often in developing countries, used surveys of local fishers to make this link (Chitará-Nhandimo *et al*. 2022; S.G. Cole and Moksnes 2016; de la Torre-Castro *et al*. 2014; Dirhamsyah 2007; Praisankul and Nabangchang-Srisawalak 2016; Samonte-Tan *et al*. 2007).

Despite established methods of using production function models to value habitat-fishery linkages (Barbier 2007), only two studies used this method. Anderson calculated the long run consumer and producer surplus in the Virginia hard-shell blue crab fishery associated with an increase in seagrass habitat at \$1,044 ha^{-1} and \$776 ha^{-1} respectively (1989). Hoagland *et al.* calculated the marginal productivity of the coral reef-seagrass ecosystem in the fisheries of the Red Sea on the coast of the Kingdom of Saudi Arabia to be \$24 - \$329 $ha^{-1} y^{-1}$ under different fishing regimes (2013).

3.3.2 Seagrass Regulating Services

Regulating services were addressed by 70 studies, the majority of which value climate regulation. Seagrasses remove waste from water and cycle nutrients, thus contributing to the quality of coastal waters. These services are described as bio-remediation (2.1.1.1), filtration/sequestration/accumulation of nutrients by plants (2.1.1.2) and regulating the chemical condition of salt waters (2.2.5.2) in the CICES classification. These services have similar impacts on human well-being, and determining which service is being valued can be difficult if it is not made clear in the study. A review of CICES 4.3 classes and the indicators used to measure them indicated that these services were often studied using the same indicators and the practical difference between them was small (Czúcz *et al*. 2018). When studies referred to general wastewater treatment, it was assumed they were valuing bio-remediation, and when they referred to a particular nutrient removal, it was assumed

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they were valuing filtration, following Costanza *et al.*[1] (1997). The WTP for improvements to water quality was examined in some studies (Börger and Piwowarczyk 2016; Duijndam *et al*. 2020), which can be achieved through bio-remediation or filtration – as it was not explicit which of these services was being valued, the service was assumed to be regulating the chemical condition of salt waters. Only one study reported a negative benefit associated with this service, S.C.L. Watson *et al*. (2020) found that there was a net loss of phosphorous from seagrass, meaning the economic value of phosphorus removal is negative. These services were often valued using cost methods, see Table 5 for examples.

One study used a choice experiment to value the reduction in algae caused by the filtration service of seagrasses in the Gulf of Gdansk, Poland (Börger and Piwowarczyk 2016). The WTP to reduce the presence of algae ranged between $36 and $39 per household, and the WTP for improved visibility due to seagrass was $8. Other choice experiments investigated WTP for improved water quality in the Caribbean (Duijndam *et al*. 2020), and WTP for seagrass as an indicator of "clean, clear, sunlit waters" in Tasmania (Kragt and Bennett 2011). The oft cited study by Costanza *et al.* (1997) estimated the value of nutrient cycling by seagrass to be $19,002 ha^{-1} y^{-1} (1994 USD). This value and the underlying assumption that one third of the service is provided by coastal systems is used to estimate the value of this service in other locations through benefit transfer (Batker *et al*. 2010; Campagne *et al*. 2015; A.O. Cole *et al*. 2014; Han *et al*. 2008).

Further regulating services provided by seagrass include erosion protection (2.2.1.1) and the regulation of the hydrological cycle and water flow (2.2.1.3). Valuations for these services were made using replacement cost methods but were not as common. The value of erosion protection ranged from $120 ha^{-1} y^{-1} in Turkey (Bann and Başak 2013) to $4,028 ha^{-1} in 2005 in Guangxi Province, China (Han *et al*. 2008). The regulation of the hydrological cycle and water flow was valued in Martinique at $15,464 ha^{-1} y^{-1} (Failler *et al*. 2015). Chen, Swallow and Yue (2020) found household WTP for "living shorelines" in East Virginia (a combination of seagrass and saltmarsh restoration to protect the coast) ranged from $35 – $4,430.

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[1] In Costanza *et al.*'s global valuation of ES and Natural Capital, nutrient cycling was defined as the storage, internal cycling, processing, and acquisition of nutrients such as nitrogen and phosphorous, while waste treatment referred to the recovery and removal or breakdown of excess foreign nutrients (1997). These definitions correspond to CICES 2.1.1.2 and CICES 2.1.1.1 respectively.

Maintaining nursery habitats and populations (2.2.2.3) was the most frequently studied regulating service after climate regulation. As mentioned previously, the nursery habitat contributes to the importance of commercial fisheries. Adjusted market prices were used in much the same way as for valuing the provisioning service of seagrasses, where the modelled biomass was combined with prices. However, these values focused specifically on fishery enhancement and the population and growth of juveniles in the habitat. This was studied in Gran Canaria, Spain (Tuya *et al*. 2014), Australia (Blandon and zu Ermgassen 2014; R. Watson *et al*. 1993), Portugal (Erzini *et al*. 2022), and Japan (Kamimura *et al*. 2011). The lowest value found using this method was \$140 ha^{-1} y^{-1} (Erzini *et al*. 2022), and the highest value was \$22,788 ha^{-1} y^{-1} (Blandon and zu Ermgassen 2014).

Table 5. Filtration and bio-remediation service of seagrass valued with cost methods

Method	**Value (2018 Int$)**	**Description**	**Source**
Avoided damage costs	25 million	Annual avoided damages globally through reduced cases of gastroenteritis	(Ascioti *et al*. 2022)
Replacement costs	1,501 ha^{-1} y^{-1}	Wastewater treatment provided by seagrasses in Martinique	(Failler *et al*. 2015)
Replacement costs	8.5 million	Increase in denitrification from seagrass between 1982 and 2010 in Tampa Bay, Florida	(Russell and Greening 2015)
Replacement cost	87,507 ha^{-1} y^{-1}	Value of nitrogen removal on southeast coast of the UK	(S.C.L. Watson *et al*. 2020)
Replacement cost*	-19,979 ha^{-1} y^{-1}	Value of phosphorous removal on the southeast coast of the UK	(S.C.L. Watson *et al*. 2020)
Replacement cost	480 – 1,173 ha^{-1} y^{-1}	Nitrogen removal by seagrass along Adelaide coast	(Gaylard *et al*. 2023)

* This value is negative as study found that seagrasses were a source of phosphorous rather than a sink

This service was also valued through stated preference methods (Antinori 2021; Duijndam *et al*. 2020; Rogers 2013; Pascoe *et al*. 2019; Tsuge and Washida 2003; Uehara *et al*. 2018). A contingent valuation study in Japan elicited WTP for restoration of 10 ha of *Zostera marina* based on its importance as a nursery habitat, and the aggregated WTP for the country was $1bn (Tsuge and Washida 2003). Uehara *et al.* ran the same survey again in 2015 and found that the mean WTP for this project had increased by 17.4% (2018). A choice experiment in Australia estimated WTP for a 5% increase in seagrass area in a proposed marine park, given the importance of its nursery service, as between $34 - $42 per household per year (Rogers 2013).

3.3.3 Seagrass Cultural Services

Twenty-nine studies addressed the cultural value of seagrass ecosystems, some of which provided values for a bundle of cultural ES (A.O. Cole *et al*. 2014; Pascoe *et al*. 2019). The contribution of seagrass to recreational fishing (characteristics of living systems that enable activities promoting health, recuperation or enjoyment through active or immersive interactions (3.1.1.1) was the most frequently studied cultural service for seagrass. Port Phillip Bay in Melbourne, Australia has been the site for multiple valuations of this service. Jänes, Carnell, *et al*. (2021) examine the impact of seagrass on a particular species and combine fish abundance models with recreational fishing trip values from the Victorian Fisheries Authority (VFA) dataset. The recreational fishing value of King George Whiting supported by seagrass is estimated to be $583 - $4,439 ha^{-1} y^{-1}. Huang *et al*. (2020) also use the recreational fishing dataset from the VFA to estimate WTP for changes to fishing site and find that a 10% increase in seagrass in Port Phillip Bay is associated with increased annual recreational benefits of $560,405. The Mapping Ocean Wealth Australia report used travel cost and choice modelling on an existing dataset, and valued recreational fishing related to seagrass at $738 ha^{-1} y^{-1} in the same location (Carnell *et al*. 2019). The value of recreational fishing was also studied through a combination of travel cost values and fish and angler distribution surveys in Florida (Fulford *et al*. 2016), through a survey of the local population in East Bintan, Indonesia (Wahyudin *et al*. 2018), and through a residency index approach in Europe (Jackson *et al*. 2015). A report investigating the value of potential Marine Protected Areas for divers and anglers in the UK found WTP to visit Blakeny seagrass site was between $10 and $92 (Kenter *et al*. 2013).

Although tourism is not explicitly included as a cultural service in CICES, it was included in the TEEB. Notwithstanding the debate around whether tourism is a cultural ES – see Pueyo-Ros (2018) – where tourism was valued in a paper it has been included in the review under the assumption that it relates to characteristics of a living system that enable activities promoting health, recuperation or enjoyment through passive or observational interactions, e.g., sightseeing (3.1.1.2). Dirhamsyah (2007) estimate the value of seagrass for foreign and local tourism at \$5,160 ha^{-1} y^{-1}. They attribute all foreign tourist expenditure to the presence of seagrass and use a benefit transfer from a travel cost study at a similar site to estimate local tourism value. This is a problematic form of valuation, as it is highly unlikely that all tourist visits to the site are due to the presence of seagrass. The value of seagrass for tourism was also calculated in Thailand (Praisankul and Nabangchang-Srisawalak 2016) and Martinique (Failler *et al*. 2015).

Seagrass enables scientific investigation (3.1.2.1) and is often used as a bioindicator. Three studies use research funding for seagrass related projects as a proxy for this value (Campagne *et al*. 2015; Dirhamsyah 2007). In the CICES terminology the simple descriptor of the existence value (3.2.2.1) of an ecosystem is that it is something we think should be conserved. This service can only be valued through stated preference methods. Stated preference surveys that estimated WTP for seagrass restoration (Praisankul and Nabangchang-Srisawalak 2016; Rolfe and Windle 2010), for preservation (Bundal *et al*. 2018; Pascoe *et al*. 2019), for maintaining good environmental condition of a specific species (Halkos and Galani 2016), and for protecting endangered species (Wallmo and Lew 2016; Petcharat and Lee 2020) were all presumed to value the existence of seagrass.

3.4. Saltmarsh

Nineteen services were valued for saltmarsh, with the majority of valuations for regulating services (see Figure 8 and Table 6). More saltmarsh studies than seagrass studies valued cultural ES, and less valued provisioning. Some studies valued services for “coastal wetlands” with no further description of the ecosystems. When the description of the sites in the text and comparison with the known distribution of saltmarshes confirmed the likelihood of the ecosystem being a saltmarsh, they were included in this review. A range of values from primary studies found in this

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DOI: 10.15351/2373-8456.1174

review for saltmarsh ES that can be compared for a like for like basis can be found in Table S4.

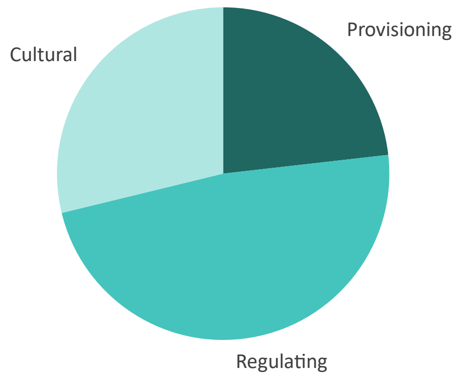

Figure 8. Valuation studies for saltmarsh ES according to CICES section

Table 6. Studies valuing saltmarsh ES and location

Services	**No. of Studies**[1]	**Primary study locations**
Provisioning services		
Food grown by humans (1.1.1.1)	1	LKA
Reared animals (1.1.3.1)	4 (1)	GBR, NLD, USA
Aquaculture (1.1.4.1)	1	USA
Materials from wild plants (1.1.5.2)	5 (3)	CHN
Food from wild animals (1.1.6.1)	24 (4)	AUS, CHN, GBR, KOR, LKA
Regulating services		
Decomposing wastes (2.1.1.1)	9 (4)	KOR, LKA, USA
Filtering wastes (2.1.1.2)	15 (7)	CHN, GBR, USA
Controlling erosion rates (2.2.1.1)	3 (3)	
Regulating flows of water (2.2.1.3)	31 (12)	CHN, GBR, LKA, NLD, USA
Pollination (2.2.2.1)	1	NLD
Providing habitats (2.2.2.3)	18 (6)	AUS, CHN, GBR, USA
Disease control (2.2.3.2)	1	USA

Climate regulation (2.2.6.1)	27 (4)	AUS, CHN, GBR, IRL, KOR, LKA, NLD, PRT, USA
Cultural services		
Active recreation (3.1.1.1)	31 (14)	AUS, CHN, GBR, ESP, LKA, NLD, USA
Passive recreation (3.1.1.2)	6 (2)	AUS, USA
Researching nature (3.1.2.1)	2 (1)	GBR
Cultural and heritage value (3.1.2.3)	2 (2)	
Aesthetic value (3.1.2.4)	4	USA
Existence value (3.2.2.1)	7	CHN, FRA, ITA, USA

[1] Number of which benefit transfer studies in brackets

3.4.1. Saltmarsh Provisioning Services

Cultivated terrestrial plants grown for nutritional purposes (1.1.1.1) and animals reared for nutritional purposes (1.1.3.1) were not often valued. This is not surprising given the somewhat limited use of saltmarsh for agriculture production. However, there are some examples such as the Muthurajawela Wetlands in Sri Lanka, where the gross returns from saltmarsh based agriculture (coconuts, bananas and vegetables) were attributed entirely to the marsh area, giving a value of \$731 ha^{-1} y^{-1} (Emerton and Kekulandala 2003). Though not a direct valuation of saltmarsh agriculture, a choice experiment near Jiangsu-Yancheng Coastal Wetlands in China investigated what subsidy would be necessary for farmers to enroll in a more sustainable form of saltmarsh agriculture by using less pesticides, and found that the minimum WTA per farmer ranged from \$22 to \$591 ha^{-1} y^{-1}, depending on the program characteristics (Bennett *et al*. 2018). Saltmarsh has also traditionally been used in agriculture as grazing pasture for ruminants, in France for example, saltmarsh-grazed lamb is a premium product (Gedan *et al*. 2009; Jones *et al*. 2011). In the Scheide Estuary in the Netherlands, saltmarsh contributes to added value of this product by \$949 ha^{-1} (Boerema *et al*. 2016). A 1995 UK study estimated the gross margins for livestock grazing on saltmarsh in the UK at \$199 - \$541 ha^{-1} (Posford Duvivier 1996) and another study estimated the grazing value at \$39 ha^{-1} (S.E. King and Lester 1995). The potential value of saltmarsh-based aquaculture (1.1.4.1) in the US was valued by Gosselink at \$6,857 ha^{-1} y^{-1} (1974). The use of saltmarsh plant fibers for direct use or processing (1.1.5.2) was valued using adjusted market prices in Lianyugang, China at \$90 ha^{-1} y^{-1}, where saltmarsh plants are collected for use as a fodder. (Sun *et al*. 2017).

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DOI: 10.15351/2373-8456.1174

Much like seagrasses, multiple saltmarsh ES contribute to commercial fisheries by providing food and nursery habitat for commercial species, and through regulating services (Jänes, Macreadie, *et al*. 2021). When the service was not explicitly mentioned, it was assumed the contribution of saltmarshes to the production of wild animals for food was being valued. Twenty-three studies valued CICEs 1.1.6.1 – wild animals used for nutritional purposes - three of which used benefit transfer.

Market prices were a common way to value this service. In some cases, they were not adjusted at all. For example, Gosselink *et al.* (1974), assigned the entire value of coastal fisheries to saltmarsh in Georgia, Louisiana and Florida – based on the assumption that the existence of the fishery depended on the existence of the habitat. Similarly, the value of Muthurajawela Wetlands is expressed as the entire value of the local fishery and 10% of the downstream catch (Emerton and Kekulandala 2003). Stable isotope analysis was also used to trace the contribution of saltmarsh plants to the diet of commercial fish, and then adjust prices accordingly. In Australia, the gross value of production of commercial fish catch attributable to saltmarsh ranged from \$5 ha^{-1} y^{-1} in Victoria (Jänes *et al*. 2020) to \$422 ha^{-1} in Wallis Lake, New South Wales (Raoult *et al*. 2022). A residency index was used by McCormick *et al.* (2021) to assign a value to saltmarsh based on commercial landings. They found that 22.2% - 24.7% of UK landings value and 45.6% - 49% of European landing values in 2015 could be attributed to UK saltmarsh, giving values of \$147 ha^{-1} and \$817 ha^{-1} respectively. Modelling the biomass of fish found in seagrass areas and combining with catch values was a method used by Carnell *et al*. (2019) and Minello *et al*. (2012). Only two studies used production function methods to estimate this service; (Costanza *et al*. 1989; Stevenson 2001). The marginal productivity of one hectare of saltmarsh in a coastal fishery in Louisiana was estimated at \$135 (Costanza *et al*. 1989).

Stated preference methods were also used to value the contribution of saltmarsh to commercial fisheries. Household WTP to improve fisheries productivity through conserving Louisiana's coastal wetlands was \$212 (Petrolia *et al*. 2014). Similarly, household WTP to increase fish catch through saltmarsh restoration in Alabama and Louisiana ranged from \$42 - \$102 (Interis and Petrolia 2016)

3.4.2. Saltmarsh Regulating Services

The most studied regulating service was hydrological cycle and water flow regulation, including flood control and coastal protection (2.2.1.3), making up 30% of the valuations of saltmarsh regulating services. As with seagrass studies, distinguishing between valuations of bio-remediation (2.1.1.1) and filtration (2.1.1.2) was difficult, and was done in the same way as detailed above. Both services were valued through replacement cost methods and benefit transfer. The high capital costs associated with building and maintaining treatment plants that would provide the service currently offered by saltmarsh means high values are found for this service. Replacement cost estimates for bio-remediation ranged from \$104 ha^{-1} y^{-1} for installing domestic sewage treatment in Sri Lanka (Emerton and Kekulandala 2003) to \$154,139 ha^{-1} y^{-1} for complete tertiary treatment of artificial nutrients in the Mid-Atlantic estuaries of the US (Gosselink *et al*. 1974). For filtration, the replacement cost estimates ranged from \$823 ha^{-1} y^{-1} in Florida, USA (Russell and Greening 2015) to \$181,210 ha^{-1} y^{-1} on the southeast UK coast (S.C.L. Watson *et al*. 2020), both figures representing the value for nitrogen removal.

Flood control and coastal protection, (2.2.1.3) was valued through replacement cost methods, stated preference methods, historical damage cost avoided, and benefit transfer. Table 7 shows the values calculated using cost methods. Stated preference methods were also used to value this service. As mentioned, Chen, Swallow and Yue *et al.*, investigated WTP for nature based solutions for coastal protection involving seagrass and saltmarsh (2020). In the UK, aggregate household consumer surplus from flood prevention by intertidal and saltmarsh areas in SSSIs was estimated at \$22.2m y^{-1} (Christie and Rayment 2012). Also in the UK, the aggregate WTP for managed realignment, a nature based coastal defense strategy, ranged from \$6,158 ha^{-1} y^{-1} to \$137,948 ha^{-1} y^{-1} under different policy scenarios (Luisetti *et al*. 2011).

A post Hurricane Katrina study in the US compared preferences for coastal restoration as a means to improve storm protection in New Orleans and nationwide. The average individual WTP for coastal restoration was \$120, although it was not always statistically significant for the New Orleans sample, and lower income households had no significant WTP for this service (Landry *et al*. 2011). A contingent valuation study in the UK found the mean household WTP to prevent a reduction in saltmarsh to preserve their flood protection service ranged from \$67 to \$622 y^{-1} (Mangi *et al*. 2011). In Louisiana, a contingent valuation survey estimated

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household WTP/WTA to prevent/accept coastal wetlands loss at $954 and $5,087 respectively (Petrolia and Kim 2011). In Ireland, the coastal protection service of saltmarsh was valued using benefit transfer at $3,060 ha^{-1} y^{-1} (Norton *et al*. 2018).

One study valued pollination (2.2.2.1), estimating that Dutch saltmarshes contributed $207 ha^{-1} in 2015 to increased crop yield through pollinating services, using what they describe as a damage cost avoided approach, modelling the relationship between pollinator dependent crops and habitat suitability for crops (Horlings *et al*. 2020)

While many studies valued the contribution of saltmarsh to commercial fisheries, only two studies used fishery market data to explicitly value the service of maintaining nursery populations and habitats (2.2.2.3). An early study used the production function method to estimate the productivity of marsh in the blue crab fishery of Virginia at $2 ha^{-1} (Lynne *et al*. 1981). In the UK, the importance of saltmarsh as a nursery ground for bass was valued at $13 ha^{-1} (Luisetti *et al*. 2011). This service was also valued through choice experiments that elicited WTP to improve habitat conditions for saltmarsh fauna. Household WTP to improve saltmarsh habitat for protected bird species was estimated to be between $3 and $5 (Luisetti *et al*. 2011). A restoration option that improved 5 acres of marsh habitat for fish nurseries in Rhode Island, US was valued at $26 per household (Bauer *et al*. 2004).

3.4.3. Saltmarsh Cultural Services

Cultural services made up a larger proportion of valuations for saltmarsh than for seagrass, with 36 studies valuing these services. Over half of these studies were related to recreational values, or characteristics of living systems that enable activities promoting health, recuperation, or enjoyment through active/immersive or passive/observational activities (3.1.1.1 and 3.1.1.2). Stated and revealed preference methods were used to value these services. Table 8 shows a sample of values for this service.

. Table 7. Values for flood control and coastal protection of saltmarsh using cost methods

Method	Value (2018 Int$)	Description	Source
Avoided damage cost	259,117 y^{-1}	Annual value of flood protection provided by managed realignment	(MacDonald *et al*. 2020)
Avoided damage cost	29,252ha^{-1}	Median value of avoided damages per storm in China between 1989-2016	(Liu *et al*. 2019)
Avoided damage cost	206,762 ha^{-1}	Mean value of avoided damaged per storm in China between 1989-2016	(Liu *et al*. 2019)
Avoided damage cost	2,429 y^{-1}	Average avoided property damages due to the presence of saltmarsh per house	(Narayan *et al*. 2017).
Avoided damage cost	9,872 ha^{-1} y^{-1}	Avoided flood damage cost through presence of saltmarsh in Scheide Estuary, the Netherlands	(Boerema *et al*. 2016)
Avoided damage cost	10,231-40,333 ha^{-1}	Present value of increased storm damages associated with loss of saltmarsh	(Costanza *et al*. 1989)
Replacement cost	1,257 ha^{-1}	Replacement cost of disturbance regulation of saltmarsh in Lianyungang, China	(Sun *et al*. 2017).
Replacement cost	15.2m - 210.2m	Capital savings on coastal defense by Tetney Marshes and St. Peter’s flats, UK	(Mangi *et al*. 2011).
Replacement cost	11,714 ha^{-1} y^{-1}	Replacing and maintaining the flood control measures supplied by Muthurajawela marsh	(Emerton and Kekulandala 2003)
Replacement cost	772,004 ha^{-1} 15,440 ha^{-1}	Capital savings on sea defense provided by saltmarsh, UK Annual maintenance cost savings	(S.E. King and Lester 1995).

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DOI: 10.15351/2373-8456.1174

Table 8. Value of saltmarsh recreation service

Method	Value (2018 Int$)	Description	Source
Travel cost and contingent valuation	246 ha^{-1} - 967 ha^{-1}	Recreational fishing in Louisiana	(Costanza *et al*. 1989)
Travel cost and contingent b**ehavior** model	168 – 190 per visit	Value per trip of visit to La Pletera saltmarsh, Catalonia	(Pueyo-Ros *et al*. 2018)
Travel cost and on-site expenditures	127 ha^{-1}	Recreation at Muthurajawela wetlands	(Emerton and Kekulandala 2003)
Travel cost	73 per visit	Tourist visit to Nansha Wetland, China	(Xu and He 2022)
Travel cost	317 ha^{-1} y^{-1}	Hunting and fishing in Saginaw Bay saltmarsh, Michigan	(Whitehead *et al*. 2009)
Fishery production and WTP for recreational fishing days	5,059 - 33,369 ha^{-1}	Capitalized value of saltmarsh in East and West Coast of Florida for recreational fishing	(Bell 1997)
Contingent valuation	52.9 million	Consumer surplus of recreation on Louisiana saltmarsh	(Bergstrom *et al*. 1990)
Choice modelling	8,705 - 194,797 y^{-1}	Birdwatching on saltmarsh in Australia	(Carnell *et al*. 2019)
Choice modelling and contingent valuation	8 – 79 per visit	Mean individual WTP among divers and anglers for visit to Blakeny saltmarsh site, UK	(Kenter *et al*. 2013)

Characteristics that enable scientific investigation or the creation of traditional ecological knowledge (3.1.2.1) were also valued. The aggregate household consumer surplus for research and education opportunities provided by intertidal mudflats and saltmarsh in SSSIs in the UK was \$15.24m y^{-1}, according to an approach that combined choice modelling with weighting scores from experts (Christie and Rayment 2012). This study also estimated values for "sense of experience" and "charismatic species," which were taken to refer to characteristics that have an existence value (3.2.2.1). Hedonic modelling and choice modelling was used in Connecticut, US to value the aesthetic service of saltmarsh (3.1.2.4) and found increased house prices of \$17,958 - \$317,595 due to proximity to restored saltmarsh (Earnhart 2001). The only other study to value aesthetics was Yoskowitz *et al*. (2017), using benefit transfer from similar ecosystems.

The existence value of saltmarsh had seven associated studies. Stated preference surveys that investigated WTP for protection or preservation of saltmarsh habitats, or for charismatic or endangered species who use these habitats, were assumed to be calculating the existence value. A choice experiment estimated the marginal value of a hectare of saltmarsh on Deben Estuary ranged from \$34 ha^{-1} to \$45 ha^{-1}, depending on the exact project aims (Grilli *et al*. 2022). In Brest roadstead, France, a contingent valuation survey found WTP to protect saltmarshes against invasive species was \$17-\$30 per household (Voltaire *et al*. 2017). The mean WTP per tourist for protection of Nansha Wetlands, China, was valued with choice modelling at \$27 y^{-1} (Xu and He 2022). The non-use value for Saginaw Bay saltmarsh was \$93 ha^{-1} y^{-1}, found through contingent valuation (Whitehead *et al*. 2009). Other studies valued cultural services of saltmarshes through benefit transfer, e.g. Brenner *et al.* (2010), sometimes as a bundle of cultural services, e.g. A.O. Cole *et al*. (2014). The full range of values for seagrass and saltmarsh services from the literature, which can be compared on a like for like basis, can be found in the Supplementary Materials section, in Tables S3 and S4, respectively.

4. DISCUSSION

4.1 Ecosystem condition

The literature shows a broad range of values for saltmarsh and seagrass ES, based on a variety of methods (See Table 9). The level of services an ecosystem can provide is dependent on the condition of the ecosystem itself. A saltmarsh

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DOI: 10.15351/2373-8456.1174

threatened by anthropogenic impacts such as eutrophication will not be able to provide the same level of ES as a saltmarsh in good condition in a protected area. S.C.L. Watson *et al*. (2022) show that the value of regulating services provided by BCEs depends on the condition of the habitat. However, the condition and protected status of the ecosystem in question is only reported in 28% of studies. Just over half of the studies that valued seagrass ES reported the species in question, which may be an issue where service provision varies with species (Lavery *et al*. 2013). The reporting of both of these metrics should be improved where possible, not only for the quality of the original assessment, but also to inform any benefit transfer studies developed using these values.

4.2. Methods

4.2.1. Direct Market Valuation

Market prices were used to value the contribution of blue carbon ecosystems to the provision of wild food, the maintenance of nursery habitats and populations, and in some cases the climate regulation service. These prices were adjusted in most cases to value the services related to commercial fisheries, while for climate regulation the market value of carbon was not adjusted. Using market data carries the implicit assumption that the market is competitive and the prices therefore are reflective of marginal costs (Pascual *et al*. 2010). Whether the carbon market or the commercial fish market are functioning well is debatable. The negative externalities of commercial fishing have been well-documented. About 90% of the world's fisheries were subject to overfishing in 2011 (World Bank 2017), a practice that is contributing to the global extinction crisis (Dulvy *et al*. 2021). It was estimated that in 2012 the industry was forgoing billions of dollars in benefits compared to a sustainable management scenario (World Bank 2017). The industry is also heavily subsidized, to the tune of $35.4 billion in 2018, despite evidence that subsidies that artificially inflate profits result in overcapacity and overfishing (Sumaila *et al*. 2019). In this context, it is questionable whether landed prices reflect the true value of the fish caught, and to use these prices in ESV may give rise to distorted values. Rather than adjusting market prices through the methods mentioned here, isolating the impact of the ecosystem on fishery production through a production function approach may be more of an appropriate economic method. However, this method has only been used by six studies in this review, raising the question of whether there is sufficient data available to inform this approach. (Pascual *et al*. 2010).

The replacement cost method was commonly used to value the bio-remediation, filtration and coastal defense services. This method equates the cost of replacing a service with the benefit of that service. This may be misleading as the true benefit is the demand for the benefits these services bring (i.e. clean water) minus the cost of providing it (Barbier 2007), so using just cost figures can lead to unrealistically high values. In some cases, this value may be appropriate to inform policy decisions. If the choice is between constructing a treatment plant or restoring the saltmarsh that provides this service, comparing the costs of construction and restoration is suitable (Barbier 2007). For bio-remediation and filtration services, the impact on human well-being may be difficult to quantify and the paucity of data may in some cases require replacement cost methods as the best available option. The overuse of replacement costs to estimate the value of coastal protection by BCEs was cited in Himes-Cornell *et al*. (2018), and it has been advised that more reliable estimates can be generated using a damage function approach (Barbier 2016).

Damages are those to property, infrastructure, industry, and in some studies loss of life (Liu *et al*. 2019; Narayan *et al*. 2017). Therefore, the avoided damage costs depend on the baseline wealth of the affected communities. This raises ethical issues. For example, the storm protection benefit of mangroves is associated with higher economic benefits in high income countries, but a greater number of beneficiaries, i.e. human lives protected, in lower-income countries (Menéndez *et al*. 2020). Using this method to value the flood control and coastal protection service of saltmarshes and seagrasses runs the risk of providing greater justification for preservation and protection of these ecosystems that are located in wealthier areas (zu Ermgassen *et al*. 2021), a particularly insidious risk when it is considered that the global poor in general are more dependent on ecosystems and their services than the global rich (Ghermandi *et al*. 2013).

Methods using direct market valuation present an exchange value, which is a financial, rather than an economic value and does not take welfare into account (Tinch *et al*. 2021). While exchange values are necessary for current natural capital frameworks, welfare values are necessary to inform public policy (Tinch *et al*. 2021). This and the lack of critical discussion about the quality of the original market data are the main issues with direct market valuation observed in these

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studies. The availability of market data does not always mean that a method based on market values is the most appropriate for the context in which the valuation is taking place.

4.2.2. Stated Preference

Stated preference methods are used in 49 studies found in this review, with choice experiments being the dominant method. Stated preference has been the source of much controversy – see Hausman (2012); Kling *et al*. (2012) – yet they remain the best available option for non-use values. Studies used choice modelling and contingent valuation to investigate conservation and recreation values for saltmarsh habitats, which appear to be activities familiar to the respondents. However, a particularly salient issue for stated preference surveys relating to seagrass ecosystems is that public perception of the role of seagrasses is low (Barañano *et al*. 2022; Losciale *et al*. 2022), and WTP has been found to correlate with public awareness (Dewsbury *et al*. 2016). When this is the case, sufficient information needs to be provided to respondents to enable them to form preferences, and it is questionable whether these preferences are reliable when they have low prior knowledge of the ecosystem (Bateman *et al*. 2008). This may be an issue for some studies found in this review. A choice experiment in South Korea that aimed to investigate public perceptions of blue carbon found that only 5% of the respondents had heard of blue carbon, and only 5.7% of respondents had heard of seagrass previously (Kim *et al*. 2022). A contingent valuation survey to investigate WTP for conservation in the Philippines found that almost 70% of respondents had no idea what seagrass is (Bundal *et al*. 2018). Even when respondents are familiar with the site in question, it is unlikely that many will be aware of seagrasses and their role there. The low prior perception of seagrasses may not be an issue once experiments are designed with this in mind (Bateman *et al*. 2008), but steps taken to address this should be well-documented in studies.

A further issue with using stated preference is that ecosystems found in more affluent areas may be valued higher due to inherent inequalities in ability to pay, and a review of coastal ESV did find that GDP per capita was significantly correlated with the value of the ecosystem (Rao *et al*. 2015) An example of this is in a choice experiment that addresses coastal restoration in the US, focusing on a nationwide sample and a New Orleans sample (Landry *et al*. 2011). While 52% of US respondents think coastal restoration is very important and 86% of New Orleans do, a latent class analysis finds that lower income households do not have statistically significant WTP for coastal restoration while higher income households do (Landry *et al*. 2011). This is in the context of the aftermath of hurricane Katrina which severely impacted low-income New Orleans households. Similarly to the damage cost avoided method, valuations using choice modelling may provide a stronger rationale for conserving ecosystems in wealthier areas.

Stated preference methods can be resource and time intensive, and the range of coastal and marine services and ecosystems that require valuation are vast. Two studies developed methods to extrapolate values from one choice experiment to a wider context. In an attempt to value multiple coastal ecosystems and avoid the possibility of respondent fatigue and use of heuristics (Johnston *et al*. 2017), Pascoe *et al.* used a multi-criteria method called Analytic Hierarchy Process (2019). This method asked respondents to first complete a series of pairwise comparisons between coastal ecosystems, the results of which were used to develop weights for each ecosystem, which were then applied to the results of the choice experiment (Pascoe *et al*. 2019). Christie and Rayment (2012) also developed a weighting matrix with the help of experts that links ecosystems services and habitats, which was applied to the results of a choice experiment that elicited the public preferences for ES. While initially having a narrow focus, these studies both extrapolate their results to a broader context in ways that may prove useful in addressing concerns about the limitations of current ESV research in the policy context (Olander *et al*. 2017).

4.2.3. Emergy Analysis

Nine studies attempt to quantify the natural capital value of seagrass or saltmarsh ecosystems through calculating the total energy value of these ecosystems. This approach is based on the work of H.T. Odum, with the idea being that a resource can be valued and compared with another resource on the basis of the solar energy that went into producing it (Odum 1988; Zuidema *et al*. 2011). The method is known as “emergy analysis” (Odum 1988). It has been described as an eco-centric or donor side estimation of value (Hau and Bakshi 2004), in comparison to ESV which is embedded in an anthropocentric viewpoint. The Emergy Money Ratio, which is the ratio of GDP to total emergy supporting that country’s GDP (in joules) is used to convert values to monetary form (Vassallo *et al*. 2013).

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Costanza *et al*. (1989) and Gosselink *et al*. (1974) reference Odum's work in their valuations of saltmarsh based on the primary productivity of saltmarsh plants, but they do not explicitly name it emergy analysis. They calculate the primary productivity of saltmarsh plants and convert it to dollar values using an emergy conversion factor. They estimate values for coastal Louisiana marsh at \$44,624 ha^{-1} y^{-1} (Gosselink *et al*. 1974) and \$3,334 ha^{-1} y^{-1} (Costanza *et al*. 1989). More recently, five studies for Italian seagrass ecosystems have used the emergy analysis approach. Among them, Vassallo (2013) estimated annual values of approximately \$2.7 million ha^{-1} y^{-1} for *Posidonia Oceanica* seagrass in the Marine Protected Area Isola di Bergeggi in Italy. Environmental flows from the same seagrass species were valued at \$2,617 ha^{-1} y^{-1}, while the standing natural capital was estimated at \$9,544 ha^{-1} in the Islands of Ventotene and S. Stefano in Italy (Franzese *et al*. 2017). The average value across six Italian sites for the same seagrass species was also calculated at \$149,845 ha^{-1} y^{-1} (Rigo *et al.*, 2021). The range of values calculated across the same or similar ecosystems using this approach is a cause for concern. The discrepancy between values limits their reliability and applicability in natural capital accounting frameworks and ecosystem management decision-making. Some worry that using figures based on this method to justify ecosystem management decisions could be worse than using no values at all (D. King 1998).

4.2.4. Benefit Transfer

Thirty-two studies were found to use benefit transfer in at least some part of their valuation strategy. Benefit transfer uses information from studies in one location and transfers it to another. This can be useful when there is a lack of data about the initial study site and the budget to conduct primary investigations is limited. For example, large scale assessments of coastal ES were conducted for Mexico and Africa where previous research was limited (Camacho-Valdez *et al*. 2013; Trégarot *et al*. 2020). Benefit transfer was used in 43% of the grey literature and only in 12% of the peer-reviewed articles. This is understandable as these grey literature reports often deal with a specific policy site or case where the focus is on producing usable values, rather than publishing related journal articles. An issue noticed by Himes-Cornell *et al*. (2018) is that benefit transfer is often used without critical discussion as to the validity of the original source, something which is observed in some studies here. Using benefit transfer with stated preference values may be problematic as they can be very context dependent. It has been shown that that benefit transfers across habitat within a given location perform better than transfers across location for the same habitat (Interis and Petrolia 2016). Some studies used the per hectare value generated by Costanza *et al.*'s synthesis and applied this to the study area (Blackwell 2006; Han *et al*. 2008; Zuidema *et al*. 2011). Often ES provision can vary depending on the region and site specific conditions (Lavery *et al*. 2013; Nordlund *et al*. 2016), and global values may not always be appropriate for local application (Himes-Cornell *et al*. 2018).

On the other hand, benefit transfer is likely to remain an important valuation tool for some time to come, at least due to budget constraints. Studies attempting to refine the approach are necessary. This inclusion of GIS has been important step to refine value estimates (Hynes, Norton, *et al*. 2013). O'Higgins *et al*. (2010) and Camacho-Valdez *et al*. (2013) apply a spatially explicit approach to the north west US and the southern coast of Sinaloa, Mexico respectively. A culturally specific method was tested in Galway Bay to value seagrass and saltmarsh (Hynes, Norton, *et al*. 2013). In other cases, where the aim of the study was to estimate changes in ES provision due to external factors such as sea-level rise, using benefit transfer to estimate the baseline level of studies was essential to be able to carry out the next phase of work (Feagin *et al*. 2010).

4.2.5. Climate Regulation Methods

Interest in blue carbon as a tool to mitigate climate change and ensure a transition to a green/blue economy has piqued in recent years (Nellemann and Corcoran 2009), and valuing climate regulation in BCEs is an emerging research field. Most papers studying climate regulation found in this review were published since the year 2010. Thus, the values and methods presented in this review are still characterized by a great deal of uncertainty. For seagrass in particular, the dynamics of blue carbon are not yet fully understood (Unsworth *et al*. 2022). Sequestration and storage abilities appear to vary depending on water conditions and plant characteristics, so using sequestration estimates from a different species may lead to under or over-estimation of values (Lavery *et al*. 2013). For both ecosystems, how the mechanisms of sequestration and storage will change in the face of sea level rise, ocean acidification and other climate change related stressors is unclear, and only a few valuation studies have explicitly addressed this (Carr *et al*. 2018; Feagin *et al*. 2010; Garrard and Beaumont 2014). As mentioned previously, the true extent of neither saltmarsh nor seagrass ecosystems is confirmed, and state-wide, global, or regional estimates of this service hinge on this uncertainty. Perhaps most

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significant for the studies found in this review, there is no consensus over which carbon price to use, as noted in Himes-Cornell *et al*. (2018). Unless the valuation is for a policy context that calls for a specific price, where possible a range of estimates for this service should be used to reflect this uncertainty. Finally, valuing the climate regulation service should not be at the expense of understanding other services – especially given the inherent uncertainty in these values. Climate regulation is a valuable service and blue carbon may be an important funding mechanism to conserve these habitats, but BCEs are more than just carbon sinks.

4.3. Ecosystem Services

As shown in Table 6, nineteen saltmarsh ES were valued in the literature. The most frequently studied services are characteristics that enable active recreation, flood control and coastal protection, and climate regulation. Eleven services have less than four studies associated with them. For seagrass, 15 services have been studied, and non-consumptive cultural services are the least frequently studied. The variety of ES studied is not uniform across global regions, however the most frequently studied services in each region for both ecosystems are climate regulation, food from wild animals, and active recreation. Asia is the only region where the most frequently studied service for saltmarsh is coastal protection. The intense focus on climate regulation is understandable given the calls for increased research on climate related impacts and the growing interest in the role of blue carbon habitats in climate change mitigation (Duarte 2017; Nellemann and Corcoran 2009). The number of valuations focusing on the contribution of these habitats to commercial fisheries is facilitated by the availability of market data. Habitat-fishery linkages seem to be relatively well understood, and this understanding likely contributes to the number of valuations on active recreation, which commonly focuses on the role of seagrass and saltmarsh in maintaining recreational fisheries.

Agriculture can benefit from saltmarsh as grazing land as an input into the livestock production function (McKinley *et al*. 2022), and in some cases this is exploited with a price premium, such as saltmarsh-fed lamb in France (Gedan *et al*. 2009). The value of saltmarsh to agriculture and the impact improperly managed grazing can have on ecosystem functioning are likely to be important areas of research in terms of agricultural and land-use policy, especially with the growing emphasis on conserving BCEs (Muenzel and Martino 2018). However, the value of saltmarsh to agriculture through providing grazing land has only addressed by three studies, (Boerema *et al*. 2016; Posford Duvivier 1996; S.E. King and Lester 1995), two of which may now be quite dated. Understanding the value of this service will be important in policy-making decisions around land use, so that the benefits and costs of different uses of saltmarsh can be fully compared.

While North America and Europe are the sites of over 60% of the saltmarsh valuations relating to active recreation, non-consumptive cultural services remain poorly quantified in both regions, despite a strong history of non-market valuation. Cultural services are perhaps the most complex ES to value, yet there seems to be some avenues that have not been fully exploited in terms of saltmarsh ESV. Birdwatching is an established passive recreational activity and has been valued on saltmarshes in Australia (Carnell *et al*. 2019), yet not in any other locations. Saltmarshes are important sites for migratory wildfowl; in Ireland for example, the North Bull Island saltmarsh in Co. Dublin was the first designated bird sanctuary in the. country (Lewis 2019). As an activity it should prove amenable to established methods of valuation such as travel cost and choice modelling and could be an avenue for future research

The importance of saltmarsh in terms of culture, heritage and existence value is something that has also been poorly addressed by valuations to date. This may be a hangover related to the traditional dominant view of saltmarshes (and wetlands in general) as wastelands (Barbier *et al*. 1997; Gedan *et al*. 2009), yet effort should be made to understand this value. A Welsh study found that saltmarsh owners were aware of the economic and ecological benefits related to saltmarshes, but also expressed a deep personal connection to the saltmarshes, with one interviewee describing saltmarsh as a "magical sort of piece [of land]", illustrating the possible cultural, heritage and spiritual values this land may have for them (McKinley *et al*. 2022). These values are frequently disregarded in the decision-making process, yet an increased effort should be made to understand them as they may have a significant impact on human well-being.

The link between non-consumptive cultural activities and seagrass is also poorly quantified. Dewsbury *et al*. (2016) suggested that as activities such as scuba-diving, snorkeling, and boating are popular in areas with healthy coral reefs, the relationship between seagrass beds and coral reefs should be analyzed to estimate the contribution of seagrass to of these activities. Although WTP among divers to visit a seagrass site was estimated by Kenter *et al*. (2013), this was not the main

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focus of their study. Linking non-consumptive recreational activities and seagrasses is an area where more research is needed. There are other links to cultural services that are poorly understood. The historical use of seagrass fibers as a raw material - documented by Curtis (2003), and Wyllie-Echeverria and Cox (1999) - indicates it may have significance for heritage in areas where this practice used to be the norm. Spiritual and cultural values are likely to be very important for indigenous communities, but quantifying their economic value is extremely difficult (Sangha *et al*. 2019). While Sangha *et al*. (2019) estimate a general cultural value for marine and coastal ecosystems, it cannot be linked specifically to either of our ecosystems of interest. Similarly, Trégarot *et al.* (2020a) estimate a heritage value based on the relationship between the indigenous community of the National Park of Banc d'Arguin, Mauritania and their local fishery, which depends on the ecosystems of the park. Again, linking this value to one particular ecosystem is problematic, as the fishery is maintained by several interlinking services and ecosystems. The inherent complexity of valuing cultural ES for seagrass should not mean that it is disregarded. As public awareness of the role of seagrass grows it will be interesting to see how WTP for conservation of these ecosystems' changes in future research.

Future avenues for research could build on the non-market valuations for aquatic and coastal ecosystems. It has been shown that the people are willing to pay to improve water quality (Doherty *et al*. 2014), and recreationalists have preferences for improving the quality status of bathing water (Hynes, Tinch, *et al*. 2013). The relationship between the seagrass and saltmarsh and water quality, through their filtration and bio-remediation services, indicates non-market valuation relating to water quality may be a means to value these services. Another pathway to valuation relates to the fact that extreme weather events on our coasts are now a regular occurrence, and it's predicted that by 2030 approximately 11% of the global population will be living in low-elevation coastal zones[2] and at risk of flooding (Neumann *et al*. 2015). The coastal defense and flood protection services of saltmarsh and seagrass, given the high concentration of coastal activity and the increased climate pressures, may be significant but this service remains undervalued for seagrasses. Finally, coastal communities have been found to have a respect for the marine environment and an outlook that champions the

[2] Low-elevation coastal zones (LCEZ) are commonly defined as areas along the coast that below 10 m of elevation and are contiguous and hydrologically connected (Neumann *et al.*, 2015).

conservation of marine ecosystems (Farrell *et al*. 2017), and future valuation of the associated cultural services should account for these perspectives.

5. CONCLUSION

ESV of saltmarsh and seagrass ecosystems began in the 1970s and 80s respectively. In total, 162 studies were identified in this review that value these ecosystems. While saltmarsh valuation studies have been increasing steadily, the last 10 years has seen a comparatively large increase in the number of valuation studies for seagrass, possibly driven by the recent recognition of their importance as a blue carbon habitat. Research is spread unevenly across the globe, with hardly any valuation studies found in South America. Saltmarsh valuation studies have been concentrated in the US and the UK, and Australia is a hotspot for seagrass studies. Studies valuing climate regulation – the blue carbon aspect – have grown in recent years with 41 seagrass studies and 26 saltmarsh studies valuing this service.

The value of carbon sequestration in seagrasses ranges from \$8 ha^{-1} y^{-1} in the Northern Territories of Australia, (Sangha *et al.*, 2019) to \$1,146 ha^{-1} y^{-1} in the Datça-Bozburun peninsulas in Turkey (Bann and Başak 2013). The range for saltmarsh is similar, from \$3 ha^{-1} y^{-1} in Bhitharkanika, India (Dhivya *et al*. 2023), to \$1,540 ha^{-1} in the Southeast Coast of the UK (S.C.L. Watson *et al*. 2022). These large ranges stem from differences in sequestration rates and the carbon price used. The reliability of these estimates depends also on whether field samples or literature reviews have been used to inform sequestration and storage figures.

Apart from climate regulation, the most frequently studied services for seagrass were the contribution to commercial fisheries and maintaining nursery habitats, services which are clearly linked. Direct market valuation of commercial fisheries using market prices for fish was the main method used to value this service. The prices were adjusted to reflect the contribution of seagrass to the fishery through different methods. Values calculated using market prices for this service ranged from \$14 ha^{-1} y^{-1} (Jackson *et al*. 2015) to \$742 ha^{-1} y^{-1} (Unsworth *et al*. 2010). Maintaining nursery habitats was valued using market prices as well, but the prices were adjusted to reflect the importance of the nursery habitat specifically. This service appeared to be more valuable, as estimates ranged from \$140 ha^{-1} y^{-1} (Erzini *et al*. 2022) to \$22,788 ha^{-1} y^{-1} (Blandon and zu Ermgassen 2014). While it is understood that the link between seagrass and fisheries is significant on a global

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level, ecological data on the abundance and distribution of fish in seagrass meadows is still lacking in some regions to be able to clearly quantify the value of this service (Nordlund *et al*. 2018).

The most frequently studied services for saltmarsh were active recreation and coastal protection. Coastal protection was valued using cost methods and stated preference methods. The values of coastal protection estimated using replacement costs ranged from \$1,257 ha^{-1} (Sun *et al*. 2017) to \$772,004 ha^{-1} (S.E. King and Lester 1995). Annual per hectare values estimated using damage cost avoided methods were generally lower – avoided flood damages through the presence of saltmarshes in the Scheide estuary were estimated at 9,872 ha^{-1} y^{-1}(Boerema *et al*. 2016). Updating these figures with primary data would be useful, as it was estimated using benefit transfer methods originally.

Active recreation was estimated using travel cost methods and contingent valuation, and the activities valued included recreational fishing, birdwatching, and tourist visits to saltmarsh sites. These valuation methods have been used extensively to value recreation at terrestrial sites, but similar to many other marine ecosystems they have seen only limited use for recreation taking place in and around saltmarshes and especially seagrasses. Given the importance of saltmarshes to birdwatchers, and the existence of strong birdwatching organizations in many countries, surveying these organization members could be a means to value these blue carbon sites. In general, non-consumptive cultural services are not often valued in the literature, especially for seagrass (Dewsbury *et al*. 2016).

Despite the traditional perception of wetlands as wastelands (Barbier *et al*. 1997), there is a growing appreciation and an associated body of literature on the value of saltmarshes and seagrasses. Valuation efforts could be enhanced further by documenting the ongoing changes in the condition of the blue ecosystem area being valued and by expanding the range of cultural services being studied. Global efforts to develop a coherent system of natural capital accounting as part of the UN SEEA framework, with associated ecosystem extent, condition and service accounts, should assist in this regard. Improving the extent and condition of these ecosystems will have economic costs, and it will be important from a policy perspective to have reliable estimates on the ecosystem service benefits from any restoration/conservation to compare to those costs. Information on these benefit values is also important in terms of the development of practical solutions for the financing of blue carbon ecosystem projects.

Table 9: Saltmarsh and seagrass services identified and valued in the literature, by method

Services	CICES Code	Saltmarsh	Seagrass	MP		DC		RC		TC		PF		HM		CV		CM		BT		RA		C	
Food grown by humans	1.1.1.1	✓		1																					
Reared animals	1.1.3.1	✓		3																1					
Aquaculture	1.1.4.1	✓	✓		2															1					
Materials from wild plants	1.1.5.2	✓	✓	2	1				1											2	2	1			
Food from wild animals	1.1.6.1	✓✓✓	✓✓✓	10	21		1					4	5			1		3	1	4	5	1			
Decomposing wastes	2.1.1.1	✓✓	✓			1	1	3	1											4	3	1			
Filtering wastes	2.1.1.2	✓✓	✓✓			1		5	4									1	1	7	11	1	1		
Controlling erosion rates	2.2.1.1	✓	✓				1													2	3	1			
Regulating flows of water	2.2.1.3	✓✓✓	✓✓			5	1	4	2							2		7	2	12	2	1			
Pollination	2.2.2.1	✓				1																			
Providing habitats	2.2.2.3	✓✓✓	✓✓✓	1	6				1			2	1			1	1	8	6	5	5	1	1		
Disease control	2.2.3.2	✓																1							
Seawater quality	2.2.5.2		✓✓		1														5		2				
Climate regulation	2.2.6.1	✓✓✓	✓✓✓														1	3	2	4	5		1	20	35
Active recreation	3.1.1.1	✓✓✓	✓✓✓	2	1					5	2	1				4	3	4	7	14	3	1			
Passive recreation	3.1.1.2	✓	✓		2													4	2	2	1				
Researching nature	3.1.2.1	✓	✓		2												1	1			1	1			
Cultural and heritage value	3.1.2.3																			1		1			
Aesthetic value	3.1.2.4	✓	✓		1									1				1		2					
Existence value	3.2.2.1	✓✓	✓✓✓													3	4	2	7	2	2				

Note: ✓ indicates less than 5 primary valuations found in the literature, ✓✓ indicates 5-10 primary valuations found in the literature, ✓✓✓ indicated over 10 valuations found in the literature. MP=adjusted market prices, DC=damage cost avoided, RC=replacement costs, TC=travel costs, PF=production function, HM=hedonic modelling, CV=contingent valuation, CM=choice modelling, BT=benefit transfer, RA=rapid ecosystem assessment, C=carbon calculation methods. Dark grey indicates method used for saltmarsh, light grey indicates method used for seagrass. Numbers refer to numbers of studies.

https://cbe.miis.edu/joce/vol10/iss1/2
DOI: 10.15351/2373-8456.1174

References

Alldred, Mary, and Stephen B. Baines. 2016. "Effects of wetland plants on denitrification rates: a meta-analysis." *Ecological applications* 26 (3): 676-685. https://doi.org/10.1890/14-1525.

Anderson, Eric. E. 1989. "Economic Benefits of Habitat Restoration: Seagrass and the Virginia Hard-Shell Blue Crab Fishery " *North American Journal of Fisheries Management* 9: 140-149. https://doi.org/10.1577/1548-8675(1989)009<0140:EBOHRS>2.3.CO;2.

Antinori, Camille M. 2021. "Eelgrass Restoration in San Francisco Bay: An Interdisciplinary Stated Preference Classroom Experiment." *Journal of Ocean and Coastal Economics* 8 (1): 1. https://doi.org/10.15351/2373-8456.1133.

Arias, P.A., N Bellouin, E Coppola, R.G. Jones, G. Krinner, J Marotzke, V Naik, M.D. Palmer, G-K Plattner, J Rogelj, M Rojas, J Sillmann, T Storelvmo, P.W Thorne, B Trewin, K Achuta Rao, B Adhikary, R.P. Allan, K. Armour, G Bala, R Barimalala, S Berger, J.G. Canadell, C Cassou, A Cherchi, W Collins, W.D. Collins, S.L. Connors, S Corti, F Cruz, F.J. Dentener, C Dereczynski, A Di Luca, A Diongue Niang, F.J. Doblas-Reyes, A Dosio, H Douville, F Engelbrecht, V Eyring, E Fischer, P Forster, B Fox-Kemper, J.S. Fuglestvedt, J.C. Fyfe, N.P. Gillett, L Goldfarb, I Gorodetskaya, J.M. Gutierrez, R Hamdi, E Hawkins, H.T. Hewitt, P Hope, A.S. Islam, C Jones, D.S. Kaufman, R.E. Kopp, Y Kosaka, J Kossin, S Krakovska, J-Y Lee, J Li, T Mauritsen, T.K Maycock, M Meinshausen, S-K Min, P.M.S. Monteiro, T Ngo-Duc, F Otto, I Pinto, A Pirani, K Raghavan, R Ranasinghe, A.C. Ruane, L Ruiz, J-B Sallée, B.H. Samset, S Sathyendranath, S.I. Seneviratne, A.A. Sörensson, S Szopa, I Takayabu, A-M Tréguier, B van den Hurk, R Vautard, K von Schuckmann, S Zaehle, X Zhang, and K Zickfeld. 2021. "Technical Summary " In *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by V. Masson-Delmotte, P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou, 33-144. Cambridge, United Kingdom and New York, NY, USA.

Ascioti, Fortunato A., Maria Cristina Mangano, Claudio Marcianò, and Gianluca Sarà. 2022. "The sanitation service of seagrasses – Dependencies and implications for the estimation of avoided costs." *Ecosystem services* 54: 101418. https://doi.org/10.1016/j.ecoser.2022.101418.

Balata, Gavino, and Alessio Tola. 2018. "Cost-opportunity analysis of the use of Posidonia oceanica as a source of bio-energy in tourism-oriented territories. The case of Alghero." *Journal of cleaner production* 172: 4085-4098. https://doi.org/10.1016/j.jclepro.2017.02.072.

Bann, C, and E Başak. 2013. *Economic Analysis of Datça-Bozburun Special Environmental Protection Area. Project PIMS 3697.* (Turkey: UNDP).

Bañolas, G., S. Fernández, F. Espino, R. Haroun, and F. Tuya. 2020. "Evaluation of carbon sinks by the seagrass Cymodocea nodosa at an oceanic island: Spatial variation and economic valuation." *Ocean & Coastal Management* 187: 105112. https://doi.org/10.1016/j.ocecoaman.2020.105112.

Barañano, Carlota, Gonzalo Méndez, María Isabel Míguez, and Emilio Fernández. 2022. "Enhancing recognition of seagrass ecosystems through communication planning based on historical and present social perception studies." *Marine policy* 146. https://doi.org/10.1016/j.marpol.2022.105296.

Barbier, Edward B. 2007. "Valuing ecosystem services as productive inputs." *Economic policy* 22 (49): 177-229. https://doi.org/10.1111/j.1468-0327.2007.00174.x.

---. 2016. "The protective service of mangrove ecosystems: A review of valuation methods." *Marine Pollution Bulletin* 109 (2): 676-681. https://doi.org/10.1016/j.marpolbul.2016.01.033.

Barbier, Edward B., Mike Acreman, and Duncan Knowler. 1997. "Economic valuation of wetlands: a guide for policy makers and planners."

Barracosa, Helena, Carmen B. De Los Santos, Ma Rcio Martins, Ca Tia Freitas, and Rui Santos. 2019. "Ocean literacy to mainstream ecosystem services concept in formal and informal education: the example of coastal ecosystems of southern Portugal." *Frontiers in Marine Science* 6. https://doi.org/10.3389/fmars.2019.00626.

Bateman, Ian J., Diane Burgess, W. George Hutchinson, and David I. Matthews. 2008. "Learning design contingent valuation (LDCV): NOAA guidelines, preference learning and coherent arbitrariness." *Journal of environmental economics and management* 55 (2): 127-141. https://doi.org/10.1016/j.jeem.2007.08.003.

Bateman, Ian J., Georgina M. Mace, Carlo Fezzi, Giles Atkinson, and Kerry Turner. 2011. "Economic Analysis for Ecosystem Service Assessments." *Environmental & resource economics* 48 (2): 177-218. https://doi.org/10.1007/s10640-010-9418-x.

Batker, David, Maya Kocian, Briana Lovell, and Jennifer Harrison-Cox. 2010. *Flood protection and ecosystem services in the Chehalis River Basin.* Earth Economics (WA, USA: Chehalis River Basin Authority).

Bauer, Dana Marie, Nicole E. Cyr, and Stephen K. Swallow. 2004. "Public preferences for compensatory mitigation of salt marsh losses: A contingent choice of alternatives." *Conservation biology* 18 (2): 401-411. https://doi.org/10.1111/j.1523-1739.2004.00367.x.

Beaumont, N. J., L. Jones, A. Garbutt, J. D. Hansom, and M. Toberman. 2014. "The value of carbon sequestration and storage in coastal habitats." *Estuarine, coastal and shelf science* 137 (1): 32-40. https://doi.org/10.1016/j.ecss.2013.11.022.

Bell, Frederick W. 1997. "The economic valuation of saltwater marsh supporting marine recreational fishing in the southeastern United States." *Ecological economics* 21 (3): 243-254. https://doi.org/10.1016/S0921-8009(96)00105-X.

Bennett, Michael T., Yazhen Gong, and Riccardo Scarpa. 2018. "Hungry birds and angry farmers: Using choice experiments to assess "eco-compensation" for coastal wetlands protection in China." *Ecological economics* 154: 71-87. https://doi.org/10.1016/j.ecolecon.2018.07.016.

Bergstrom, John C., John R. Stoll, John P. Titre, and Vernon L. Wright. 1990. "Economic value of wetlands-based recreation." *Ecological economics* 2 (2): 129-147. https://doi.org/10.1016/0921-8009(90)90004-E.

Blackwell, Boyd Dirk. 2006. "The Economic Value of Australia's Natural Coastal Assests: Some Preliminary Findings." Australia New Zealand Society for Ecological Economics 2005 Conference Proceedings, Massey University, New Zealand.

Blandon, Abigayil, and Philine S. E. zu Ermgassen. 2014. "Quantitative estimate of commercial fish enhancement by seagrass habitat in southern Australia." *Estuarine, coastal and shelf science* 141: 1-8. https://doi.org/10.1016/j.ecss.2014.01.009.

Blue Carbon Initiative. 2015. *Guidance for national blue carbon activities.*

Boerema, Annelies, Lindsay Geerts, Lotte Oosterlee, Stijn Temmerman, and Patrick Meire. 2016. "Ecosystem service delivery in restoration projects: the effect of ecological succession on the benefits of tidal marsh restoration." *Ecology and Society* 21 (2). https://doi.org/10.5751/ES-08372-210210.

Boerema, Annelies, Alanna J. Rebelo, Merche B. Bodi, Karen J. Esler, Patrick Meire, and Jason Rohr. 2017. "Are ecosystem services adequately quantified?" *The Journal of applied ecology* 54 (2): 358-370. https://doi.org/10.1111/1365-2664.12696.

Börger, Tobias, and Joanna Piwowarczyk. 2016. "Assessing non-market benefits of seagrass restoration in the Gulf of Gdansk." *Journal of Ocean and Coastal Economics* 3 (1). https://doi.org/10.15351/2373-8456.1034.

Breaux, Andree, Stephen Farber, and John Day. 1995. "Using natural coastal wetlands systems for wastewater treatment: an economic benefit analysis." *Journal of environmental management* 44 (3): 285-291. https://doi.org/10.1006/jema.1995.0046.

Bundal, Kristine Shiela, Rodelio Subade, and Roald Ray Taperla. 2018. "Willingness to pay of households for conservation of seagrasses in Nueva Valencia, Guimaras, Philippines." *Asian Fisheries Society*. https://doi.org/10.33997/j.afs.2018.31.4.005.

Burke, Shannon, Sadhbh McCarrick, Elke Eichelmann, and Grace Cott. 2021. "Assessment of Blue Carbon Stocks of North Bull Island, Dublin, Ireland." 16th SWS Europe Chapter conference.

Camacho-Valdez, Vera, Arturo Ruiz-Luna, Andrea Ghermandi, and Paulo A. L. D. Nunes. 2013. "Valuation of ecosystem services provided by coastal wetlands in northwest Mexico." *Ocean & coastal management* 78: 1-11. https://doi.org/10.1016/j.ocecoaman.2013.02.017.

Campagne, Carole Sylvie, Jean-Michel Salles, Pierre Boissery, and Julie Deter. 2015. "The seagrass Posidonia oceanica: Ecosystem services identification and economic evaluation of goods and benefits." *Marine pollution bulletin* 97 (1-2): 391-400. https://doi.org/10.1016/j.marpolbul.2015.05.061.

Carleton, Tamma A, and Solomon M Hsiang. 2016. "Social and economic impacts of climate." *Science* 353 (6304): aad9837. https://doi.org/10.1126/science.aad9837.

Carnell, P.E, S.E Reeves, E. Nicholson, P. Macreadie, D. Ierodiaconou, M. Young, J. Kelvin, H. Janes, A. Navarro, J. Fitzsimons, and C.L. Gillies. 2019. *Mapping Ocean Wealth Australia: The value of coastal wetlands to people and nature.* (Melbourne, Australia). https://www.bluecarbonlab.org/our-research/ecosystem-services/.

Carr, Edward W., Yosef Shirazi, George R. Parsons, Porter Hoagland, and Christopher K. Sommerfield. 2018. "Modeling the economic value of blue carbon in Delaware estuary wetlands: historic estimates and future projections." *Journal of environmental management* 206: 40-50. https://doi.org/10.1016/j.jenvman.2017.10.018.

Chen, Zhenshan, Stephen K Swallow, and Ian T Yue. 2020. "Non-participation and heterogeneity in stated: A double hurdle latent class approach for climate change adaptation plans and ecosystem services." *Environmental and Resource Economics* 77: 35-67. https://doi.org/10.1007/s10640-020-00434-z.

Chitará-Nhandimo, Sádia, Assucena Chissico, Marlino Eugénio Mubai, António de Sacramento Cabral, Almeida Guissamulo, and Salomão Bandeira. 2022. "Seagrass invertebrate fisheries, their value chains and the role of LMMAs in sustainability of the coastal communities—case of southern Mozambique." *Diversity* 14 (3): 170. https://doi.org/10.3390/d14030170.

Christie, Mike, and Matt Rayment. 2012. "An economic assessment of the ecosystem service benefits derived from the SSSI biodiversity conservation policy in England and Wales." *Ecosystem services* 1 (1): 70-84. https://doi.org/10.1016/j.ecoser.2012.07.004.

Cole, Anthony Owen, me ōna tupuna, D Clark, and MG Patterson. 2014. *Towards a 'total economic value' of coastal marine ecosystem services in Nelson Bays, Nelson Tasman region, New Zealand.* iPansophy Limited (Tauranga, New Zealand).

Cole, Scott G, and Per-Olav Moksnes. 2016. "Valuing multiple eelgrass ecosystem services in Sweden: fish production and uptake of carbon and nitrogen." *Frontiers in Marine Science* 2: 121. https://doi.org/10.3389/fmars.2015.00121.

Costanza, Robert, Ralph d'Arge, Rudolf de Groot, Stephen Farber, Monica Grasso, Bruce Hannon, Karin Limburg, Shahid Naeem, Robert V. O'Neill, Jose Paruelo, Robert G. Raskin, Paul Sutton, and Marjan van den Belt. 1997. "The value of the world's ecosystem services and natural capital." *Nature* 387 (6630): 253-260. https://doi.org/10.1016/S0921-8009(98)00020-2.

Costanza, Robert, Rudolf de Groot, Paul Sutton, Sander van der Ploeg, Sharolyn J. Anderson, Ida Kubiszewski, Stephen Farber, and R. Kerry Turner. 2014. "Changes in the global value of ecosystem services." *Global environmental change* 26: 152-158. https://doi.org/10.1016/j.gloenvcha.2014.04.002.

Costanza, Robert, Stephen C. Farber, and Judith Maxwell. 1989. "Valuation and management of wetland ecosystems." *Ecological economics* 1 (4): 335-361. https://doi.org/10.1016/0921-8009(89)90014-1.

Cott, Grace, Pedro Beca-Carretero, and Dagmar Stengel. 2021. *Blue Carbon and Marine Carbon Sequestration in Irish Waters and Coastal Habitats.* (Ireland: Marine Institute).
Curtis, T. G. F. 2003. "Salt marshes." In *Wetlands of Ireland: distribution, ecology, uses and economic value*, edited by Marinus L. Otte. Dublin, Ireland: University College Dublin Press.
Curtis, T. G. F., and M. J. Sheehy Skeffington. 1998. "The salt marshes of Ireland: An inventory and account of their geographical variation." *Biology and environment: proceedings of the Royal Irish Academy* 98B (2): 87-104. http://www.jstor.com/stable/20500023.
Czúcz, Bálint, Ildikó Arany, Marion Potschin-Young, Krisztina Bereczki, Miklós Kertész, Márton Kiss, Réka Aszalós, and Roy Haines-Young. 2018. "Where concepts meet the real world: A systematic review of ecosystem service indicators and their classification using CICES." *Ecosystem services* 29: 145-157. https://doi.org/10.1016/j.ecoser.2017.11.018.
Davidson, Kate E., Mike S. Fowler, Martin W. Skov, Stefan H. Doerr, Nicola Beaumont, John N. Griffin, and Joseph Bennett. 2017. "Livestock grazing alters multiple ecosystem properties and services in salt marshes: a meta-analysis." *The Journal of applied ecology* 54 (5): 1395-1405. https://doi.org/10.1111/1365-2664.12892.
de Groot, Rudolf S., Luke Brander, Sander van der Ploeg, Robert Costanza, Florence Bernard, Leon Braat, Mike Christie, Neville Crossman, Andrea Ghermandi, Lars Hein, Salman Hussain, Pushpam Kumar, Alistair McVittie, Rosimeiry Portela, Luis C. Rodriguez, Patrick ten Brink, and Pieter van Beukering. 2012. "Global estimates of the value of ecosystems and their services in monetary units." *Ecosystem services* 1 (1): 50-61. https://doi.org/10.1016/j.ecoser.2012.07.005.
de Groot, Rudolf S., Matthew A. Wilson, and Roelof M. J. Boumans. 2002. "A typology for the classification, description and valuation of ecosystem functions, goods and services." *Ecological economics* 41 (3): 393-408. https://doi.org/10.1016/S0921-8009(02)00089-7.
de la Torre-Castro, Maricela, Giuseppe Di Carlo, and Narriman S. Jiddawi. 2014. "Seagrass importance for a small-scale fishery in the tropics: The need for seascape management." *Marine Pollution Bulletin* 83 (2): 398-407. https://doi.org/10.1016/j.marpolbul.2014.03.034.
de la Torre-Castro, Maricela, and P. Ronnback. 2004. "Links between humans and seagrasses—an example from tropical East Africa." *Ocean & coastal management* 47 (7): 361-387. https://doi.org/10.1016/j.ocecoaman.2004.07.005.
de los Santos, Carmen, D. Krause-Jensen, T. Alcoverro, N. Marba, C. M. Duarte, Marieke M. van Katwijk, Juan J. Vergara, and R. Santos. 2019. "Recent trend reversal for declining European seagrass meadows." *Nature communications* 10 (1): 3356-8. https://doi.org/10.1038/s41467-019-11340-4.
de los Santos, Carmen, Abbi Scott, Ariane Arias-Ortiz, Benjamin Jones, Hilary Kennedy, Ines Mazarrasa, Len McKenzie, Lina Nordlund, Maricela Torre-Castro, Richard Unsworth, and Rohani Ambo Rappe. 2020. "Seagrass ecosystem services: Assessment and scale of benefits." Nairobi: UNEP.
DECC. 2011. A brief guide to the carbon valuation methodology for UK policy appraisal. edited by Department for Energy and Climate Change. London.
Deegan, Linda A., David Samuel Johnson, R. Scott Warren, Bruce J. Peterson, John W. Fleeger, Sergio Fagherazzi, and Wilfred M. Wollheim. 2012. "Coastal eutrophication as a driver of salt marsh loss." *Nature (London)* 490 (7420): 388-392. https://doi.org/10.1038/nature11533.
Dewsbury, Bryan M., Mahadev Bhat, and James W. Fourqurean. 2016. "A review of seagrass economic valuations: Gaps and progress in valuation approaches." *Ecosystem services* 18: 68-77. https://doi.org/10.1016/j.ecoser.2016.02.010.
Dhivya, S, N Karthi, S Balamurugan, and Devaraj Asir Ramesh. 2023. "Chapter 4 - Valuing ecologically sensitive area's ecosystem services in Bhitharkanika: implications for sustainable management." In *Water, Land, and Forest Susceptibility and Sustainability*,

https://cbe.miis.edu/joce/vol10/iss1/2
DOI: 10.15351/2373-8456.1174

edited by Uday Chatterjee, Biswajeet Pradhan, Suresh Kumar, Sourav Saha, Mohammad Zakwan, Brian D. Fath and Dan Fiscus, 97-122. Academic Press.

Dirhamsyah. 2007. "An economic valuation of seagrass ecosystems in East Bintan, Riau Archilpelago, Indonesia." *Oseanologi dan Limnologi di Indonesia* 33: 257-270. https://www.yumpu.com/en/document/read/32161861/an-economic-valuation-of-seagrass-ecosystems-lipi.

Doherty, Edel, Geraldine Murphy, Stephen Hynes, and Cathal Buckley. 2014. "Valuing ecosystem services across water bodies: Results from a discrete choice experiment." *Ecosystem Services* 7: 89-97. https://doi.org/10.1016/j.ecoser.2013.09.003.

dos Santos, Carla Marisa Teixeira. 2018. "Economic value of blue carbon: challenges and opportunities for Portuguese coastal habitats." Masters in Environmental Economics and Management, Faculdade de Economia, Universidade do Porto.

Duarte, Carlos M. 2002. "The future of seagrass meadows." *Environmental conservation* 29 (2): 192-206. https://doi.org/10.1017/S0376892902000127.

---. 2017. "Reviews and syntheses: Hidden forests, the role of vegetated coastal habitats in the ocean carbon budget." *Biogeosciences* 14 (2): 301-310. https://doi.org/10.5194/bg-14-301-2017.

Duarte, Carlos M, J. J. Middelburg, and N. Caraco. 2005. "Major role of marine vegetation on the oceanic carbon cycle." *Biogeosciences* 2 (1): 1-8. https://doi.org/10.5194/bg-2-1-2005.

Duijndam, Sem, Pieter van Beukering, Hanna Fralikhina, Anne Molenaar, and Mark Koetse. 2020. "Valuing a Caribbean coastal lagoon using the choice experiment method: The case of the Simpson Bay Lagoon, Saint Martin." *Journal for nature conservation* 56: 1-12. https://doi.org/10.1016/j.jnc.2020.125845.

Dulvy, Nicholas K., Nathan Pacoureau, Cassandra L. Rigby, Riley A. Pollom, Rima W. Jabado, David A. Ebert, Brittany Finucci, Caroline M. Pollock, Jessica Cheok, Danielle H. Derrick, Katelyn B. Herman, C. Samantha Sherman, Wade J. VanderWright, Julia M. Lawson, Rachel H. L. Walls, John K. Carlson, Patricia Charvet, Kinattumkara K. Bineesh, Daniel Fernando, Gina M. Ralph, Jay H. Matsushiba, Craig Hilton-Taylor, Sonja V. Fordham, and Colin A. Simpfendorfer. 2021. "Overfishing drives over one-third of all sharks and rays toward a global extinction crisis." *Current biology* 31 (21): 4773-4787.e8. https://doi.org/10.1016/j.cub.2021.08.062.

Dunic, Jillian C, Christopher J Brown, Rod M Connolly, Mischa P Turschwell, and Isabelle M Côté. 2021. "Long-term declines and recovery of meadow area across the world's seagrass bioregions." *Global change biology* 27 (17): 4096-4109. https://doi.org/10.1111/gcb.15684.

Dusenge, M. E., A. G. Duarte, and D. A. Way. 2019. "Plant carbon metabolism and climate change: elevated CO(2) and temperature impacts on photosynthesis, photorespiration and respiration." *New Phytol* 221 (1): 32-49. https://doi.org/10.1111/nph.15283.

Earnhart, D. 2001. "Combining revealed and stated preference methods to value environmental amenities at residential locations." *Land economics* 77 (1): 12-29. https://doi.org/10.2307/3146977.

El Zrelli, Radhouan, Ahlem Hcine, Lamia Yacoubi, Ruben H. Roa-Ureta, Nicola Gallai, Sylvie Castet, Michel Grégoire, Pierre Courjault-Radé, and Lotfi Jilani Rabaoui. 2023. "Economic losses related to the reduction of Posidonia ecosystem services in the Gulf of Gabes (Southern Mediterranean Sea)." *Marine Pollution Bulletin* 186: 114418. https://doi.org/10.1016/j.marpolbul.2022.114418.

Emadodin, Iraj, Thorsten Reinsch, Ana Rotter, Martina Orlando-Bonaca, Friedhelm Taube, and Jamileh Javidpour. 2020. "A perspective on the potential of using marine organic fertilizers for the sustainable management of coastal ecosystem services." *Environmental Sustainability* 3 (1): 105-115. https://doi.org/10.1007/s42398-020-00097-y.

Emerton, Lucy, and L.D.C.B Kekulandala. 2003. Assessment of the Economic Value of Muthurajawela Wetland. Sri Lanka: IUCN.

Environment and Climate Change Canada. 2022. "Environmental Valuation Reference Inventory (EVRI)." Accessed 04-Nov-2022. https://www.evri.ca/.

Erzini, Karim, Filipe Parreira, Zineb Sadat, Margarida Castro, Luís Bentes, Rui Coelho, Jorge M. S. Gonçalves, Pedro G. Lino, Begoña Martinez-Crego, Pedro Monteiro, Frederico Oliveira, Joaquim Ribeiro, Carmen B. de los Santos, and Rui Santos. 2022. "Influence of seagrass meadows on nursery and fish provisioning ecosystem services delivered by Ria Formosa, a coastal lagoon in Portugal." *Ecosystem services* 58. https://doi.org/10.1016/j.ecoser.2022.101490.

European Commission. 2000. EU Water Framework Directive (WFD) In *Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for Community action in the field of water policy*, edited by European Parliament. Official Journal (OJ L 327): European Comission.

Failler, Pierre, Élise Pètre, Thomas Binet, and Jean-Philippe Maréchal. 2015. "Valuation of marine and coastal ecosystem services as a tool for conservation: The case of Martinique in the Caribbean." *Ecosystem services* 11: 67-75. https://doi.org/10.1016/j.ecoser.2014.10.011.

Farley, Joshua. 2012. "Ecosystem services: The economics debate." *Ecosystem services* 1 (1): 40-49. https://doi.org/10.1016/j.ecoser.2012.07.002.

Farrell, Desiree, Liam Carr, and Frances Fahy. 2017. "On the subject of typology: How Irish coastal communities' subjectivities reveal intrinsic values towards coastal environments." *Ocean & Coastal Management* 146: 135-143. https://doi.org/10.1016/j.ocecoaman.2017.06.017.

Feagin, Rusty A., M. Luisa Martinez, Gabriela Mendoza-Gonzalez, and Robert Costanza. 2010. "Salt marsh zonal migration and ecosystem service change in response to global sea level rise: A case study from an urban region." *Ecology and society* 15 (4): 14. https://doi.org/10.5751/ES-03724-150414.

Fernández, Emilio, Carlota Baranano, Sebastián Villasante, and Gonzalo Méndez. 2022. "Historical evolution of the social perception on ecosystem services provided by seagrasses through analysis of the written press in North West Spain (1860–2020)." *Ocean & Coastal Management* 216: 105983. https://doi.org/10.1016/j.ocecoaman.2021.105983.

Field, Christopher B., and Katharine J. Mach. 2017. "Rightsizing carbon dioxide removal." *Science (American Association for the Advancement of Science)* 356 (6339): 706-707. https://doi.org/10.1126/science.aam9726.

Fisher, Brendan, R. Kerry Turner, and Paul Morling. 2009. "Defining and classifying ecosystem services for decision making." *Ecological economics* 68 (3): 643-653. https://doi.org/10.1016/j.ecolecon.2008.09.014.

Foundation for Sustainable Development. 2021. Ecosystem Services Valuation Database (ESVD).

Fourqurean, J., C. Duarte, H. Kennedy, and NHolmer Marbà, M Mateo, MAApostolaki, E.T.Kendrick, G.AKrause-Jensen, D McGlathery K.J Serrano, O. 2012. "Seagrass ecosystems as a globally significant carbon stock." 5: 505-509. https://doi.org/10.1038/ngeo1477.

Franzese, Pier Paolo, Elvira Buonocore, Luigia Donnarumma, and Giovanni F. Russo. 2017. "Natural capital accounting in marine protected areas: The case of the Islands of Ventotene and S. Stefano (Central Italy)." *Ecological modelling* 360: 290-299. https://doi.org/10.1016/j.ecolmodel.2017.07.015.

Fredriksen, Stein, Hartvig Christie, and Christoffer Boström. 2004. "Deterioration of eelgrass (Zostera marina L.) through destructive grazing by the gastropod Rissoa membranacea (J. Adams)." *Sarsia* 89 (3): 218-222. https://doi.org/10.1080/00364820410005593.

Fulford, Richard, David Yoskowitz, Marc Russell, Darrin Dantin, and John Rogers. 2016. "Habitat and recreational fishing opportunity in Tampa Bay: Linking ecological and ecosystem services to human beneficiaries." *Ecosystem services* 17: 64-74. https://doi.org/10.1016/j.ecoser.2015.11.009.

Ganguly, D., G. Singh, R. Purvaja, R. Bhatta, A. Paneer Selvam, K. Banerjee, and R. Ramesh. 2018. "Valuing the carbon sequestration regulation service by seagrass ecosystems of

https://cbe.miis.edu/joce/vol10/iss1/2
DOI: 10.15351/2373-8456.1174

Palk Bay and Chilika, India." *Ocean & coastal management* 159: 26-33. https://doi.org/10.1016/j.ocecoaman.2017.11.009.
Garrard, Samantha L., and Nicola J. Beaumont. 2014. "The effect of ocean acidification on carbon storage and sequestration in seagrass beds a global and UK context." *Marine pollution bulletin* 86 (1-2): 138-146. https://doi.org/10.1016/j.marpolbul.2014.07.032.
Gaylard, Sam, Stefan Gabrynowicz, Paul Lavery, and Michelle Waycott. 2023. "Contribution of seagrass productivity to waste treatment in a highly oligotrophic urbanised coast." *Ecosystem Services* 62: 101534. https://doi.org/10.1016/j.ecoser.2023.101534.
Gedan, Keryn B., Matthew L. Kirwan, Eric Wolanski, Edward B. Barbier, and Brian R. Silliman. 2010. "The present and future role of coastal wetland vegetation in protecting shorelines: answering recent challenges to the paradigm." *Climatic change* 106 (1): 7-29. https://doi.org/10.1007/s10584-010-0003-7.
Gedan, Keryn B., B. R. Silliman, and M. D. Bertness. 2009. "Centuries of human-driven change in salt marsh ecosystems." *Annual review of marine science* 1 (1): 117-141. https://doi.org/10.1146/annurev.marine.010908.163930.
Ghermandi, Andrea, Helen Ding, and Paulo A. L. D. Nunes. 2013. "The social dimension of biodiversity policy in the European Union: Valuing the benefits to vulnerable communities." *Environmental science & policy* 33: 196-208. https://doi.org/10.1016/j.envsci.2013.06.004.
Ghermandi, Andrea, J. C. J. M. van den Bergh, L. M. Brander, H. L. F. de Groot, and P. A. L. D. Nunes. 2010. "Values of natural and human-made wetlands: A meta-analysis." *Water resources research* 46 (12): n/a. https://doi.org/10.1029/2010WR009071.
Gómez-Baggethun, Erik, Rudolf de Groot, Pedro L. Lomas, and Carlos Montes. 2010. "The history of ecosystem services in economic theory and practice: From early notions to markets and payment schemes." *Ecological economics* 69 (6): 1209-1218. https://doi.org/10.1016/j.ecolecon.2009.11.007.
Gómez-Baggethun, Erik, and Manuel Ruiz-Pérez. 2011. "Economic valuation and the commodification of ecosystem services." *Progress in physical geography* 35 (5): 613-628. https://doi.org/10.1177/0309133311421708.
González-García, Alberto, Marina Arias, Susana García-Tiscar, Paloma Alcorlo, and Fernando Santos-Martín. 2022. "National blue carbon assessment in Spain using InVEST: Current state and future perspectives." *Ecosystem services* 53: 101397. https://doi.org/10.1016/j.ecoser.2021.101397.
Gosselink, James G. , Eugene P. Odum, and R.M. Pope. 1974. *The Value of Tidal Marsh.Centre for Wetland Resources*. Baton Rouge: Center for Wetland Resources, Louisiana State University.
Govers, L. L., L. P. Lamers, T. J. Bouma, J. Eygensteyn, J. H. de Brouwer, A. J. Heniks, C. M. Huijbers, and M. M. van Katwijk. 2014. "Seagrasses as indicators for coastal trace metal pollution: A global meta-analysis serving as a benchmark, and a caribbean case study." *Environmental pollution (1987)* 195c: 210-217. https://doi.org/10.1016/j.envpol.2014.08.028.
Grassi, Francesco, Marcello Mastrorilli, Carlo Mininni, Angelo Parente, Angelo Santino, Marcello Scarcella, and Pietro Santamaria. 2015. "Posidonia residues can be used as organic mulch and soil amendment for lettuce and tomato production." *Agronomy for Sustainable Development* 35 (2): 679-689. https://doi.org/10.1007/s13593-014-0268-8.
Green, Alix, Michael A. Chadwick, and Peter J. S. Jones. 2018. "Variability of UK seagrass sediment carbon: Implications for blue carbon estimates and marine conservation management." *PloS one* 13 (9): e0204431-e0204431. https://doi.org/10.1371/journal.pone.0204431.
Grilli, Gaetano, Silvia Ferrini, Tiziana Luisetti, and R. Kerry Turner. 2022. "The role of choice experiments in natural capital accounting approaches: fast track versus simulated exchange value in the Deben Estuary saltmarshes." *Journal of environmental planning and management* 65 (7): 1281-1300. https://doi.org/10.1080/09640568.2021.1957794.

Guerry, Anne D., Stephen Polasky, Jane Lubchenco, Rebecca Chaplin-Kramer, Gretchen C. Daily, Robert Griffin, Mary Ruckelshaus, Ian J. Bateman, Anantha Duraiappah, Thomas Elmqvist, Marcus W. Feldman, Carl Folke, Jon Hoekstra, Peter M. Kareiva, Bonnie L. Keeler, Shuzhuo Li, Emily McKenzie, Zhiyun Ouyang, Belinda Reyers, Taylor H. Ricketts, Johan Rockström, Heather Tallis, and Bhaskar Vira. 2015. "Natural capital and ecosystem services informing decisions: From promise to practice." *PNAS* 112 (24): 7348-7355. https://doi.org/10.1073/pnas.1503751112.

Haines-Young, Roy, and Marion Potschin. 2010. "The links between biodiversity, ecosystem services and human well-being." In *Ecosystem Ecology: a new synthesis*, edited by David G. Raffaelli and Christopher L. J. Frid, 110-139. Cambridge University Press.

Haines-Young, Roy, and Marion B Potschin. 2018. Common international classification of ecosystem services (CICES) V5. 1 and guidance on the application of the revised structure. Nottingham: Fabis Consulting Ltd.

Halkos, George Emm., and Georgia K. Galani. 2016. "Assessing willingness to pay for marine and coastal ecosystems: A Case Study in Greece." https://mpra.ub.uni-muenchen.de/68767/.

Han, Qiuying, Xiaoping Huang, Ping Shi, and Jingping Zhang. 2008. "Seagrass bed ecosystem service valuation: A case research on Hepu seagrass bed in Guangxi province." *Marine Science Bulletin* 10: 87-96. http://hdl.handle.net/1834/5874.

Hanley, Nick, Stephen Hynes, David Patterson, and Niels Jobstvogt. 2015. "Economic valuation of marine and coastal ecosystems: is it currently fit for purpose?" *Journal of Ocean and Coastal Economics*. https://doi.org/10.15351/2373-8456.1014.

Hau, Jorge L., and Bhavik R. Bakshi. 2004. "Promise and problems of emergy analysis." *Ecological modelling* 178 (1): 215-225. https://doi.org/10.1016/j.ecolmodel.2003.12.016.

Hausman, Jerry. 2012. "Contingent valuation: from dubious to hopeless." *Journal of economic perspectives* 26 (4): 43-56. https://doi.org/10.1257/jep.26.4.43.

Himes-Cornell, Amber, Linwood Pendleton, and Perla Atiyah. 2018. "Valuing ecosystem services from blue forests: A systematic review of the valuation of salt marshes, sea grass beds and mangrove forests." *Ecosystem services* 30: 36-48. https://doi.org/10.1016/j.ecoser.2018.01.006.

Hoagland, P., H. L. Kite-Powell, D. Jin, and A. R. Solow. 2013. "Supply-side approaches to the economic valuation of coastal and marine habitat in the Red Sea." *Journal of King Saud University. Science* 25 (3): 217-228. https://doi.org/10.1016/j.jksus.2013.02.006.

Horlings, Edwin, Sjoerd Schenau, Lars Hein, Marjolein Lof, Linda de Jongh, and Michael Polder. 2020. *Experimental monetary valuation of ecosystem services and assets in the Netherlands.* (The Netherlands: Wageningen University & Research).

Horton, Benjamin P., Ian Shennan, S. L. Bradley, Niamh Cahill, Matthew Kirwan, Robert E. Kopp, and Timothy A. Shaw. 2018. "Predicting marsh vulnerability to sea-level rise using Holocene relative sea-level data." *Nature communications* 9 (1): 2687-7. https://doi.org/10.1038/s41467-018-05080-0.

Huang, Biao, Mary A. Young, Paul E. Carnell, Simon Conron, Daniel Ierodiaconou, Peter I. Macreadie, and Emily Nicholson. 2020. "Quantifying welfare gains of coastal and estuarine ecosystem rehabilitation for recreational fisheries." *The Science of the total environment* 710: 134680-134680. https://doi.org/10.1016/j.scitotenv.2019.134680.

Hughes, Zachary. 2015. *Ecological and Economic Assessment of Potential Eelgrass Expansion at Sucia Island, WA.* (White Paper).

Hynes, Stephen, Daniel Norton, and Nick Hanley. 2013. "Adjusting for cultural differences in international benefit transfer." *Environmental & resource economics* 56 (4): 499-519. https://doi.org/10.1007/s10640-012-9572-4.

Hynes, Stephen, Dugald Tinch, and Nick Hanley. 2013. "Valuing improvements to coastal waters using choice experiments: An application to revisions of the EU Bathing Waters Directive." *Marine Policy* 40: 137-144. https://doi.org/10.1016/j.marpol.2012.12.035.

https://cbe.miis.edu/joce/vol10/iss1/2
DOI: 10.15351/2373-8456.1174

Interis, Matthew G., and Daniel R. Petrolia. 2016. "Location, location, habitat: how the value of ecosystem services varies across location and by habitat." *Land economics* 92 (2): 292-307. https://doi.org/10.3368/le.92.2.292.

Interwies, Eduard, and Stefan Görlitz. 2013. *Protection of the Canary Current Large Marine Ecosystem (CCLME) Project –GCP/INT/023/GFF.* (FAO and UNEP).

Jackson, Emma L., § Siân E. Rees, Catherine Wilding, and Martin J. Attrill. 2015. "Use of a seagrass residency index to apportion commercial fishery landing values and recreation fisheries expenditure to seagrass habitat service." *Conservation biology* 29 (3): 899-909. https://doi.org/10.1111/cobi.12436.

Jänes, Holger, Paul Carnell, Mary Young, Daniel Ierodiaconou, Gregory P. Jenkins, Paul Hamer, Philine S. E. Zu Ermgassen, Jonathan R. Gair, and Peter I. Macreadie. 2021. "Seagrass valuation from fish abundance, biomass and recreational catch." *Ecological indicators* 130: 108097. https://doi.org/10.1016/j.ecolind.2021.108097.

Jänes, Holger, Peter I. Macreadie, Emily Nicholson, Daniel Ierodiaconou, Simon Reeves, Matthew D. Taylor, and Paul E. Carnell. 2020. "Stable isotopes infer the value of Australia's coastal vegetated ecosystems from fisheries." *Fish & Fisheries* 21 (1): 80-90. https://doi.org/10.1111/faf.12416.

Jänes, Holger, Peter I. Macreadie, Justin Rizzari, Daniel Ierodioconou, Simon E. Reeves, Patrick G. Dwyer, and Paul E. Carnell. 2021. "The value of estuarine producers to fisheries: A case study of Richmond River Estuary." *Ambio* 51 (4): 875-887. https://doi.org/10.1007/s13280-021-01600-3.

Jayathilake, Dinusha R. M., and Mark J. Costello. 2018. "A modelled global distribution of the seagrass biome." *Biological conservation* 226: 120-126. https://doi.org/10.1016/j.biocon.2018.07.009.

Johnston, Robert J, Kevin J Boyle, Wiktor Adamowicz, Jeff Bennett, Roy Brouwer, Trudy Ann Cameron, W Michael Hanemann, Nick Hanley, Mandy Ryan, and Riccardo Scarpa. 2017. "Contemporary guidance for stated preference studies." *Journal of the Association of Environmental and Resource Economists* 4 (2): 319-405. https://doi.org/10.1086/691697.

Jones, Laurence, Angus Garbutt, Andrew Cooper, Stewart Angus, Pat Doody, Mark Everard, Paul Gilchrist, Jim Hansom, Robert Nicholls, Kenneth Pye, Neil Ravenscroft, Sue Rees, Peter Rhind, and Andrew Whitehouse. 2011. "Coastal Margins [chapter 11]." In *UK National Ecosystem Assessment. Understanding Nature's Value to Socirty. Technical Report.*, 411-457. Cambridge: UNEP-WCMC.

Kamimura, Yasuhiro, Akihide Kasai, and Jun Shoji. 2011. "Production and prey source of juvenile black rockfish Sebastes cheni in a seagrass and macroalgal bed in the Seto Inland Sea, Japan: estimation of the economic value of a nursery." *Aquatic ecology* 45 (3): 367-376. https://doi.org/10.1007/s10452-011-9360-1.

Kazmierczak, Richard F. 2001. Economic linkages between coastal wetlands and water quality: A review of value estimates reported in the published literature. IDEAS Working Paper Series from RePEc. St. Louis: Federal Reserve Bank of St Louis, St. Louis.

Kenter, Jasper O, Rosalind Bryce, Althea Davies, Niels Jobstvogt, Verity Watson, Susan Ranger, Jean-Luc Solandt, Calum Duncan, Mike Christie, and Heather Crump. 2013. *The value of potential marine protected areas in the UK to divers and sea anglers.* (Cambridge, UK: UNEP-WCMC).

Kim, Ju-Hee, Jungho Nam, and Seung-Hoon Yoo. 2022. "Public perceptions of blue carbon in South Korea: Findings from a choice experiment." *Marine policy* 144. https://doi.org/10.1016/j.marpol.2022.105236.

King, Dennis. 1998. "The dollar value of wetlands: trap set, bait taken, don't swallow." *National wetlands newsletter* 20: 7-11.

King, Susanna E., and John N. Lester. 1995. "The value of salt marsh as a sea defence." *Marine pollution bulletin* 30 (3): 180-189. https://doi.org/10.1016/0025-326X(94)00173-7.

Kling, Catherine L., Daniel J. Phaneuf, and Jinhua Zhao. 2012. "From Exxon to BP: Has some number become better than no number?" *The Journal of economic perspectives* 26 (4): 3-26. https://doi.org/10.1257/jep.26.4.3.

Kragt, Marit E., and J. W. Bennett. 2011. "Using choice experiments to value catchment and estuary health in Tasmania with individual preference heterogeneity." *The Australian journal of agricultural and resource economics* 55 (2): 159-179. https://doi.org/10.1111/j.1467-8489.2011.00533.x.

Landry, Craig E., Paul Hindsley, Okmyung Bin, Jamie B. Kruse, John C. Whitehead, and Ken Wilson. 2011. "Weathering the storm: measuring household willingness-to-pay for risk-reduction in post-Katrina New Orleans." *Southern economic journal* 77 (4): 991-1013. https://doi.org/10.4284/0038-4038-77.4.991.

Lavery, Paul S., Miguel-Ángel Mateo, Oscar Serrano, and Mohammad Rozaimi. 2013. "Variability in the carbon storage of seagrass habitats and its implications for global estimates of blue carbon ecosystem service." *PloS one* 8 (9): e73748-e73748. https://doi.org/10.1371/journal.pone.0073748.

Lewis, LJ. 2019. *An assessment of the effects of recreational and other activities on the waterbirds using the Bull Island saltmarsh. Final Report.* Dublin City & County Council (Dublin, Ireland).

Liu, Xin, Yebao Wang, Robert Costanza, Ida Kubiszewski, Ning Xu, Meihua Yuan, and Ruiying Geng. 2019. "The value of China's coastal wetlands and seawalls for storm protection." *Ecosystem services* 36: 100905. https://doi.org/10.1016/j.ecoser.2019.100905.

Losciale, Riccardo, Rachel Hay, Michael Rasheed, and Scott Heron. 2022. "The public perception of the role, importance, and vulnerability of seagrass. A case study from the Great Barrier Reef." *Environmental development* 44. https://doi.org/10.1016/j.envdev.2022.100757.

Luisetti, Tiziana, E. L. Jackson, and R. K. Turner. 2013. "Valuing the European 'coastal blue carbon' storage benefit." *Marine pollution bulletin* 71 (1-2): 101-106. https://doi.org/10.1016/j.marpolbul.2013.03.029.

Luisetti, Tiziana, R. Kerry Turner, Julian E. Andrews, Timothy D. Jickells, Silke Kröger, Markus Diesing, Lucille Paltriguera, Martin T. Johnson, Eleanor R. Parker, Dorothee C. E. Bakker, and Keith Weston. 2019. "Quantifying and valuing carbon flows and stores in coastal and shelf ecosystems in the UK." *Ecosystem services* 35: 67-76. https://doi.org/10.1016/j.ecoser.2018.10.013.

Luisetti, Tiziana, R. Kerry Turner, Ian J. Bateman, Sian Morse-Jones, Christopher Adams, and Leila Fonseca. 2011. "Coastal and marine ecosystem services valuation for policy and management: Managed realignment case studies in England." *Ocean & coastal management* 54 (3): 212-224. https://doi.org/10.1016/j.ocecoaman.2010.11.003.

Lynne, Gary D., Patricia Conroy, and Frederick J. Prochaska. 1981. "Economic valuation of marsh areas for marine production processes." *Journal of environmental economics and management* 8 (2): 175-186. https://doi.org/10.1016/0095-0696(81)90006-1.

MacDonald, Michael A., Chris de Ruyck, Rob H. Field, Alan Bedford, and Richard B. Bradbury. 2020. "Benefits of coastal managed realignment for society: Evidence from ecosystem service assessments in two UK regions." *Estuarine, Coastal and Shelf Science* 244: 105609. https://doi.org/10.1016/j.ecss.2017.09.007.

Mangi, Stephen C., Clare E. Davis, Laura A. Payne, Melanie C. Austen, Dave Simmonds, Nicola J. Beaumont, and Tim Smyth. 2011. "Valuing the regulatory services provided by marine ecosystems." *Environmetrics (London, Ont.)* 22 (5): 686-698. https://doi.org/10.1002/env.1095.

McArthur, Lynne C., and John W. Boland. 2006. "The economic contribution of seagrass to secondary production in South Australia." *Ecological modelling* 196 (1): 163-172. https://doi.org/10.1016/j.ecolmodel.2006.02.030.

McHarg, Ellen, Elena Mengo, Lisa Benson, Jody Daniel, Andre Joseph-Witzig, Paulette Posen, and Tiziana Luisetti. 2022. "Valuing the contribution of blue carbon to small

https://cbe.miis.edu/joce/vol10/iss1/2
DOI: 10.15351/2373-8456.1174

island developing states' climate change commitments and Covid-19 recovery." *Environmental science & policy* 132: 13-23. https://doi.org/10.1016/j.envsci.2022.02.009.
McKenzie, Len J., Lina M. Nordlund, Benjamin L. Jones, Leanne C. Cullen-Unsworth, Chris Roelfsema, and Richard K. F. Unsworth. 2020. "The global distribution of seagrass meadows." *Environmental research letters* 15 (7): 74041. https://doi.org/10.1088/1748-9326/ab7d06.
McKinley, Emma, Rachel Harvey, RC Ballinger, Kate Davidson, JN Griffin, and MW Skov. 2022. "Coastal agricultural landscapes: Mapping and understanding grazing intensity on Welsh saltmarshes." *Ocean & Coastal Management* 222: 106128. https://doi.org/10.1016/j.ocecoaman.2022.106128.
McLeod, Elizabeth, Gail L. Chmura, Steven Bouillon, Rodney Salm, Mats Björk, Carlos M. Duarte, Catherine E. Lovelock, William H. Schlesinger, and Brian R. Silliman. 2011. "A blueprint for blue carbon: toward an improved understanding of the role of vegetated coastal habitats in sequestering CO2." *Frontiers in ecology and the environment* 9 (10): 552-560. https://doi.org/10.1890/110004.
McMahon, Lucy, Cai J. T. Ladd, Annette Burden, Ed Garrett, Kelly R. Redeker, Peter Lawrence, and Roland Gehrels. 2023. "Maximizing blue carbon stocks through saltmarsh restoration." *Frontiers in Marine Science* 10. https://doi.org/10.3389/fmars.2023.1106607.
McOwen, Chris J., Lauren V. Weatherdon, Jan-Willem Van Bochove, Emma Sullivan, Simon Blyth, Christoph Zockler, Damon Stanwell-Smith, Naomi Kingston, Corinne S. Martin, Mark Spalding, and Steven Fletcher. 2017. "A global map of saltmarshes." *Biodiversity data journal* 5 (1): e11764-13. https://doi.org/10.3897/BDJ.5.e11764.
MEA. 2005. *Millennium Ecosystem Assessment: Ecosystems and human well-being: a framework for assessment. Island Press.* (Washington DC).
Menéndez, Pelayo, Iñigo J. Losada, Saul Torres-Ortega, Siddharth Narayan, and Michael W. Beck. 2020. "The global flood protection benefits of mangroves." *Scientific Reports* 10 (1): 4404. https://doi.org/10.1038/s41598-020-61136-6.
Milon, J. Walter, and Sergio Alvarez. 2019. "The elusive quest for valuation of coastal and marine ecosystem services." *Water* 11 (7): 1518. https://doi.org/10.3390/w11071518. https://www.mdpi.com/2073-4441/11/7/1518.
Minello, Thomas J., Lawrence P. Rozas, Philip A. Caldwell, and Christopher Liese. 2012. "A comparison of salt marsh construction costs with the value of exported shrimp production." *Wetlands (Wilmington, N.C.)* 32 (5): 791-799. https://doi.org/10.1007/s13157-011-0237-9.
Moher, David, Alessandro Liberati, Jennifer Tetzlaff, and Douglas G. Altman. 2010. "Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement." *International Journal of Surgery* 8 (5): 336-341. https://doi.org/10.1016/j.ijsu.2010.02.007.
Montero-Hidalgo, Miriam, Fernando Tuya, Francisco Otero-Ferrer, Ricardo Haroun, and Fernando Santos-Martín. 2023. "Mapping and assessing seagrass meadows changes and blue carbon under past, current, and future scenarios." *Science of The Total Environment* 872: 162244. https://doi.org/10.1016/j.scitotenv.2023.162244.
Muenzel, Dominic, and Simone Martino. 2018. "Assessing the feasibility of carbon payments and Payments for Ecosystem Services to reduce livestock grazing pressure on saltmarshes." *Journal of Environmental Management* 225: 46-61. https://doi.org/10.1016/j.jenvman.2018.07.060.
Musembi, Peter, Bernerd Fulanda, James Kairo, and Michael Githaiga. 2019. "Species composition, abundance and fishing methods of small-scale fisheries in the seagrass meadows of Gazi Bay, Kenya." *Journal of the Indian Ocean Region* 15 (2): 139-156. https://doi.org/10.1080/19480881.2019.1603608.
Narayan, Siddharth, Michael W. Beck, Paul Wilson, Christopher J. Thomas, Alexandra Guerrero, Christine C. Shepard, Borja G. Reguero, Guillermo Franco, Jane Carter Ingram, and Dania Trespalacios. 2017. "The value of coastal wetlands for flood damage reduction

in the Northeastern USA." *Scientific reports* 7 (1): 9463-9463. https://doi.org/10.1038/s41598-017-09269-z.
Nellemann, Christian, and Emily Corcoran. 2009. *Blue carbon: the role of healthy oceans in binding carbon: a rapid response assessment*. UNEP/Earthprint.
Neumann, Barbara, Athanasios T. Vafeidis, Juliane Zimmermann, and Robert J. Nicholls. 2015. "Future coastal population growth and exposure to sea-level rise and coastal flooding - a global assessment." *PLOS ONE* 10 (3): e0118571. https://doi.org/10.1371/journal.pone.0118571.
Newell, Roger I. E., and Evamaria W. Koch. 2004. "Modeling seagrass density and distribution in response to changes in turbidity stemming from bivalve filtration and seagrass sediment stabilization." *Estuaries* 27 (5): 793-806. https://doi.org/10.1007/BF02912041.
Nordhaus, William D. 2017. "Revisiting the social cost of carbon." *Proceedings of the National Academy of Sciences - PNAS* 114 (7): 1518-1523. https://doi.org/10.1073/pnas.1609244114.
Nordlund, Lina M., Evamaria W. Koch, Edward B. Barbier, and Joel C. Creed. 2016. "Seagrass ecosystem services and their variability across genera and geographical regions." *PloS one* 11 (10): e0163091-e0163091. https://doi.org/10.1371/journal.pone.0163091.
Nordlund, Lina M., Richard K. F. Unsworth, Martin Gullström, and Leanne C. Cullen-Unsworth. 2018. "Global significance of seagrass fishery activity." *Fish and fisheries (Oxford, England)* 19 (3): 399-412. https://doi.org/10.1111/faf.12259.
Norgaard, Richard B. 2010. "Ecosystem services: From eye-opening metaphor to complexity blinder." *Ecological economics* 69 (6): 1219-1227. https://doi.org/10.1016/j.ecolecon.2009.11.009.
Norton, Daniel, Stephen Hynes, and J Boyd. 2018. *Valuing Ireland's blue ecosystem services.*
O'Higgins, Timothy G., Steven P. Ferraro, Darrin D. Dantin, Steve J. Jordan, and Marnita M. Chintala. 2010. "Habitat scale mapping of fisheries ecosystem service values in estuaries." *Ecology and society* 15 (4): 7. https://doi.org/10.5751/ES-03585-150407.
Ochieng, C, and PLA Erftemeijer. 2003. "The seagrasses of Kenya and Tanzania." In *World atlas of seagrasses*, edited by Frederick Short, T. and Edmund Green, P.: University of California.
Odum, Howard T. 1988. "Self-organization, transformity, and information." *Science* 242 (4882): 1132-1139. https://www.jstor.org/stable/1702630.
Olander, Lydia, Stephen Polasky, James S Kagan, Robert J Johnston, Lisa Wainger, David Saah, Lynn Maguire, James Boyd, and David Yoskowitz. 2017. "So you want your research to be relevant? Building the bridge between ecosystem services research and practice." *Ecosystem Services* 26: 170-182. https://doi.org/10.1016/j.ecoser.2017.06.003.
Orth, Robert J., Tim J. B. Carruthers, William C. Dennison, Carlos M. Duarte, James W. Fourqurean, Kenneth L. Heck, A. Randall Hughes, Gary A. Kendrick, W. Judson Kenworthy, Suzanne Olyarnik, Frederick T. Short, Michelle Waycott, and Susan L. Williams. 2006. "A global crisis for seagrass ecosystems." *Bioscience* 56 (12): 987-996. https://doi.org/10.1641/0006-3568(2006)56[987:AGCFSE]2.0.CO;2.
Pascoe, Sean, Amar Doshi, Mladen Kovac, and Angelica Austin. 2019. "Estimating coastal and marine habitat values by combining multi-criteria methods with choice experiments." *Ecosystem services* 38: 100951. https://doi.org/10.1016/j.ecoser.2019.100951.
Pascual, Unai, Roldan Muradian, Luke Brander, Erik Gómez-Baggethun, Berta Martín-López, Madhu Verma, Paul Armsworth, Michael Christie, Hans Cornelissen, and Florian Eppink. 2010. *The economics of valuing ecosystem services and biodiversity.* (TEEB).
Paul, M., and C. L. Amos. 2011. "Spatial and seasonal variation in wave attenuation over Zostera noltii." *Journal of Geophysical Research: Oceans* 116 (C8): n/a. https://doi.org/10.1029/2010JC006797.
Pendleton, Linwood, Daniel C. Donato, Brian C. Murray, Stephen Crooks, W. Aaron Jenkins, Samantha Sifleet, Christopher Craft, James W. Fourqurean, J. Boone Kauffman, Núria

Marbà, Patrick Megonigal, Emily Pidgeon, Dorothee Herr, David Gordon, and Alexis Baldera. 2012. "Estimating global "blue carbon" emissions from conversion and degradation of vegetated coastal ecosystems." *PloS one* 7 (9): e43542-e43542. https://doi.org/10.1371/journal.pone.0043542.
Penk, Marcin R, and Philip M Perrin. 2022. "Variability of plant and surface soil carbon concentration among saltmarsh habitats in Ireland." *Estuaries and Coasts*: 1-15. https://doi.org/0.1007/s12237-021-01042-w.
Petcharat, Areeyapat, and Yohan Lee. 2020. "Measuring the nonuse value of the dugong (Dugong dugon) in Thailand." *Journal of Asia-Pacific biodiversity* 13 (1): 62-69. https://doi.org/10.1016/j.japb.2019.12.002.
Petrolia, Daniel R, Matthew G Interis, and Joonghyun Hwang. 2014. "America's wetland? A national survey of willingness to pay for restoration of Louisiana's coastal wetlands." *Marine Resource Economics* 29 (1): 17-37. https://doi.org/10.1086/676289.
Petrolia, Daniel R, and Tae-Goun Kim. 2011. "Preventing land loss in coastal Louisiana: Estimates of WTP and WTA." *Journal of environmental management* 92 (3): 859-865. https://doi.org/10.1016/j.jenvman.2010.10.040.
Pickering, Catherine, and Jason Byrne. 2014. "The benefits of publishing systematic quantitative literature reviews for PhD candidates and other early-career researchers." *Higher education research and development* 33 (3): 534-548. https://doi.org/10.1080/07294360.2013.841651.
Portugal, EEA Grants. 2018. "BlueForests Education." https://www.eeagrants.gov.pt/en/programmes/blue-growth/projects/projects/blueforests-education/.
Posford Duvivier. 1996. *Financial values of five important marine/coastal wildlife areas in England.* (UK: English Nature).
Potschin, Marion B, and Roy Haines-Young. 2016. "Defining and measuring ecosystem services." In *Routledge handbook of ecosystem services*, 25-44. Routledge.
Praisankul, Suhatai, and Orapan Nabangchang-Srisawalak. 2016. The economic value of seagrass ecosystem in Trang Province, Thailand. Kasetsart University Fisheries Research Bulletin.
Prendergast, Hew D. V. 2002. "Useful marine monocots—more collections than data?" *Economic botany* 56 (2): 110-112. https://doi.org/10.1663/0013-0001(2002)056[0110:UMMCTD]2.0.CO2.
Pueyo-Ros, Josep. 2018. "The role of tourism in the Ecosystem Services Framework." *Land (Basel)* 7 (3): 111. https://doi.org/10.3390/land7030111.
Pueyo-Ros, Josep, Xavier Garcia, Anna Ribas, and Rosa M. Fraguell. 2018. "Ecological restoration of a coastal wetland at a mass tourism destination. Will the recreational value increase or decrease?" *Ecological economics* 148: 1-14. https://doi.org/10.1016/j.ecolecon.2018.02.002.
Rao, Nalini S., Andrea Ghermandi, Rosimeiry Portela, and Xuanwen Wang. 2015. "Global values of coastal ecosystem services: A spatial economic analysis of shoreline protection values." *Ecosystem Services* 11: 95-105. https://doi.org/10.1016/j.ecoser.2014.11.011.
Raoult, V., M. D. Taylor, R. K. Schmidt, I. D. Cresswell, C. Ware, and T. F. Gaston. 2022. "Valuing the contribution of estuarine habitats to commercial fisheries in a seagrass-dominated estuary." *Estuarine, coastal and shelf science* 274: 107927. https://doi.org/10.1016/j.ecss.2022.107927.
Rendón, Olivia R., Angus Garbutt, Martin Skov, Iris Möller, Meghan Alexander, Rhoda Ballinger, Kayleigh Wyles, Greg Smith, Emma McKinley, John Griffin, Merryn Thomas, Kate Davidson, Jordi F. Pagès, Simon Read, and Nicola Beaumont. 2019. "A framework linking ecosystem services and human well-being: Saltmarsh as a case study." *People and Nature* 1 (4): 486-496. https://doi.org/10.1002/pan3.10050.
Ribeiro, Hugo, Ana P. Mucha, C. Marisa R. Almeida, and Adriano A. Bordalo. 2010. "Hydrocarbon degradation potential of salt marsh plant–microorganisms associations." *Biodegradation (Dordrecht)* 22 (4): 729-739. https://doi.org/10.1007/s10532-010-9446-9.

Riegel, Simone, Laure Kuhfuss, and Timothy Stojanovic. 2023. "Nature-based solutions for climate change mitigation: Assessing the Scottish Public's preferences for saltmarsh carbon storage." *Ecological Economics* 211: 107863. https://doi.org/https://doi.org/10.1016/j.ecolecon.2023.107863.

Rogers, Abbie A. 2013. "Public and expert preference divergence: evidence from a choice experiment of marine reserves in Australia." *Land economics* 89 (2): 346-370. https://doi.org/10.3368/le.89.2.346.

Rolfe, John, and Jill Windle. 2010. Valuing environmental improvements in the Great Barrier Reef: Ecological and preference heterogeneity in local area case studies. IDEAS Working Paper Series from RePEc. St. Louis: Federal Reserve Bank of St Louis.

Russell, Marc, and Holly Greening. 2015. "Estimating benefits in a recovering estuary: Tampa Bay, Florida." *Estuaries and coasts* 38 (Suppl 1): 9-18. https://doi.org/10.1007/s12237-013-9662-8.

Samonte-Tan, Giselle P. B., Alan T. White, Mary Ann Tercero, John Diviva, Esperanza Tabara, and Ciemon Caballes. 2007. "Economic valuation of coastal and marine resources: Bohol Marine Triangle, Philippines." *Coastal management* 35 (2-3): 319-338. https://doi.org/10.1080/08920750601169634.

Sangha, Kamaljit K., Natalie Stoeckl, Neville Crossman, and Robert Costanza. 2019. "A state-wide economic assessment of coastal and marine ecosystem services to inform sustainable development policies in the Northern Territory, Australia." *Marine policy* 107: 103595. https://doi.org/10.1016/j.marpol.2019.103595.

Santos, Rui, and Pedro Duarte. 1991. "Marine plant harvest in Portugal." *Journal of Applied Phycology* 3 (1): 11-18. https://doi.org/10.1007/BF00003915.

Saunders, Megan I., Christopher Doropoulos, Elisa Bayraktarov, Russell C. Babcock, Daniel Gorman, Aaron M. Eger, Maria L. Vozzo, Chris L. Gillies, Mathew A. Vanderklift, Andy D. L. Steven, Rodrigo H. Bustamante, and Brian R. Silliman. 2020. "Bright spots in coastal marine ecosystem restoration." *Current Biology* 30 (24): R1500-R1510. https://doi.org/10.1016/j.cub.2020.10.056.

Schmidt, J. P., Rebecca Moore, and Merryl Alber. 2014. "Integrating ecosystem services and local government finances into land use planning: A case study from coastal Georgia." *Landscape and urban planning* 122: 56-67. https://doi.org/10.1016/j.landurbplan.2013.11.008.

Short, Frederick T, and Edmund Green. 2003. *World atlas of seagrasses*. UNEP. University of California Press.

Sinclair, Elizabeth A., Jennifer Verduin, Siegfried L. Krauss, Jethro Hardinge, Janet Anthony, and Gary A. Kendrick. 2013. "A genetic assessment of a successful seagrass meadow (Posidonia australis) restoration trial." *Ecological management & restoration* 14 (1): 68-71. https://doi.org/10.1111/emr.12028.

Smith, Pete, Steven J Davis, Felix Creutzig, Sabine Fuss, Jan Minx, Benoit Gabrielle, Etsushi Kato, Robert B Jackson, Annette Cowie, and Elmar Kriegler. 2016. "Biophysical and economic limits to negative CO2 emissions." *Nature climate change* 6 (1): 42-50. https://doi.org/10.1038/nclimate2870.

Stevenson, J R. 2001. "The application of a production function model to estimate the indirect-use value of salt marshes in Scotland: Linkages to the fishing industry." MSc, Institute of Ecology and Resource Management, University of Edinburgh.

Sumaila, U. Rashid, Naazia Ebrahim, Anna Schuhbauer, Daniel Skerritt, Yang Li, Hong Sik Kim, Tabitha Grace Mallory, Vicky W. L. Lam, and Daniel Pauly. 2019. "Updated estimates and analysis of global fisheries subsidies." *Marine Policy* 109: 103695. https://doi.org/https://doi.org/10.1016/j.marpol.2019.103695.

Sun, Xiang, Yangfan Li, Xiaodong Zhu, Kai Cao, and Lan Feng. 2017. "Integrative assessment and management implications on ecosystem services loss of coastal wetlands due to reclamation." *Journal of cleaner production* 163: S101-S112. https://doi.org/10.1016/j.jclepro.2015.10.048.

Tinch, Rob, Stephen Hynes, Claire W Armstrong, and Wenting Chen. 2021. "Prospects for valuation in marine decision making in Europe." *Journal of Ocean and Coastal Economics* 8, no. 11 (2). https://doi.org/10.15351/2373-8456.1150.

Tinch, Rob, and Laure Ledoux. 2006. *Economics of Managed Realignment in the UK—Final Report to the Coastal Futures Project.* (UK: Environmental Futures Limited).

Tol, Richard S. J. 2005. "The marginal damage costs of carbon dioxide emissions: an assessment of the uncertainties." *Energy policy* 33 (16): 2064-2074. https://doi.org/10.1016/j.enpol.2004.04.002.

Trégarot, Ewan, Grégoire Touron-Gardic, Cindy C. Cornet, and Pierre Failler. 2020. "Valuation of coastal ecosystem services in the Large Marine Ecosystems of Africa." *Environmental development* 36: 100584. https://doi.org/10.1016/j.envdev.2020.100584.

Tsuge, Takahiro, and Toyoaki Washida. 2003. "Economic valuation of the Seto Inland Sea by using an Internet CV survey." *Marine pollution bulletin* 47 (1-6): 230-236. https://doi.org/10.1016/S0025-326X(03)00058-4.

Tuan, Tran Huu, Mai Van Xuan, Do Nam, and Stale Navrud. 2009. "Valuing direct use values of wetlands: A case study of Tam Giang–Cau Hai lagoon wetland in Vietnam." *Ocean & coastal management* 52 (2): 102-112. https://doi.org/10.1016/j.ocecoaman.2008.10.011.

Tuya, Fernando, Ricardo Haroun, and Fernando Espino. 2014. "Economic assessment of ecosystem services: Monetary value of seagrass meadows for coastal fisheries." *Ocean & coastal management* 96: 181-187. https://doi.org/10.1016/j.ocecoaman.2014.04.032.

Uehara, Takuro, Takahiro Tsuge, and Takahiro Ota. 2018. "Long-term evolution of preferences for conservation projects in the Seto Inland Sea, Japan: a comprehensive analytic framework." *PeerJ* 6: e5366. https://doi.org/10.7717/peerj.5366.

UN. 2022. *World Economic Situation and Prospects as of mid 2022.* United Nations Department of Econnomic and Social Affairs.

UNFCCC, 2015, "Adoption of the Paris Agreement."

Unsworth, Richard K. F., C. Leanne Cullen-Unsworth, Benjamin L. H. Jones, and Richard J. Lilley. 2022. "The planetary role of seagrass conservation." *Science (American Association for the Advancement of Science)* 377 (6606): 609-613. https://doi.org/10.1126/science.abq6923.

Unsworth, Richard K. F., Leanne C. Cullen, Jules N. Pretty, David J. Smith, and James J. Bell. 2010. "Economic and subsistence values of the standing stocks of seagrass fisheries: Potential benefits of no-fishing marine protected area management." *Ocean & coastal management* 53 (5): 218-224. https://doi.org/10.1016/j.ocecoaman.2010.04.002.

Van der Ploeg, Sander, Rudolf S De Groot, and Yafei Wang. 2010. *The TEEB Valuation Database: overview of structure, data and results.* (Wageningen, the Netherlands Foundation for Sustainable Development).

Vassallo, Paolo, Chiara Paoli, Alessio Rovere, Monica Montefalcone, Carla Morri, and Carlo Nike Bianchi. 2013. "The value of the seagrass Posidonia oceanica: A natural capital assessment." *Marine pollution bulletin* 75 (1-2): 157-167. https://doi.org/10.1016/j.marpolbul.2013.07.044.

Voltaire, Louinord, Hermann Pythagore Pierre Donfouet, Claudio Pirrone, and Agathe Larzillière. 2017. "Respondent uncertainty and ordering effect on willingness to pay for salt marsh conservation in the Brest Roadstead (France)." *Ecological economics* 137: 47-55. https://doi.org/10.1016/j.ecolecon.2017.02.029.

Wahyudin, Yudi, Tridoyo Kusumastanto, Luky Adrianto, and Yusli Wardiatno. 2018. "A social ecological system of recreational fishing in the seagrass meadow conservation area on the east coast of Bintan Island, Indonesia." *Ecological economics* 148: 22-35. https://doi.org/10.1016/j.ecolecon.2018.01.013.

Wallmo, Kristy, and Daniel K. Lew. 2016. "A comparison of regional and national values for recovering threatened and endangered marine species in the United States." *Journal of environmental management* 179: 38-46. https://doi.org/10.1016/j.jenvman.2016.04.053.

Watson, Reg, Rob Coles, and W.J Lee Long. 1993. "Simulation estimates of annual yield and landed value for commercial penaeid prawns from a tropical seagrass habitat, Northern Queensland, Australia." 44(1): 211-219. https://doi.org/10.1071/MF9930211.

Watson, Stephen C. L., Joanne Preston, Nicola J. Beaumont, and Gordon J. Watson. 2020. "Assessing the natural capital value of water quality and climate regulation in temperate marine systems using a EUNIS biotope classification approach." *The Science of the total environment* 744: 140688-140688. https://doi.org/10.1016/j.scitotenv.2020.140688.

Watson, Stephen C. L., Gordon J. Watson, Nicola J. Beaumont, and Joanne Preston. 2022. "Inclusion of condition in natural capital assessments is critical to the implementation of marine nature-based solutions." *Science of The Total Environment* 838: 156026. https://doi.org/10.1016/j.scitotenv.2022.156026.

Wawo, Mintje, Luky Adrianto, Dietriech G. Bengen, and Yusli Wardiatno. 2014. "Valuation of seagrass ecosystem services in Kotania bay marine nature tourism park, Western Seram, Indonesia." *Asian journal of scientific research* 7 (4): 591-591. https://doi.org/10.3923/ajsr.2014.591.600.

Waycott, Michelle, Carlos M. Duarte, Tim J. B. Carruthers, Robert J. Orth, William C. Dennison, Suzanne Olyarnik, Ainsley Calladine, James W. Fourqurean, Kenneth L. Heck, Jr., A. Randall Hughes, Gary A. Kendrick, W. Judson Kenworthy, Frederick T. Short, and Susan L. Williams. 2009. "Accelerating loss of seagrasses across the globe threatens coastal ecosystems." *Proceedings of the National Academy of Sciences - PNAS* 106 (30): 12377-12381. https://doi.org/10.1073/pnas.0905620106.

Weis, J.S., K.E.A. Segarra, and Patricio Bernal. 2016. "Chapter 49. Salt Marshes." In *The First Global Integrated Marine Assessment*. United Nations.

Whitehead, John C, Peter A Groothuis, Rob Southwick, and Pat Foster-Turley. 2009. "Measuring the economic benefits of Saginaw Bay coastal marsh with revealed and stated preference methods." *Journal of Great Lakes Research* 35 (3): 430-437. https://doi.org/10.1016/j.jglr.2009.03.005.

Wilson, James G, and Violetta Koutsagiannopolou. 2014. "Abundance, biomass, and productivity of invertebrate hyperbenthos in a temperate saltmarsh creek system." *Hydrobiologia* 728 (1): 141-151. https://doi.org/10.1007/s10750-014-1813-9.

World Bank. 2017. *The sunken billions revisited : progress and challenges in global marine fisheries.* (Washington, District of Columbia: World Bank Group).

Wyllie-Echeverria, S., and P. A. Cox. 1999. "seagrass (Zostera marina [Zosteraceae]) industry of Nova Scotia (1907-1960)." *Economic botany* 53 (4): 419-426. https://doi.org/10.1007/BF02866721.

Xu, Songjun, and Xiaoling He. 2022. "Estimating the recreational value of a coastal wetland park: Application of the choice experiment method and travel cost interval analysis." *Journal of environmental management* 304: 114225-114225. https://doi.org/10.1016/j.jenvman.2021.114225.

Yoskowitz, David, Cristina Carollo, Jennifer Beseres Pollack, Carlota Santos, and Kathleen Welder. 2017. "Integrated ecosystem services assessment: Valuation of changes due to sea level rise in Galveston Bay, Texas, USA." *Integrated environmental assessment and management* 13 (2): 431-443. https://doi.org/10.1002/ieam.1798.

Zarate-Barrera, Tatiana G., and Jorge H. Maldonado. 2015. "Valuing blue carbon: Carbon sequestration benefits provided by the marine protected areas in Colombia." *PloS one* 10 (5): e0126627-e0126627. https://doi.org/10.1371/journal.pone.0126627.

zu Ermgassen, Philine S. E., Ronald Baker, Michael W. Beck, Kate Dodds, Sophus O. S. E. zu Ermgassen, Debbrota Mallick, Matthew D. Taylor, and R. Eugene Turner. 2021. "Ecosystem services: delivering decision-making for salt marshes." *Estuaries and Coasts* 44 (6): 1691-1698. https://doi.org/10.1007/s12237-021-00952-z.

Zuidema, Chris, Richard Plate, and Angela Dikou. 2011. "To preserve or to develop? East Bay dredging project, South Caicos, Turks and Caicos Islands." *Journal of coastal conservation* 15 (4): 555-563. https://doi.org/10.1007/s11852-011-0144-5.

https://cbe.miis.edu/joce/vol10/iss1/2
DOI: 10.15351/2373-8456.1174