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Critical gaps in seagrass protection reveal the need to address multiple pressures and cumulative impacts

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ABSTRACT

Management is failing to adequately protect coastal ecosystems. Here we reviewed the policies, legislation, plans and management frameworks intended to protect seagrass meadows in 20 case-studies with the aim of identifying critical gaps in seagrass protection. The case-studies were chosen to represent a range of regions known to have high cumulative impacts or outstanding seagrass management. We asked five 'key questions' in our review to identify gaps in seagrass protection: 1) are seagrass habitats identified as an ecosystem of environmental significance, 2) what are their main threats, 3) does management consider cumulative impacts and 4) multiple pressures, and 5) are these habitats recovering? Seagrass protection was enacted inconsistently, through a range of legislative, policy and planning processes that only sought to mitigate some of the known pressures. Although the importance of preserving biodiversity and ecosystem services were acknowledged in over 80% of the case-studies, actionable plans to specifically address known pressures were lacking. Poor integration across jurisdictional realms and sectoral management approaches prevented the holistic strategy needed to address multiple pressures. We suggest a priority for enhancing protection of seagrass ecosystems is improving legislation, policies and planning frameworks to consider multiple pressures and cumulative impacts from marine and land-based activities. Management of seagrass ecosystems is likely to be indicative of trends in coastal management more generally, highlighting the urgent need to address multiple pressures and cumulative impacts in legislation and policies.

1. Introduction

The world's coastlines are experiencing unprecedented increases in human population, with 40% of the Earth's human population residing within 100 km of the coast (Bengtsson et al., 2006). Coastal ecosystems are overburdened with human activities driven by coastal, industrial and port development, energy generation, agriculture, fisheries and aquaculture (Halpern et al., 2007). Further, the escalating threat of climate change will be one of the top threats to biodiversity by mid-century (IPBES, 2018). Human activities impose multiple pressures on coastal ecosystems by reducing water quality, biodiversity and habitat availability, and altering hydrological processes and food web dynamics. Inadequate management of multiple pressures can reduce the capacity to provide ecosystem services such as fisheries (Cullen-Unsworth and Unsworth, 2018). The combined or interactive effects of multiple threats from past, present and future activities, defined here as the cumulative impact, are also undermining ecosystem resilience (Ortiz et al., 2018).

The lack of integration of coastal management approaches may be one of the fundamental reasons why coastal ecosystems remain largely unprotected from multiple pressures. Some important hurdles to the integration of management include crossing spatial jurisdictions (e.g. land, water catchments, wetlands and coastal marine environments); overcoming institutional segmentation that imposes sectoral management policies and; coordinating across international boundaries (Elliott, 2014). These hurdles can be overcome with conceptual frameworks such as Integrated Coastal Zone Management (ICZM) (Cicin-Sain and Belfiore, 2005), marine spatial planning (Qiu and Jones, 2013), and ecosystem-based management (McLeod and Leslie, 2009). Although significant development of these concepts have been made, particularly with policy in the European Union (EU) (Borja et al., 2016), there is still a need to translate policy objectives into specific 'on ground' targets and measures (Katsanevakis et al., 2011). For example, lack of institutional structures to support ICZM (Karabiyik, 2012) and human capacity constraints (Goble et al., 2017), impede the ability to translate policy into measurable objectives. It is currently unknown how commonly

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Table 1
Policy and planning terminology.

Terminology	Definition
Environmental Legislation	Provides the fundamental legal support for the development of policies and plans
Environmental Policies	Provide statements of principle and commitment concerning environmental issues and help guide decision-making processes. They are part of a suite of tools used to manage threats and are often used in conjunction with other non-legally binding tools such as strategic vision statements, guidelines and best practise standards.
Regulatory Systems	Are used to implement legislation and provide decision-making systems to manage human use of the environment, e.g. Environmental Impact Assessment (EIA), Assessment of Environmental Effects (AEE), Strategic Impact Assessment (SIA) or Strategic Environmental Assessment (SEA) toolbox.
Management Plans	Herein, referred to as 'Plans', specify how legislation and policies will be implemented thereby providing direct actions on programs of work. This term encompasses any planning framework such as Marine Spatial Plans, Marine Protected Areas, zoning plans or management strategies over a designated marine/coastal area.
Governance structures	The institutional structure upon which management of a coastal/marine area is based.
Management Frameworks	The set of methodologies, procedures and measures that facilitate environmental management.

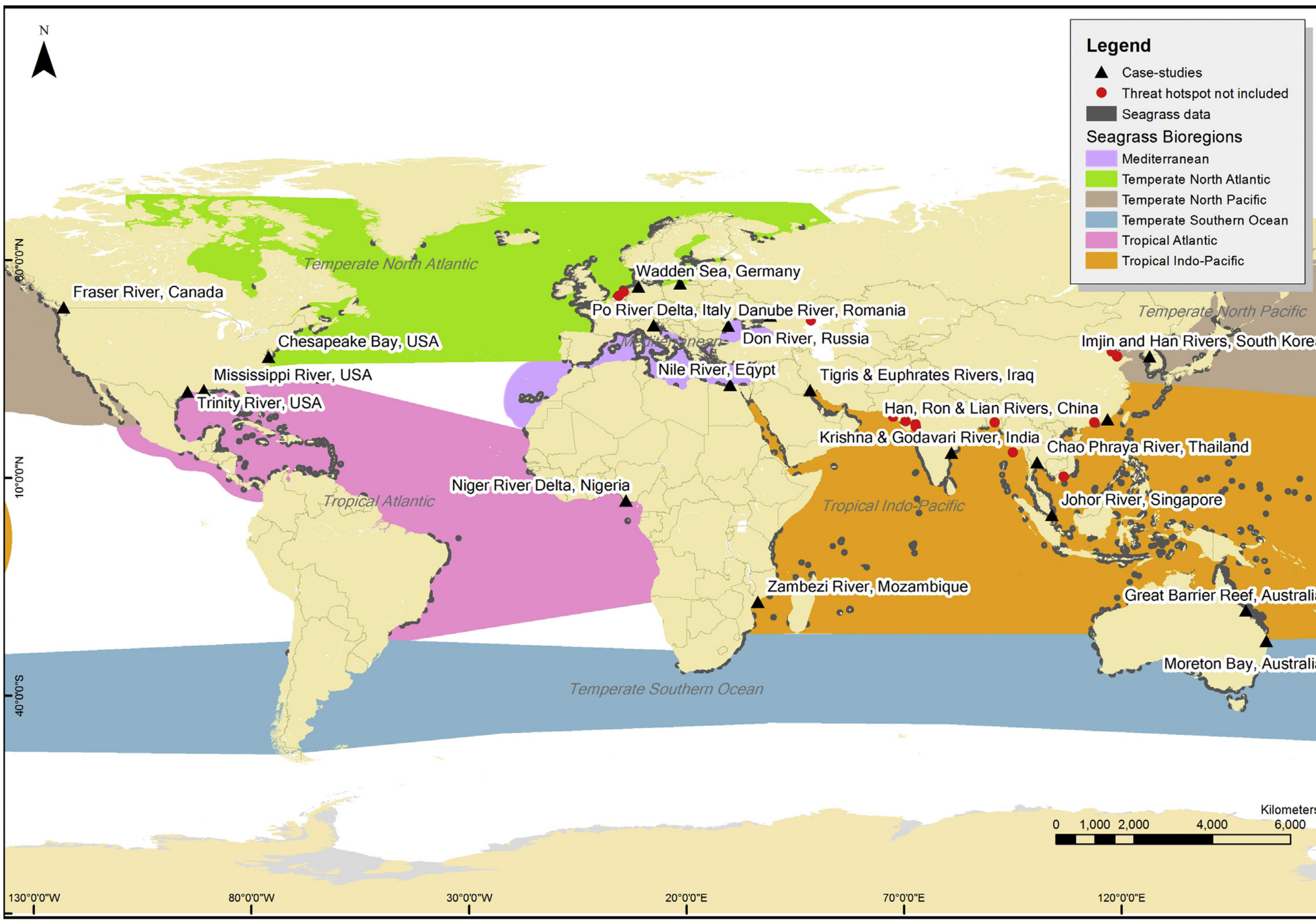

Fig. 1. Location of selected sites for review overlaid with seagrass bioregions (Short et al., 2007) and global seagrass distribution as points and polygons (UNEP-WCMC and Short, 2018). "Threat hotspots not included" are Halpern et al. (2009) hotspot locations without a representative case study site in the present study.

these concepts are applied globally to protect coastal ecosystems.

Seagrass ecosystems provide a useful case-study to explore the current state of management in coastal areas challenged by multiple pressures and cumulative impacts. Seagrass meadows are often at their most extensive in estuaries and bays where ports and cities co-occur. Seagrasses also provide numerous ecosystem services (e.g. Campagne et al., 2015; Sievers et al., 2019). Further, they are considered ecosystem engineers and global biological sentinels of multiple anthropogenic pressures in coastal ecosystems (Orth et al., 2006). Their high global rates of decline (losses of 7% per year in the two decades from 1990 (Waycott et al., 2009)) means they are among the most threatened and vulnerable ecosystems on earth.

In this review, we analyse the frameworks underpinning the management of seagrass habitats. We explore how management tools (namely legislation, policies, and regulatory and planning tools, Table 1) contribute to protecting seagrass ecosystems in 20 regions subject to high cumulative impacts. We developed a methodology that could be applied by governments or non-government organisations in any region to rapidly assess the status of protection of coastal ecosystems. This review highlights gaps in management, and identifies priorities for rapid integration of the science of cumulative impacts into policy and legislative frameworks. Doing so can enhance the protection of coastal ecosystems.

2. Methods

2.1. Scope of the review

Our objectives were to: (1) review the different management tools used to prevent or mitigate threats to seagrass habitats; (2) evaluate how management plans, herein referred to as 'Plans', address multiple pressures over a broad spectrum of activities to support the conservation and protection of seagrass habitats; and (3) identify management frameworks that have supported the stability or recovery of seagrass habitats. Management tools include legislation, policy, regulatory systems and management plans (Table 1).

2.2. Selection of regions

We chose 20 regions for review to best represent the geographic distribution of seagrass, and the range of potential pressures and governance structures. Fifteen coastal regions were selected from locations where seagrass meadows (UNEP-WCMC and Short, 2018) intersected with hotspots of threat (threat clusters) from land-based pressures (Halpern et al., 2009). This threat ranking approach was chosen because it provided a method for prioritising areas most at risk from land-based impacts (based on watershed processes contributing to nutrient and pollution input and coastal human population size) which directly applied to seagrass threats. Three additional regions with governance structures known to value seagrass habitats and/or support seagrass conservation goals were also included to give a deeper understanding of how directed management of multiple pressures can be achieved. Two other regions were included to ensure coverage over the majority of global seagrass bioregions (Fig. 1, Table A2).

2.3. Search criteria

We evaluated how comprehensive seagrass protection was in each case-study by asking five questions of the grey and peer-reviewed literature (Table 2). We used two search strategies to assemble comprehensive information relevant to each question. Grey and peer-reviewed literature were searched using Google and Google Scholar with search terms including the region of interest, threat activity (energy generation, industrial development, port development, coastal urbanisation, invasive species, fisheries, water quality, climate change) and tools (coastal management, plan, work program, governance, policy, spatial planning). Grey literature is an important resource for management policies and plans (Adams et al., 2017; Corlett, 2011) and here included government documents or reports, legislation (acts, laws, regulations, decrees, subordinate legislation, etc.), non-governmental organization reports, intergovernmental organization reports (e.g. International Union Conservation Nature (IUCN)), political union reports (EU)), reports from environmental consultancies, and reports from private companies. To address the question "Are seagrass habitats stable or recovering?" (Q5, Table 2), only peer-reviewed literature was searched using Web of Science for studies of trends in seagrass status (areal coverage, diversity or productivity) in review regions. Peer-review literature provided the confidence that trends were measured to an international standard. Search terms included the region of interest as well as the following: seagrass (SAV, submerged, aquatic vegetation, eelgrass), rate of change (loss, change, recovery, stability, impact, decline, increase, gain) and area (cover, area, distribution, production, bed, diversity) and management (intervention, plan, restoration). In total we reviewed 658 documents across the 20 case-studies (Table A1).

2.4. Evaluation criteria

To aid analysis of the literature we categorized the main threats to seagrass according to the Drivers-Activities-Pressures-State-Impact-Responses (DAPSIR) model (adapted from Elliott et al. (2017)). The division of threats into drivers and activities (Fig. 2) enabled an understanding of if, and how, multiple threats and cumulative impacts were considered by management in each case-study region. Evidence of compliance and/or monitoring were identified as well as community led education and research programs.

Drivers are the basic human needs of society; such as food provisioning (Table A3). **A**ctivities are the primary threats to seagrass and are often the level at which government policies and institutional structures are formed, e.g. fisheries are a threat to seagrass as fishing gear (nets, raking) are capable of directly damaging seagrass habitat (Table A.4). **P**ressures are the mechanism through which activities (threats) have an effect, e.g. one of the pressures of fisheries is abrasion of the seabed (Table A.5). **S**tate change was the change to the natural environment from unmanaged singular or multiple pressures, e.g. abrasion fragments meadows (Table A3). **I**mpact is the social or economic consequence of state environmental change, e.g. loss in fishing productivity from fragmentation of seagrass habitat. **R**esponses were the actions of management to prevent, detect or mitigate threat, restore lost habitat/species or adapt to environmental change. For example, fragmented seagrass beds might be recovered through prohibition on use of benthic fishing gear in seagrass habitat (Fig. 3).

The DAPSIR framework (and its predecessors) has been used as a tool for managers to understand the causes, consequences and responses to change in both the terrestrial and marine realm (Pinto et al., 2013). It has been widely applied to link science with management and policy, e.g. Thailand (Baldwin et al., 2016) and South Africa (Goble et al., 2017). Here we have used this tool to explore how management actions are currently implemented to address the pressures of human activities on seagrass. This process clearly identifies where gaps in regulatory, policy and planning frameworks exist.

Table 2
Key questions to decide what legislative, policy and planning actions are needed to adequately protect seagrass habitats.

	Question	Action
1	Are seagrass habitats explicitly identified as an ecosystem of environmental significance by legislation?	Review legislation to determine if seagrass is specifically protected and if so, how their values are considered (e.g. biodiversity, ecosystem services).
2	What are the main anthropogenic threats to seagrass and how are they managed?	Review grey and peer-reviewed literature to identify the main activities that threaten seagrass and determine which threats relate to the case-study area. Review legislation, policies, plans, guidelines and peer-reviewed literature to see if threats to seagrass are (A) specifically addressed and/or (B) protected indirectly through regulations that may benefit seagrass.
3	Have cumulative impact policies been developed?	Review cumulative impact policies and peer-reviewed literature governing the impact assessment toolbox and determine if they consider the cumulative effects of past, current and future activities.
4	Do Plans consider multiple pressures?	Construct an integrated DAPSIR for all activities identified in (2). Review Plans in detail to see if pressures to seagrass are specifically addressed with an action.
5	Are seagrass habitats stable or recovering?	Review peer-reviewed literature to determine if monitoring data exists for seagrass, particularly information addressing historic baselines and trends through time.

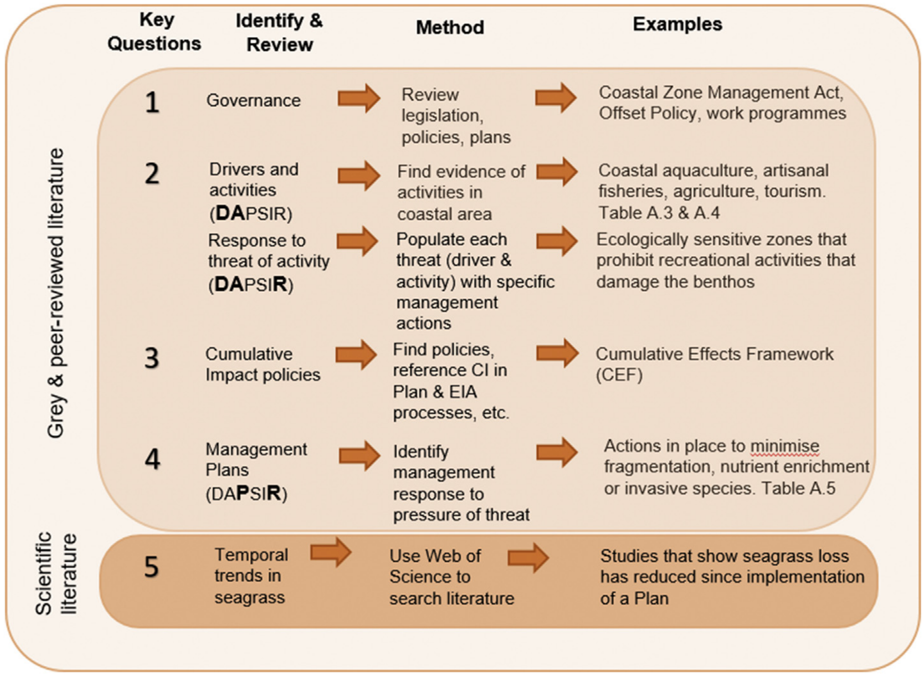

Fig. 2. Methodology used in the review to answer the 5 key questions.

3. Results of key questions

3.1. Are seagrass habitats explicitly identified as an ecosystem of environmental significance by legislation?

Seagrass habitats lacked protection through legislation, policies or spatial plans in half of the case-study regions, particularly for countries with a low human development index (HDI) (Table A.6). These regions include the coastal seas adjacent to the Danube River (Romania), Chao Praya River (Thailand), Nile River (Egypt), Niger River (Nigeria), Krishna & Godavari Rivers (India), Zambezi River (Mozambique), Don River (Russia), Tigris and Euphrates Rivers (Iraq), Han, Ron and Lian Rivers (China), and Johor River (Singapore). Without legislative protection seagrass habitats in these areas remain at risk of decline, because there are no instruments to acknowledge their importance or minimise impact through regulatory systems (e.g. offset policies), planning processes (e.g. marine protected areas or zoning plans) or conservation agendas.

3.2. What are the main anthropogenic threats to seagrass and how are they currently managed?

Activities that impact on water quality through energy generation, industrial and port development, agriculture and coastal urbanisation were consistently identified as primary threats across all case-studies (acknowledging that we chose many case-study regions partly on the basis of a high cumulative threat index from land-based threats). Fisheries, coastal infrastructure, recreation and tourism, and transport and shipping (invasive species) were also commonly identified. Major industrial development was identified only in some case-study regions such as in the state of Schleswig-Holstein (German Wadden Sea) and the city of Rostov-on-Don (Don River, Russia). Climate change was not recognised as a significant threat across the majority of case-studies, which may explain the lack of actions specifically targeting climate

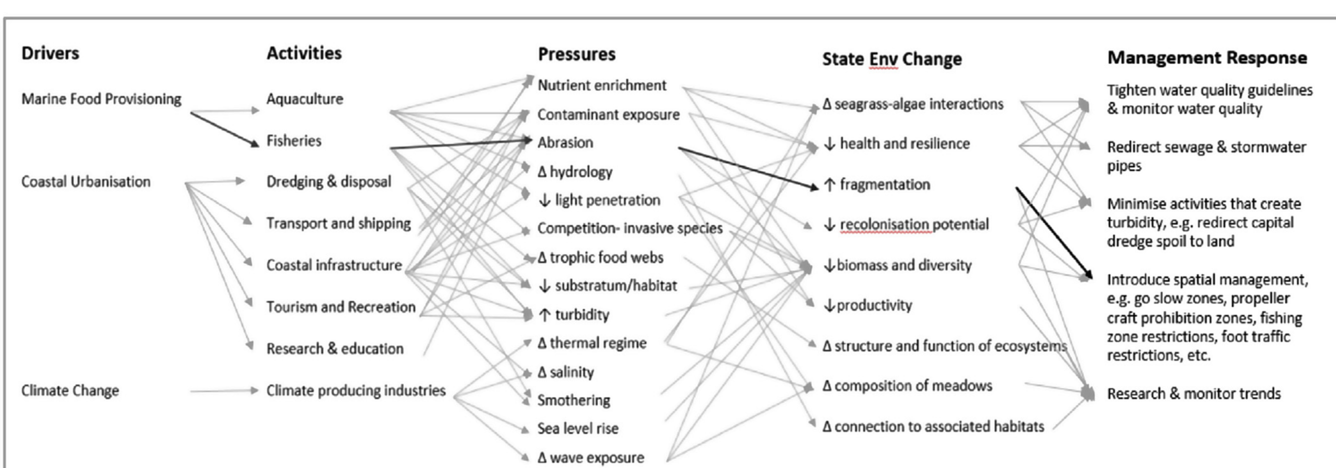

Fig. 3. An example of the Driver-Activity-Pressure-State Change-Management Response relationships for seagrass for some of the activities identified through the review, highlighting a pathway from 'marine food provisioning to environmental changes'. Adapted and expanded from Smith et al. (2016). See Table A.3, A.4 and A.5 for further information.

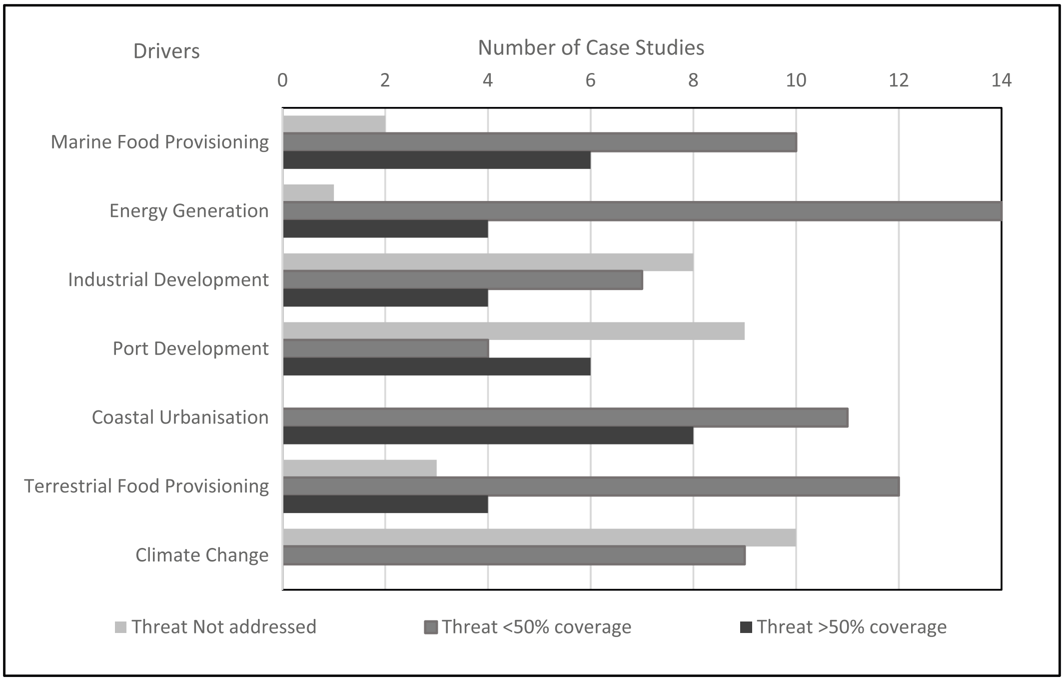

Fig. 4. Summary of findings on seagrass threats from the 20 case-studies reviewed. Coverage refers to the percentage of threats within each driver targeted with a management action.

change (Fig. 4). Government reports indicated that the main threats to coastal ecosystems are known in most case-study regions. However, measures to mitigate against threats to seagrass habitats specifically were only implemented in case-studies that directly identified the national or regional importance of seagrass habitats through legislation. For example in Nigeria, the former National Policy on the Environment (Federal Ministry of Environment, 2016) acknowledged the main threats facing coastal ecosystems and had policy statements to address threats. However, Nigeria lacked the legal framework to implement its policy, so coastal ecosystems remained at risk (Mmom and Chukwu-Okeah, 2011).

The main threats to seagrass were managed through a complex array of management tools, including legislation, policy, strategies, plans, work programs, public outreach practices, guidelines and best practice procedures. No single tool covered all threats. Threats were not equally addressed with management actions across all drivers (Fig. 4) and within each case-study (Fig. 5). Poor representation of threats was evident particularly for countries with a HDI rank of higher than 52, and not part of the EU (Table A.6). The threat to water quality and from fisheries were addressed in the majority of case-studies regardless of economic status and HDI (Table A.6). However, there was considerable variability in management of threats from other activities.

Water quality regulations are in place globally and primarily targeted at reducing nutrient, chemical and biological contaminants in waste-water. However, waste-water pollution still occurs in over 50% of the case-studies due to inadequate levels of treatment (generally only primary treatment), inadequate coverage, and/or aging infrastructure, as well as an inability to process seasonal overflows (Table A.6). For example in the urban areas of Andhra Pradesh Province in India, only 15% of waste-water is treated through treatment plants (Ministry of Environment and Forests, 2013). Monitoring of wastewater was carried out across the majority of case-studies, however they varied from random checks to routine monitoring (Table A.6). Very few countries treat storm water or tackle diffuse run-off. The state of Schleswig-Holstein (Germany), Singapore and Seoul Capital Area (Republic of Korea) are the only case-studies that have management policies in place to minimise run-off pollution (Table A.6). Measures to manage non-point source pollution exist for some industries such as setting a minimal distance to coasts for agriculture and forestry (State of Louisiana, USA).

Spatial restrictions on bottom trawling in coastal areas have been implemented in 75% of case-studies on a permanent, seasonal and/or periodical basis to protect coastal habitats. However, seasonal or periodical restrictions are suspected to offer little protection for habitats. In some regions spatial restrictions were the main form of control on fishing activities (e.g. Alexandria Province, Egypt). Measures to reduce benthic impacts to coastal habitat from non-trawl related fishing activity such as intertidal dredging, raking or digging, were rare, particularly in areas not covered by a Plan. For example along the extensive tidal flats in the western Republic of Korea, there are limited provisions to mitigate the impact of harvesting bivalves within intertidal seagrass, despite the prevalence of this activity (Hahm et al., 2014), and its effect on seagrass habitat (Park et al., 2011). However, implementation of regulations has occurred in some regions. For example, regulations protect some seagrass meadows in Venice Lagoon by restricting mechanical clam fishing to specified areas (Facca et al., 2014).

The main mechanisms for regulating coastal development were through permit approval processes. Requirements for an Environmental Impact Assessment (EIA) for coastal development activities in the coastal zone were in place at all case-studies except Iraq. This process can potentially play a pivotal role in protecting coastal ecosystems particularly against large-scale port development, coastal wind-farms or extraction industries. However, the EIA process minimises impact to seagrass only if meadows are protected specifically through legislation. For example, all marine plants are protected under fisheries legislation in Moreton Bay and the Great Barrier Reef, Australia, meaning that destruction, damage or disturbance of marine plants without approval is prohibited. Further, the EIA process is only effective if seagrass is valued for its ecosystem services. For example, none of the large state-led coastal land reclamations have been rejected in the Republic of Korea, despite protection for tidal flats (including seagrass) through legislation, largely because research on seagrass was limited to biodiversity and did not account for their functional roles (Lee et al., 2016).

Although 80% of case-studies have policies, adaptation strategies or action plans for climate change, only two regions, Great Barrier Reef (Great Barrier Reef Marine Park Authority, 2012) and German Wadden Sea (Common Wadden Sea Secretariat, 2010; Hofstede and Stock,

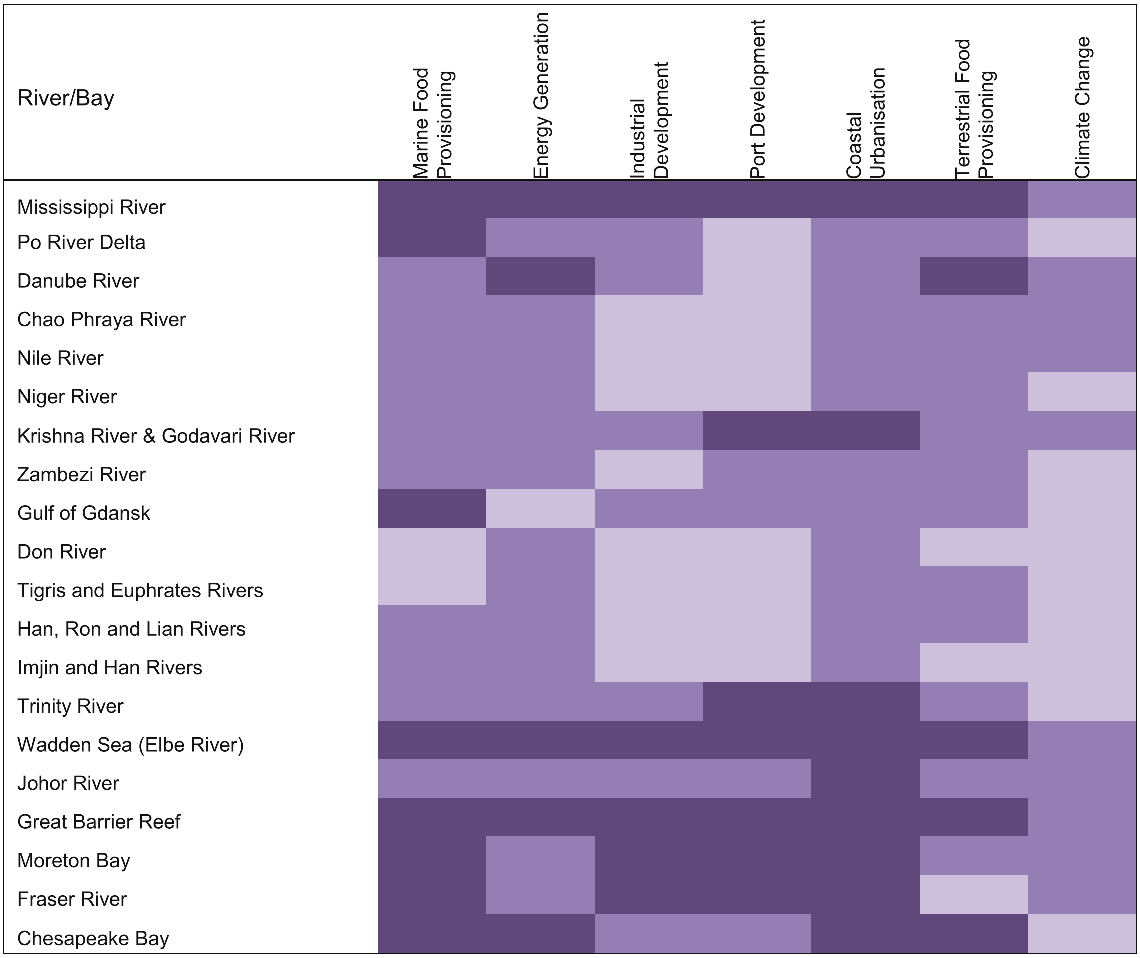

Fig. 5. How comprehensively threats were addressed in each case study. Light purple indicates threat not addressed. Lilac indicates < 50% of the threat was addressed and dark purple indicates > 50% of the threats were addressed through all regulatory and policy avenues. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

2016), specifically mention the value of an ecosystem based approach to climate change adaptation and mitigation. The absence of measures to mitigate the effects of rising sea level and sea temperature on coastal ecosystems indicates that climate change is not yet making the political agenda for seagrass protection, despite the threat it poses to seagrass (Kim et al., 2015). All case-study regions are signatories on the Paris Agreement (UNFCCC, 2015) except Russia and Iraq, and broad reductions in emissions should reduce the risk to seagrass habitats (Jordà et al., 2012).

The development of climate mitigation strategies specific to seagrass ecosystems is nascent. Some countries are working on ‘eco engineering’ alternatives to grey infrastructure that may allow seagrass habitats to migrate as the sea level rises. For example, options for mitigating coastal erosion in Thailand include restoring mangroves and planting bamboo fencing as ‘bioshields’ (Saengsupavanich, 2013). However, other regions prioritised historic and cultural protection over coastal habitat protection. For example, Venice (Italy) is building a system of storm surge mobile barriers at the lagoon inlets that will reduce seawater intrusion into Venice city during abnormal tides (above 1.1 MSL). The barriers are predicted to have adverse consequences for coastal habitats under sea-level rise projections (Bellafiore et al., 2014).

The main mechanism through which countries minimised the risk of invasive species to seagrass habitats was through limiting activities that create vectors for invasive species, primarily through ballast water management. Seven countries had ratified or agreed to the International Convention for the Control and Management of Ships’ Ballast Water and Sediments, which came into force in September 2017 (International Maritime Organisation, 2018). Countries of case-studies not signatory to this convention such as USA and Australia had their own ballast water regulations and guidelines in place minimising the risk of spread, (e.g. Department of Agriculture and Water Resources, 2017). Measures to mitigate the risk of biofouling were mainly limited to regional/national guidelines and International Maritime Organization guidelines. With the exception of the EU, it was not clear that other case-studies had legislation or policies to address the threat of invasive species from mariculture and aquaria.

3.3. Does management consider cumulative impacts?

There was little protection for seagrass or any coastal resources from cumulative impacts in the majority of case-studies. Of the 20 review regions, cumulative impact policies were absent from 14 case-study regions (Table A.6). This is concerning given that cumulative impact policies provide the main mechanism for decision-makers to consider multiple threats and cumulative effects through EIA, SIA, SEA, AEE or equivalent processes. The absence of cumulative impact policies means that only the footprint of the proposed activity requires assessment through these processes, rather than the impact on the receiving environment from the sum of all past, present and proposed future activities and land-based threats (Bidstrup et al., 2016; Willsteed et al., 2017). The six regions where cumulative impacts are accounted for include Moreton Bay and the Great Barrier Reef (Australia), Chesapeake Bay, Mississippi River and Trinity Bay (USA), and Fraser River

(Canada). The USA provides the most comprehensive framework for considering cumulative impacts, which involves regulations, guidelines and handbooks to assist government practitioners.

The EU requires member states to consider the nature of cumulative effects compared to other existing projects through the EIA and SEA Directives, but lacks a specific policy helping to achieve this. The lack of policy supporting actions has hampered the ability of member states to thoroughly assess cumulative impacts, such as in the Veneto Region of Italy (Ostoich and Wolf, 2017). Further, the documents that guide the assessment of cumulative effects are almost 20 years old (Walker and Johnston, 1999) and do not include the significant advancements made towards assessing cumulative impacts (Bidstrup et al., 2016; Brown et al., 2014).

3.4. Do plans consider multiple pressures?

Plans can be an essential tool to address the interactions among multiple pressures and cumulative impacts, because they are capable of facilitating the integration across different sectors and jurisdictions (Portman, 2011). However, not all management plans achieve this. Only five of the 15 regions in the high cumulative impact zones had Plans in place and only two of these specifically addressed multiple pressures on seagrass (Table 3): the Trilateral Wadden Sea Plan (Common Wadden Sea Secretariat, 2010) (German component assessed only) and the Pilot Draft Plan for the Western Part of the Gulf of Gdansk, Poland (Zaucha, 2010).

Three of the five additional case-studies included in the review had spatial Plans protecting seagrass from multiple pressure (Australian Government, 2015; Chesapeake Bay Program, 2015a, 2015b, 2015c; Queensland Government, 2008). Three of these case-studies did not use the Plans in an integrated way to address multiple pressures on seagrass habitat (Table 3). For example, the Moreton Bay Zoning Plan only limits fishing and recreational use up to the mean high water spring tide and it lacks integration with the urban-land use plan. Therefore, there is no mechanism to manage the system holistically, because different sectors are responsible for water quality management and coastal development within the bay. Conversely, the Chesapeake Bay Program focused predominantly on improving water quality to reduce impacts to seagrass and other submerged aquatic habitats. The Australian Federal Government acknowledged the lack of cohesion in management to address threats to the Great Barrier Reef Marine Protected Area from a zoning plan alone and developed interrelated Plans that built on the original Zoning Plan (Queensland Government, 2004) to reduce pressures from marine and coastal activities (e.g. Australian Government, 2018, 2015). However overall, there was insufficient information within the Plans to ascertain how, and if, they controlled for cumulative impacts. No Plans referenced cumulative impact policies, despite such policies being available for some case-studies (Moreton Bay, the Great Barrier Reef, Chesapeake Bay, Mississippi River, Trinity Bay and Fraser River) suggesting that management plans are lagging behind policy recommendations on cumulative impacts.

Plans are particularly important to support implementation of legal instruments. For example, in India, seagrass is defined, as an 'ecologically sensitive area' in the Coastal Regulation Zone 2011 and states are required to develop a Coastal Zone Management Plan in order to protect these areas at the regional level. However, the timeframe for states to develop these plans continues to be delayed (Ministry of Environment Forest and Climate Change, 2017). Thus, in India there has been minimal protection for seagrass habitats, as national laws have not been translated into actionable outcomes at the regional level.

Table 3
Activities (relating to threats to seagrass) addressed through a management Plan in the five regions that had management plans in place.

Plan [a]	Activities addressed by a Plan [b]																	
	Fisheries & aquaculture	Energy generation	Extractive industries	Land-based industries	Port development - dredging	Transport & shipping	Transport & shipping -biosecurity	Coastal infrastructure - reclamation	Coastal infrastructure - construction	Coastal infrastructure - water quality	Tourism & recreation	Military	Agriculture	Climate change	Zoning scheme	Integrated with urban plan	% Pressures addressed	Seagrass stable or recovering (references)
WSP	shaded	shaded	shaded	dark grey	shaded	shaded	shaded	shaded	shaded	shaded		dark grey	shaded	shaded	shaded	shaded	**79**	Stable with habitat to recolonise (Folmer et al., 2016; Reise and Kohlus, 2008)
CB				shaded	shaded				shaded	shaded		shaded	shaded				**29**	Recovering (Lefcheck et al., 2018; Ruhl and Rybicki, 2010)
MB	shaded	dark grey	shaded		shaded						shaded	dark grey			shaded		**37**	Likely stable along the eastern banks (Roelfsema et al., 2009), losses along the western banks
GBR	shaded	shaded	shaded	shaded	shaded	shaded		shaded	shaded	shaded	shaded	shaded	shaded		shaded		**68**	Generalised declining trends (Coles et al., 2015)
PDP	shaded	dark grey	dark grey	shaded	shaded	shaded		dark grey	shaded	shaded						shaded	**45**	Recovering (Bostrom et al., 2003) but prior to development of the Plan

[a] WSP (Common Wadden Sea Secretariat, 2010), CB (Chesapeake Bay Program, 2015a), MB (Queensland Government, 2008), GBR (Australian Government, 2015), PDP (Zaucha, 2010).
[b] Description of activities in Table A.4. Shaded area indicates threat addressed through a Plan. Dark grey indicates not applicable as it is not identified as a major activity in the case-study region. White cells indicate that the activity is not considered within the Plan (Reise and Kohlus, 2008; Roelfsema et al., 2009; Ruhl and Rybicki, 2010).

3.5. Are seagrass habitats stable or recovering in areas that address multiple pressures to seagrass?

The only evidence we identified from the peer-reviewed literature that attributed the stability or recovery of seagrass to the implementation of a Plan was from Chesapeake Bay and the German Wadden Sea (see references in Table 3). Chesapeake Bay's Program focused on reducing nutrients and sediment in the surrounding catchment and includes ambitious restoration and monitoring goals. By 2015, the program had achieved an interim goal of restoring 36,500 ha of seagrass, although this was short of the project's planned 90,000 ha by 2017 (Orth et al., 2017). The recovery of seagrass through improving water quality has been documented elsewhere (Sherwood et al., 2017). For example, Singapore managed to retain its seagrass diversity despite over 80% of its shoreline being modified (Lai et al., 2015), through applying stringent water quality standards and laws (Yaakub et al., 2014). This occurred despite the lack of a specific management plan for the coastal environment. The German Wadden Sea Plan employed a more holistic approach that spatially zones and manages most activities capable of exerting anthropogenic pressure on seagrass. In the German Wadden Sea, the potential for new sites to be colonised indicates the effectiveness of the current management regime (Folmer et al., 2016).

The other three case-studies with a Plan in place show variable seagrass trends. Annual environment report cards for Moreton Bay and the Great Barrier Reef indicate that some seagrass meadows are becoming more fragmented and declining in area, while other meadows remain stable (Coles et al., 2015; Maxwell et al., 2015). Seagrass is recovering in the western part of the Gulf of Gdansk (Węsławski et al., 2013), however the recovery occurred prior to development of the Plan from efforts to reduce eutrophication (Bostrom et al., 2003). Active seagrass restoration projects are also underway in the western part of the Gulf of Gdansk (Institute of Oceanology Polish Academy of Sciences, n.d.).

4. Discussion

We found that protection for seagrass is inadequate for the majority of case-studies in this review. Management frameworks are still dominated by sectoral management approaches and there remains poor integration across jurisdictional realms. The institutional structures that dominate the case-study regions prevent the holistic approach needed to address interactions among multiple pressures and cumulative impacts. There were several examples of Plans that addressed multiple threats, but none of these Plans addressed cumulative impacts. The data required to set regional thresholds for exceedance, such as identifying minimal lights requirements for seagrass are being collected in some regions, such as the GBR (Chartrand et al., 2012). Yet the flexibility of management plans to cross jurisdictions and sectors to incorporate science into a cumualtive impact framework which considers multiple threats (e.g., water quality and coastal development) is still in its infancy (Seitz et al., 2011; Therivel and Ross, 2007). Threat maps and dynamic quantitiative modelling approaches may go some way towards assiting managers to develop these frameworks such as shown for the Great Barrier Reef (Anthony et al., 2013). These findings suggest that the translation of research on cumulative impacts and multiple pressures into management frameworks are a priority for improving protection of seagrass. This will require greater effort to translate science into policy, such as through transdisciplinary research or knowledge translation (Curran et al., 2011; Pohl, 2008).

The following priorities could fill management gaps, and speed development and implementation of Plans that address multiple pressures and cumulative impacts.

1. Seagrass habitats require more recognition of their value on a global scale (Cullen-Unsworth and Unsworth, 2018). In democratic societies, the recognition of value puts pressure on government to create policies for protection. The multitude and complexity of pressures faced by seagrass suggest seagrass require their own legislative and planning frameworks. Plans that implement zoning schemes and are integrated with urban or land-use plans provide the most effective method to manage multiple pressures and cumulative impacts. Importantly, such plans can also overcome sectoral and jurisdictional barriers. Management needs to be supported by research that considers the importance of functional roles and quantifies ecosystem services (Ruiz-Frau et al., 2017). Allowing local communities and stakeholders to have an active voice in planning and budgeting will also contribute to the success of management activities (Chirenje et al., 2013). Public education and outreach documents, such as codes of practice, guidelines, vision statements, procedures and programs of work, are important tools to support environmental awareness and should be developed through public engagement in conjunction with planning and regulatory frameworks. For example, in the Gulf of Thailand buoys are used to mark the perimeter of valued seagrass beds in an effort to increase environmental awareness and minimise impact by coastal users (Department of Marine and Coastal Resources, 2016).
2. Monitoring of seagrass habitat requires a consistent approach across its range to detect inter-annual trends, because this will support both planning and approval processes and monitoring is essential to highlight the level of management intervention required (Ruiz-Frau et al., 2017). Monitoring information will also support the development for specific policy documents to manage multiple pressures and assess cumulative impacts. For example, the lack of information on seagrass distribution and diversity in China has hindered national conservation programs for seagrass (Zheng et al., 2013). Monitoring needs to extend into the subtidal sea, particularly for EU member states, to ascertain if protection gaps exists for subtidal seagrass habitat. Support to assist monitoring efforts of seagrass is gaining traction. For example, the United Nations Environment Program Northwest Pacific Action Plan (NOWPOP) Special Monitoring and Coastal Environmental Assessment Regional Activity Centre (CEARAC) is currently developing a tool for mapping seagrass distribution with satellite images using cloud computing technology in the NOWPAP regions (Russia, China, Republic of Korea and Japan) (NOWPAP-CEARAC, 2018).
3. More support is needed for countries with a medium to low HDI that are potentially suffering from extensive seagrass loss and lack adequate governance (Wonah, 2017), institutional knowledge and resources to effectively protect their coastal area (e.g. Nigeria). These losses are occurring despite the many avenues of support from the IUCN, United Nations and EU (Mmom and Chukwu-Okeah, 2011). The Memorandum of Understanding between the Republic of Korea and the Trilateral Wadden Sea Nations provides an example of how countries can transfer knowledge and provide support (Ministry of Land Transport and Maritime Affairs of the Republic of Korea and the Trilateral Cooperation on the Protection of the Wadden Sea, 2009), which could be replicated elsewhere.
4. Management Plans need to consider how local actions to protect seagrass can account for the impacts of climate change. The importance of choosing eco-engineering design to reinforce coastal stability needs to be part of climate change policies.
5. Cumulative impact polices need to be developed to enable consideration of multiple pressures and cumulative impacts through the EIA and similar processes. There are examples of Plans that address multiple pressures and cumulative impacts. These examples may guide management in regions that lag in addressing these issues. For instance, the German Wadden Sea Plan, effectively a Trilateral Wadden Sea Plan, provides the most comprehensive framework for the management of multiple pressures among 20 case-studies.

We comprehensively reviewed management literature in 20 regions, fifteen of which are exposed to the most threatening watershed processes. Seagrass ecosystems may also be highly threatened in regions unassociated with rivers, such as in regions with extensive coastal development (Holon et al., 2015). This review could be expanded in the future to cover more regions and consider hotspots of coastal development threat. In terms of coverage, we included some non-English language literature and case-studies from a range of seagrass bioregions and countries. The broad range of sites we reviewed means it is likely that we represented the current status of seagrass management globally. Future efforts could review more non-English language literature to improve our understanding of seagrass protection in certain hotspots of seagrass decline, which may also have low scientific capacity. In addition, the relative impacts of different threats to seagrasses varies by bioregion (Grech et al., 2012), thus future research should consider a greater number of bioregions to ask whether Plans reflect differences in the regional importance of threats. It is important that future reviews follow a comprehensive and detailed approach as we have, because many Plans intrinsically protect seagrass without specifically mentioning it as a valued habitat. There are other avenues to obtain information on existing management tools and policies in addition to a literature review process. Engagement with local agencies and experts that play a role in coastal management (e.g. Gill et al., 2017) could also be used to fill gaps in the literature.

The priorities we have proposed here are similar to regional findings about what is needed to enhance seagrass protection (Fortes, 2018; Kirkman and Kirkman, 2002). In South East Asia, a regional effort to increase awareness to conserve seagrass, monitor ecosystem changes, and manage their services and users, is urgently needed to address seagrass conservation (Fortes, 2018). In India, utilising the existing legislative framework to develop and implement management practises that reduce the risk of threats would enhance protection for seagrass (Ramesh et al., 2018). Further, educating government bodies on the importance of seagrass ecosystems and how it relates to their role as environmental managers is also considered important to enhance protection (Ramesh et al., 2018).

The inefficiencies of Plans to effectively address multiple pressures and cumulative impacts on marine environments more broadly has been shown elsewhere (Halpern et al., 2008). For example, in a review of 8 global case-studies of regional Plans, less than 20% involved adequate stakeholder engagement, ecological monitoring, adaptive management or utilised a co-management approach (Arkema et al., 2006). Similarly, other reviews have identified an emphasis on strategic sectoral objectives and top-down approaches in marine Plans (Jones et al., 2016). The DAPSIR framework can help planners to integrate different sectors, for instance, a recent model of the impact of multiple pressures on food-webs in an estuary with shared governance suggested an intergovernmental masterplan is needed to prevent a significant loss of biomass (De Jonge and Schuckel, 2019).

Future work could pair our method for reviewing legislation, policies and Plans with monitoring data to measure the impact of management on seagrass distribution and cover. Promising signs of seagrass recovery have been found in regions that had long monitoring time-series, like Chesapeake Bay (Lefcheck et al., 2018). Furthermore, new management plans could be evaluated a-priori with quantitative models of cumulative impacts to seagrass habitats (e.g. De Jonge and Schuckel, 2019). However, it remains an important question as to whether more comprehensive management of multiple pressures and cumulative impacts translates into better outcomes for conservation of coastal habitats (Micheli et al., 2013). A key challenge to overcome in assessing conservation progress is the accurate assessment of counterfactuals, i.e., what would have happened if there was no management intervention (Baylis et al., 2016). Future work could apply the DAPSIR framework to identify management actions that are most effective at addressing specific drivers and pressures.

Unfortunately, the lack of data on seagrass trends in the case study regions made it difficult to evaluate if the existence of policies and Plans was actually making a difference to seagrass ecosystems at the local level. Thus, is difficult to verify if the political will has a positive outcome for seagrass conservation for the majority of case studies. However, there are examples where social will has made a difference to seagrass conservation. For example, Singapore protected one area of seagrass against a planned reclamation project due to effective outreach programmes which changed public opinion to value seagrass over development (Wee and Hale, 2008).

In identifying the disjunction between policy and practice and how this relates to management of multiple threats, our findings are consistent with Ruckelshaus et al. (2008) and Jones et al. (2016). The novelty of this review is in presenting the core issues specific to seagrass ecosystems that hinder the progression of conservation outcomes. Further this review offers, a unique perspective in regions that are less studied. Many of the Plans we reviewed were applied to coastal ecosystems generally, so it is likely our findings of significant gaps in the protection of seagrass also apply to other ecosystems. This remains to be tested, however. Efforts to improve the protection of coastal ecosystems more generally could benefit from the methodology we developed here: the five key questions we developed (Table 1) could be applied by governments or non-government organisations in any region to rapidly assess the status of protection of coastal ecosystems. Without legislation and policies to support actions that address multiple pressures and cumulative impacts, it is likely that the status of coastal ecosystems will continue to degrade.

Declarations of interest

None.

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Appendix A. Supplementary data

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References

Adams, J.B., Smart, P., Huff, A.S., 2017. Shades of grey: guidelines for working with the grey literature in systematic reviews for management and organizational studies. Int. J. Manag. Rev. 19, 432–454. https://doi.org/10.1111/ijmr.12102.

Anthony, K.R.N., Dambacher, J.M., Walshe, T., Beeden, R., 2013. A framework for understanding cumulative impacts, supporting environmental decisions and informing resilience-based management of the Great barrier Reef world heritage area. [WWW Document]. https://www.environment.gov.au/marine/gbr/publications/framework-understanding-cumulative-impacts-supporting-environmental-decisions-and-informing, Accessed date: 12 March 2018.

Arkema, K.K., Abramson, S.C., Dewsbury, B.M., 2006. Marine ecosystem-based management: from characterization to implementation. Front. Ecol. Environ. 4, 525–532. https://doi.org/10.1890/1540-9295(2006)4[525:MEMFCT]2.0.CO;2.

Australian Government, 2018. Reef 2050 Water Quality Improvement Plan 2017-2022. [WWW Document]. https://www.reefplan.qld.gov.au/, Accessed date: 21 August 2019.

Australian Government, 2015. Reef 2050 Long-Term Sustainability Plan. [WWW Document]. http://www.environment.gov.au/marine/gbr/publications/reef-2050-long-term-sustainability-plan-2018, Accessed date: 21 August 2019.

Baldwin, C., Lewison, R.L., Lieske, S.N., Beger, M., Hines, E., Dearden, P., Rudd, M.A., Jones, C., Satumanatpan, S., Junchompoo, C., 2016. Using the DPSIR framework for transdisciplinary training and knowledge elicitation in the Gulf of Thailand. Ocean Coast Manag. 134, 163–172. https://doi.org/10.1016/j.ocecoaman.2016.09.005.

Baylis, K., Honey-Rosés, J., Börner, J., Corbera, E., Ezzine-de-Blas, D., Ferraro, P.J., Lapeyre, R., Persson, U.M., Pfaff, A., Wunder, S., 2016. Mainstreaming impact evaluation in nature conservation. Conserv. Lett. 9, 58–64. https://doi.org/10.1111/conl.12180.

Bellafiore, D., Ghezzo, M., Tagliapietra, D., Umgiesser, G., 2014. Climate change and artificial barrier effects on the Venice Lagoon: inundation dynamics of salt marshes and implications for halophytes distribution. Ocean Coast Manag. 100, 101–115. https://doi.org/10.1016/j.ocecoaman.2014.08.002.

Bengtsson, M., Shen, Y., Oki, T., 2006. A SRES-based gridded global population dataset for 1990–2100. Popul. Environ. 28, 113–131. https://doi.org/10.1007/s11111-007-0035-8.

Bidstrup, M., Kørnøv, L., Partidário, M.R., 2016. Cumulative effects in strategic environmental assessment: the influence of plan boundaries. Environ. Impact Assess. Rev. 57, 151–158. https://doi.org/10.1016/j.eiar.2015.12.003.

Borja, A., Elliott, M., Andersen, J.H., Berg, T., Carstensen, J., Halpern, B.S., Heiskanen, A.-S., Korpinen, S., Lowndes, J.S.S., Martin, G., Rodriguez-Ezpeleta, N., 2016. Overview of integrative assessment of marine systems: the ecosystem Approach in practice. Front. Mar. Sci. 3, 20. https://doi.org/10.3389/fmars.2016.00020.

Bostrom, C., Baden, S.P., Krause-Jensen, D., 2003. The seagrasses of scandinavia and the baltic sea. In: Green, E.P., Short, F.T. (Eds.), World Atlas of Seagrasses. University of California Press, Berkeley, USA.

Brown, C.J., Saunders, M.I., Possingham, H.P., Richardson, A.J., Essl, F., 2014. Interactions between global and local stressors of ecosystems determine management effectiveness in cumulative impact mapping. Divers. Distrib. 20, 538–546. https://doi.org/10.1111/ddi.12159.

Campagne, C.S., Salles, J.M., Boissery, P., Deter, J., 2015. The seagrass Posidonia oceanica: ecosystem services identification and economic evaluation of goods and benefits. Mar. Pollut. Bull. 97, 391–400. https://doi.org/10.1016/j.marpolbul.2015.05.061.

Chartrand, K., Rasheed, M.A., Petrou, K., Ralph, P.J., 2012. Establishing tropical seagrass light requirements in a dynamic port environment. In: Proceedings of the 12th International Coral Reef Symposium 9-12 July 2012. Cairns.

Chesapeake Bay Program, 2015a. Chesapeake Bay Management Stratedgy: 2017 WIP, 2025 WIP and Water Quality Standards Attainment & Monitoring Outcomes 2015-2025. [WWW Document]. https://www.chesapeakebay.net/managementstrategies/strategy/2017_and_2025_watershed_implementation_plans, Accessed date: 21 August 2019.

Chesapeake Bay Program, 2015b. Chesapeake Bay Management Stratedgy: Submerged Aquatic Vegetation Outcome 2015-2025. [WWW Document]. https://www.chesapeakebay.net/managementstrategies/strategy/submerged_aquatic_vegetation_sav, Accessed date: 21 August 2019.

Chesapeake Bay Program, 2015c. Chesapeake Bay Management Stratedgy: Fish Habitat Outcome 2015-2025. [WWW Document]. https://www.chesapeakebay.net/managementstrategies/strategy/fish_habitat, Accessed date: 21 August 2019.

Chirenje, L.I., Giliba, R.A., Musamba, E.B., 2013. Local communities' participation in decision-making processes through planning and budgeting in african countries. Chin. J. Popul. Res. Environ. 11, 10–16. https://doi.org/10.1080/10042857.2013.777198.

Cicin-Sain, B., Belfiore, S., 2005. Linking marine protected areas to integrated coastal and ocean management: a review of theory and practice. Ocean Coast Manag. 48, 847–868. https://doi.org/10.1016/j.ocecoaman.2006.01.001.

Coles, R.G., Rasheed, M.A., McKenzie, L.J., Grech, A., York, P.H., Sheaves, M., McKenna, S., Bryant, C., 2015. The Great barrier Reef world heritage area seagrasses: managing this iconic Australian ecosystem resource for the future. Estuar. Coast Shelf Sci. 153, A1–A12. https://doi.org/10.1016/j.ecss.2014.07.020.

Common Wadden Sea Secretariat, 2010. Wadden Sea plan 2010. In: Elev. Trilateral Gov. Conf. Prot. Wadden Sea, [WWW Document]. http://www.waddensea-secretariat.org/management/wadden-sea-plan-2010, Accessed date: 21 August 2019.

Corlett, R.T., 2011. Trouble with the gray literature. Biotropica 43, 3–5. https://doi.org/10.1111/j.1744-7429.2010.00714.x.

Cullen-Unsworth, L.C., Unsworth, R.K., 2018. A call for seagrass protection. Science 361, 446–448. https://doi.org/10.1126/science.aat7318.

Curran, J.A., Grimshaw, J.M., Hayden, J.A., Campbell, B., 2011. Knowledge translation research: the science of moving research into policy and practice. J. Continuing Educ. Health Prof. 31, 174–180. https://doi.org/10.1002/chp.20124.

De Jonge, V., Schuckel, U., 2019. Exploring effects of dredging and organic waste on the functioning and the quantitative biomass structure of the Ems estuary food web by applying Input Method balancing in Ecological Network Analysis. Ocean Coast Manag. 174, 38–55. https://doi.org/10.1016/j.ocecoaman.2019.03.013.

Department of Agriculture and Water Resources, 2017. Australian Ballast Water Management Requirements Version 7. [WWW Document]. http://www.agriculture.gov.au/biosecurity/avm/vessels/ballast/australian-ballast-water-management-requirements, Accessed date: 12 January 2018.

Department of Marine and Coastal Resources, 2016. Guideline to Conservation and Restoration of Seagrasses. (English Translation) [WWW Document]. https://www.dmcr.go.th/detailLib/3004, Accessed date: 6 September 2018.

Elliott, M., 2014. Integrated marine science and management: wading through the morass. Mar. Pollut. Bull. 86, 1–4. https://doi.org/10.1016/j.marpolbul.2014.07.026.

Elliott, M., Burdon, D., Atkins, J.P., Borja, A., Cormier, R., de Jonge, V.N., Turner, R.K., 2017. “And DPSIR begat DAPSI(W)R(M)!” - a unifying framework for marine environmental management. Mar. Pollut. Bull. 118, 27–40. https://doi.org/10.1016/j.marpolbul.2017.03.049.

Facca, C., Ceoldo, S., Pellegrino, N., Sfriso, A., 2014. Natural recovery and planned intervention in coastal wetlands: Venice Lagoon (northern Adriatic Sea, Italy) as a case study. Sci. World J. 2014, 968618. https://doi.org/10.1155/2014/968618.

Federal Ministry of Environment, 2016. National Policy on the Environment. (revised 2016) [WWW Document]. https://web.archive.org/web/2018, Accessed date: 20 May 2018 http://environment.gov.ng:80/media/attachments/2017/09/22/revised-national-policy-on-the-environment-final-draft.pdf (archived 09.03.18).

Folmer, E.O., van Beusekom, J.E.E., Dolch, T., Gräwe, U., van Katwijk, M.M., Kolbe, K., Philippart, C.J.M., Wiersma, Y., 2016. Consensus forecasting of intertidal seagrass habitat in the Wadden Sea. J. Appl. Ecol. 53, 1800–1813. https://doi.org/10.1111/1365-2664.12681.

Fortes, M.D., 2018. Seagrass ecosystem conservation in Southeast Asia needs to link science to policy and practice. Ocean Coast Manag. 159, 51–56. https://doi.org/10.1016/j.ocecoaman.2018.01.028.

Gill, D.A., Mascia, M.B., Ahmadia, G.N., Glew, L., Lester, S.E., Barnes, M., Craigie, I., Darling, E.S., Free, C.M., Geldmann, J., Holst, S., Jensen, O.P., White, A.T., Basurto, X., Coad, L., Gates, R.D., Guannel, G., Mumby, P.J., Thomas, H., Whitmee, S., Woodley, S., Fox, H.E., 2017. Capacity shortfalls hinder the performance of marine protected areas globally. Nature 543, 665–671. https://doi.org/10.1038/nature21708.

Goble, B.J., Hill, T.R., Phillips, M.R., 2017. An assessment of integrated coastal management governance and implementation using the DPSIR framework: KwaZulu-natal, South Africa. Coast. Manag. 45, 107–124. https://doi.org/10.1080/08920753.2017.1278144.

Great Barrier Reef Marine Park Authority, 2012. Great Barrier Reef Climate Change Adaptation Strategy and Action Plan 2012-2017. [WWW Document]. http://elibrary.gbrmpa.gov.au/jspui/handle/11017/1140, Accessed date: 12 November 2017.

Grech, A., Chartrand-Miller, K., Erftemeijer, P., Fonseca, M., McKenzie, L., Rasheed, M., Taylor, H., Coles, R., 2012. A comparison of threats, vulnerabilities and management approaches in global seagrass bioregions. Environ. Res. Lett. 7. https://doi.org/10.1088/1748-9326/7/2/024006.

Hahm, H., Jeong, S., Jeong, M., Park, S.C., 2014. Cultural resources and management in the coastal regions along the Korean tidal flat. Ocean Coast Manag. 102, 506–521. https://doi.org/10.1016/j.ocecoaman.2014.07.011.

Halpern, B.S., Ebert, C.M., Kappel, C.V., Madin, E.M.P., Micheli, F., Perry, M.T., Selkoe, K.A., Walbridge, S., 2009. Global priority areas for incorporating land–sea connections in marine conservation. Conserv. Lett. 2, 189–196. https://doi.org/10.1111/j.1755-263X.2009.00060.x.

Halpern, B.S., Selkoe, K.A., Micheli, F., Kappel, C.V., 2007. Evaluating and ranking the vulnerability of global marine ecosystems to anthropogenic threats. Conserv. Biol. 21, 1301–1315. https://doi.org/10.1111/j.1523-1739.2007.00752.x.

Halpern, B.S., Walbridge, S., Selkoe, K.A., Kappel, C.V., Micheli, F., D'Agrosa, C., Bruno, J.F., Casey, K.S., Ebert, C., H.E, F., Fujita, R., Heinemann, D., Lenihan, H.S., Madin, E.M.P., Perry, M.T., Selig, E.R., Spalding, M., Steneck, R., Watson, R., 2008. A global map of human impact on marine ecosystems. Science 319, 948–952.

Hofstede, J.L.A., Stock, M., 2016. Climate change adaptation in the Schleswig-Holstein sector of the Wadden Sea: an integrated state governmental strategy. J. Coast. Conserv. 22, 199–207. https://doi.org/10.1007/s11852-016-0433-0.

Holon, F., Boissery, P., Guilbert, A., Freschet, E., Deter, J., 2015. The impact of 85 years of coastal development on shallow seagrass beds (Posidonia oceanica L. (Delile)) in South Eastern France: a slow but steady loss without recovery. Estuar. Coast Shelf Sci. 165, 204–212. https://doi.org/10.1016/j.ecss.2015.05.017.

n.d Institute of Oceanology Polish Academy of Sciences Project on restoration and monitoring of sea beds in puck bay southern baltic polish EEZ. [WWW Document]. http://water.iopan.gda.pl/projects/Zostera/participants.html.

International Maritime Organisation, 2018. International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM). [WWW Document]. http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Control-and-Management-of-Ships%27-Ballast-Water-and-Sediments-(BWM).aspx, Accessed date: 20 September 2018.

IPBES, 2018. Summary for policymakers of the regional assessment report on biodiversity and ecosystem services for the americas of the intergovernmental science-policy platform on biodiversity and ecosystem services. In: Rice, J., Seixas, C.S., Zaccagnini, M.E., BedoyaGaitán, M., Valderrama, N., Anderson, C.B., Arroyo, M.T.K., Bustamante, M., Cavender-Bares, J., Diaz-de-Leon, A., Fennessy, S., García Márquez, J.R., Garcia, K., Helmer, E.H., Herrera, B., Klatt, B., Ometo, J.P., Rodríguez Osuna, V., Scarano, F.R., Schill, S., Farinaci, J.S. (Eds.), IPBES Secretariat, Bonn, Germany, pp. 41.

Jones, P.J.S., Lieberknecht, L.M., Qiu, W., 2016. Marine spatial planning in reality: introduction to case studies and discussion of finding. Mar. Policy 71, 256–264. https://doi.org/10.1016/j.marpol.2016.04.026.

Jordà, G., Marbà, N., Duarte, C.M., 2012. Mediterranean seagrass vulnerable to regional climate warming. Nat. Clim. Chang. 2, 821–824. https://doi.org/10.1038/nclimate1533.

Karabiyik, H.I., 2012. Bottlenecks in the Implementation of Integrated Coastal Zone Management : an Integrated Coastal Zone Management Action Plan for Turkey. World Maritime University, Sweden.

Katsanevakis, S., Stelzenmüller, V., South, A., Sørensen, T.K., Jones, P.J.S., Kerr, S., Badalamenti, F., Anagnostou, C., Breen, P., Chust, G., D'Anna, G., Duijn, M., Filatova, T., Fiorentino, F., Hulsman, H., Johnson, K., Karageorgis, A.P., Kröncke, I., Mirto, S., Pipitone, C., Portelli, S., Qiu, W., Reiss, H., Sakellariou, D., Salomidi, M., van Hoof, L., Vassilopoulou, V., Vega Fernández, T., Vöge, S., Weber, A., Zenetos, A., Hofstede, R. ter, 2011. Ecosystem-based marine spatial management: review of concepts, policies, tools, and critical issues. Ocean Coast Manag. 54, 807–820. https://doi.org/10.1016/j.ocecoaman.2011.09.002.

Kim, K., Choi, J.-K., Ryu, J.-H., Jeong, H.J., Lee, K., Park, M.G., Kim, K.Y., 2015. Observation of typhoon-induced seagrass die-off using remote sensing. Estuar. Coast Shelf Sci. 154, 111–121. https://doi.org/10.1016/j.ecss.2014.12.036.

Kirkman, H., Kirkman, J.A., 2002. The management of seagrasses in Southeast Asia. Bull.

Mar. Sci. 71, 1379–1390.
Lai, S., Loke, L.H.L., Hilton, M.J., Bouma, T.J., Todd, P.A., 2015. The effects of urbanisation on coastal habitats and the potential for ecological engineering: a Singapore case study. Ocean Coast Manag. 103, 78–85. https://doi.org/10.1016/j.ocecoaman.2014.11.006.
Lee, K.-S., Kim, S.H., Kim, Y.K., 2016. Current status of seagrass habitat in Korea. In: Finlayson, C.M., Milton, G.R., Prentice, R.C., Davidson, N.C. (Eds.), The Wetland Book II: Distribution, Description, and Conservation. Springer, Dordrecht, Netherlands, pp. 1589–1596. https://doi.org/10.1007/978-94-007-6173-5_264-1.
Lefcheck, J.S., Orth, R.J., Dennison, W.C., Wilcox, D.J., Murphy, R.R., Keisman, J., Gurbisz, C., Hannam, M., Landry, J.B., Moore, K.A., Patrick, C.J., Testa, J., Weller, D.E., Batiuk, R.A., 2018. Long-term nutrient reductions lead to the unprecedented recovery of a temperate coastal region. Proc. Natl. Acad. Sci. U. S. A. 115, 3658–3662. https://doi.org/10.1073/pnas.1715798115.
Maxwell, P., Pitt, K., Olds, A., Rissik, D., Connolly, R., 2015. Identifying habitats at risk: simple models can reveal complex ecosystem dynamics. Ecol. Appl. 25, 287–573. https://doi.org/10.1002/aqc.2573.
McLeod, K., Leslie, H., 2009. Ecosystem-Based Managment for the Oceans. Island Press, Washington DC.
Micheli, F., Halpern, B.S., Walbridge, S., Ciriaco, S., Ferretti, F., Fraschetti, S., Lewison, R., Nykjaer, L., Rosenberg, A.A., 2013. Cumulative human impacts on Mediterranean and Black Sea marine ecosystems: assessing current pressures and opportunities. PLoS One 8, e79889. https://doi.org/10.1371/journal.pone.0079889.
Ministry of Environment and Forests, 2013. Performance evaluation of sewage treatment plants under NRCD. [WWW Document]. https://www.cpcb.nic.in/openpdffile.php?id=UmVwb3J0RmlsZXMvMjlfMTQ1ODExMDk5Ml9OZXdJdGVtXzE5NV9TVFBfUkVQT1JULnBkZg==.
Ministry of Environment Forest and Climate Change, 2017. Coastal Zone Regulation (CZR). [WWW Document]. http://164.100.154.103/rules-regulations/crz-notifications, Accessed date: 5 November 2019.
Ministry of Land Transport and Maritime Affairs of the Republic of Korea and the Trilateral Cooperation on the Protection of the Wadden Sea, 2009. Memorandum of Understanding on Mutual Cooperation for the Purpose of Conservation and Management of Tidal Flat Ecosystems. [WWW Document]. https://waddensea-worldheritage.org/da/mou-korea-milestones.
Mmom, P.C., Chukwu-Okeah, G.O., 2011. Factors and processes of coastal zone development in Nigeria: a review. Res. J. Environ. Earth Sci. 3, 625–632.
NOWPAP-CEARAC, 2018. Feasibility study for assessment of seagrass distribution in the NOWPAP region. [WWW Document]. http://cearac.nowpap.org/app/website/wp-content/uploads/CEARAC_SGM_FS_2018.pdf.
Orth, R.J., Carruthers, T.J.B., Dennison CM, W.D., Fourqurean, J.W., Heck, K.L.J., Hughes, A.R., Kendrick, G.A., Kenworthy, W.J., Olyarnik, S., Short, F.T., Waycott, M., Williams, S.L., 2006. A global crisis for seagrass ecosystems. Bioscience 56, 987–996.
Orth, R.J., Dennison, W.C., Lefcheck, J.S., Gurbisz, C., Hannam, M., Keisman, J., Landry, J.B., Moore, K.A., Murphy, R.R., Patrick, C.J., Testa, J., Weller, D.E., Wilcox, D.J., 2017. Submersed aquatic vegetation in Chesapeake bay: sentinel species in a changing world. Bioscience 67, 698–712. https://doi.org/10.1093/biosci/bix058.
Ortiz, J.-C., Wolff, N.H., Anthony, K.R.N., Devlin, M., Lewis, S., Mumby, P.J., 2018. Impaired recovery of the Great barrier Reef under cumulative stress. Sci. Adv. 4 eaar6127. https://doi.org/10.1126/sciadv.aar6127.
Ostoich, M., Wolf, A., 2017. Cumulative Effect Assessment: preliminary evaluation for Environmental Impact Assessment procedure and for environmental damage estimation. Ann. Civ. Environ. Eng. 1, 63–90. https://doi.org/10.29328/journal.acee.1001008.
Park, S.R., Kim, Y.K., Kim, J.-H., Kang, C.-K., Lee, K.-S., 2011. Rapid recovery of the intertidal seagrass Zostera japonica following intense Manila clam (Ruditapes philippinarum) harvesting activity in Korea. J. Exp. Mar. Biol. Ecol. 407, 275–283. https://doi.org/10.1016/j.jembe.2011.06.023.
Pinto, R., de Jonge, V.N., Neto, J.M., Domingos, T., Marques, J.C., Patrício, J., 2013. Towards a DPSIR driven integration of ecological value, water uses and ecosystem services for estuarine systems. Ocean Coast Manag. 72, 64–79. https://doi.org/10.1016/j.ocecoaman.2011.06.016.
Pohl, C., 2008. From science to policy through transdisciplinary research. Environ. Sci. Policy 11, 46–53. https://doi.org/10.1016/j.envsci.2007.06.001.
Portman, M.E., 2011. Marine spatial planning: achieving and evaluating integration. ICES J. Mar. Sci. 68, 2191–2200. https://doi.org/10.1093/icesjms/fsr157.
Qiu, W., Jones, P.J.S., 2013. The emerging policy landscape for marine spatial planning in Europe. Mar. Policy 39, 182–190. https://doi.org/10.1016/j.marpol.2012.10.010.
Queensland Government, 2008. Marine Parks (Moreton Bay) Zoning Plan. [WWW Document]. https://www.npsr.qld.gov.au/parks/moreton-bay/zoning/pdf/map3-zoningplus, Accessed date: 16 January 2018.
Queensland Government, 2004. Marine Parks (Great Barrier Reef Coast) Zoning Plan. [WWW Document]. https://www.legislation.qld.gov.au/view/pdf/2017-09-01/sl-2004-0240, Accessed date: 15 January 2018.
Ramesh, R., Banerjee, K., Selvam, A.P., Lakshmi, A., Krishnan, P., Purvaja, R., 2018. Legislation and policy options for conservation and management of seagrass ecosystems in India. Ocean Coast Manag. 159, 46–50. https://doi.org/10.1016/j.ocecoaman.2017.12.025.
Reise, K., Kohlus, J., 2008. Seagrass recovery in the northern Wadden Sea? Helgol. Mar. Res. 62, 77–84. https://doi.org/10.1007/s10152-007-0088-1.
Roelfsema, C.M., Phinn, S.R., Udy, N., Maxwell, P., 2009. An integrated field and remote sensing approach for mapping Seagrass Cover, Moreton Bay, Australia. J. Spat. Sci. 54, 45–62. https://doi.org/10.1080/14498596.2009.9635166.
Ruckelshaus, M., Klinger, T., Knowlton, N., DeMaster, P., 2008. Marine ecosystem-based management in practice: scientific and governance challenges. Bioscience 58, 53–63.
Ruhl, H.A., Rybicki, N.B., 2010. Long-term reductions in anthropogenic nutrients link to improvements in Chesapeake Bay habitat. Proc. Natl. Acad. Sci. U. S. A. 107, 16566–16570. https://doi.org/10.1073/pnas.1003590107.
Ruiz-Frau, A., Gelcich, S., Hendriks, I.E., Duarte, C.M., Marbà, N., 2017. Current state of seagrass ecosystem services: research and policy integration. Ocean Coast Manag. 149, 107–115. https://doi.org/10.1016/j.ocecoaman.2017.10.004.
Saengsupavanich, C., 2013. Erosion protection options of a muddy coastline in Thailand: stakeholders' shared responsibilities. Ocean Coast Manag. 83, 81–90. https://doi.org/10.1016/j.ocecoaman.2013.02.002.
Seitz, E., Westbrook, C.J., Noble, B.F., 2011. Bringing science into river systems cumulative effects assessment practice. Environ. Impact Assess. Rev. 31, 172–179. https://doi.org/10.1016/j.eiar.2010.08.001.
Sherwood, E.T., Greening, H.S., Johansson, J.O.R., Kaufman, K., Raulerson, G.E., 2017. Tampa bay (Florida, USA): documenting seagrass recovery since the 1980's and reviewing the benefits. Southeast. Geogr. 57, 294–319. https://doi.org/10.1353/sgo.2017.0026.
Short, F., Carruthers, T., Dennison, W., Waycott, M., 2007. Global seagrass distribution and diversity: a bioregional model. J. Exp. Mar. Biol. Ecol. 350, 3–20. https://doi.org/10.1016/j.jembe.2007.06.012.
Sievers, M., Brown, C.J., Tulloch, V.J.D., Pearson, R.M., Haig, J.A., Turschwell, M.P., Connolly, R.M., 2019. The role of vegetated coastal wetlands for marine megafauna conservation. Trends Ecol. Evol. 34, 807–817. https://doi.org/10.1016/j.tree.2019.04.004.
Smith, C.J., Papadopoulou, K.-N., Barnard, S., Mazik, K., Elliott, M., Patrício, J., Solaun, O., Little, S., Bhatia, N., Borja, A., 2016. Managing the marine environment, conceptual models and assessment considerations for the european marine strategy framework directive. Front. Mar. Sci. 3, 144. https://doi.org/10.3389/fmars.2016.00144.
Therivel, R., Ross, B., 2007. Cumulative effects assessment: does scale matter? Environ. Impact Assess. Rev. 27, 365–385. https://doi.org/10.1016/j.eiar.2007.02.001.
UNEP-WCMC, Short, F.T., 2018. Global Distribution of Seagrasses (Version 6.0). Sixth Update to the Data Layer Used in Green and Short (2003). [WWW Document]. http://data.unep-wcmc.org/datasets/7, Accessed date: 8 May 2018.
UNFCCC, 2015. Paris Agreement. [WWW Document]. FCCC/CP/2015/L.9/Rev1.
Walker, L.J., Johnston, J., 1999. Guidelines for the Assessment of Indirect and Cumulative Impacts as Well as Impact Interactions. [WWW Document]. https://ec.europa.eu/environment/archives/eia/eia-studies-and-reports/pdf/guidel.pdf, Accessed date: 8 August 2018.
Waycott, M., Duarte, C.M., Carruthers, T.J.B., Orth, R.J., Dennison, W., Olyarnike, S., Calladine, A., Fourqurean, J.W., Heck, K.L.J., Hughes, A.R., Kendrick, G.A., Kenworthy, W.J., Short, F.T., Williams, S.L., 2009. Accelerating loss of seagrasses across the globe threatens coastal ecosystems. Proc. Natl. Acad. Sci. 106, 12377–12381.
Wee, Y.C., Hale, R., 2008. The Nature Society (Singapore) and the struggle to conserve Singapore's nature areas. Nat. Singap. 1, 41–49.
Węsławski, J.M., Kryla-Straszewska, L., Piwowarczyk, J., Urbański, J., Warzocha, J., Kotwicki, L., Włodarska-Kowalczuk, M., Wiktor, J., 2013. Habitat modelling limitations – puck bay, baltic sea – a case study. Oceanologia 55, 167–183. https://doi.org/10.5697/oc.55-1.167.
Willsteed, E., Gill, A.B., Birchenough, S.N., Jude, S., 2017. Assessing the cumulative environmental effects of marine renewable energy developments: establishing common ground. Sci. Total Environ. 577, 19–32. https://doi.org/10.1016/j.scitotenv.2016.10.152.
Wonah, E.I., 2017. The state, environmental policy and sustainable development in Nigeria. Glob. J. Arts Humanit. Soc. Sci. 5, 25–40.
Yaakub, S.M., McKenzie, L.J., Erftemeijer, P.L., Bouma, T., Todd, P.A., 2014. Courage under fire: seagrass persistence adjacent to a highly urbanised city-state. Mar. Pollut. Bull. 83, 417–424. https://doi.org/10.1016/j.marpolbul.2014.01.012.
Zaucha, J., 2010. Pilot Draft Plan for the West Part of the Gulf of Gdańsk: First Maritime Spatial Plan in Poland. [WWW Document]. https://www.msp-platform.eu/practices/zoning-polish-detailed-msp-covering-west-part-gulf-gdansk, Accessed date: 16 September 2018.
Zheng, F., Qiu, G., Fan, H., Zhang, W., 2013. Diversity distribution and conservation of Chinese seagrass species. Biodivers. Sci. 21, 517–526. https://doi.org/10.3724/SP.J.1003.2013.10038.