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Restoring near-shore marine ecosystems to enhance climate security for island ocean states: Aligning international processes and local practices

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ABSTRACT

This article contributes to a special issue examining SDG 14 and other international policy instruments for effective implementation of the Goal. This article focuses on island ocean states (IOS), or 'small island developing states' (SIDS), which are characterized by limited land and oceanic remoteness, creating local and international dependencies for food, livelihoods, trade and transport. While IOS contribute less than 1% to global green-house gases, they are directly impacted by extreme weather and climate change, in particular sea level rise. Near-shore marine ecosystems (mangroves, seagrasses and coral reefs) provide critical coastal protection and other benefits (e.g. fisheries), yet continue to be degraded from coastal development. Given their importance, restoration is needed where ecosystem function has declined, in concert with conservation of healthy sites. The overall restoration goals for IOS are to: i) enhance ecological integrity, ii) inspire local capacity building, and iii) accelerate climate change adaptation. This article examines the scope for such restoration through the UN SDGs, the Biodiversity Convention, the UN Framework Convention on Climate Change, and the Paris Agreement. Practical considerations of near-shore restoration are reviewed, emphasizing local and traditional knowledge regarding past and future perspectives. The article concludes with policy recommendations to integrate near-shore marine restoration across climate adaptation, conservation and planning processes to achieve synergies in effectiveness, essential to IOS settings. The UN SDGs provide a timely platform for IOS to align international processes with local needs to address their own goals in balancing population growth, economic development, food security and climate security.

1. Introduction

Small Island Developing States (SIDS) are considered a globally distinct collection of island nations characterized by their limited land area and oceanic remoteness. The UN formally identifies 37 tropical island countries and 20 affiliated entities as SIDS, spanning the Atlantic, Pacific and Indian Oceans, and the Caribbean, Mediterranean and South China Seas [1]. In recognition of the challenges and opportunities SIDS share, the Barbados Programme of Action (BPOA) was adopted in 1992 to provide a high-level platform for SIDS to more strategically engage from a collective position. This profile for SIDS continues to be embraced through various international processes today, e.g. the Convention on Biological Diversity (CBD) and most recently the UN Sustainable Development Goals (SDGs). Key processes include: the *2005 Mauritius Strategy of Implementation* (MSI), the 2014 *SIDS Accelerated Modalities of Action (SAMOA Pathway),* recognition of SIDS in the 2012 *UN Rio + 20 Future We Want*, and the *2030 Agenda for Sustainable Development* [2].

From a biogeographic perspective SIDS range from 'high' active volcanic islands, to low-lying oceanic atolls which result from volcanic subsidence over millennia [3]. For some high islands and atoll states, the ocean area and exclusive economic zones (EEZ) can be considerably greater than the land area. For example, the Republic of Kiribati has the 13th largest EEZ in the world, and Tuvalu's EEZ is 27,000 times larger than its land area [4]. For such nations, the term 'large ocean island states' (LOIS) is also being used, reflecting their vast sovereign ocean space as well as emerging ocean-based economies, also known as 'blue growth' [5]. Recent scholarship on the international prominence of SIDS suggests the momentum for the ocean-focused SDG 14 was in part driven by the Pacific island nations [6], reflecting their shared opportunities and challenges, as well as climate change. In this paper, the term 'island ocean states' (IOS) is used as more geographically inclusive and in recognition that some SIDS are no longer considered developing states.

While IOS are diverse physically and culturally, their predominately oceanic geographies require innovative approaches to be economically

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competitive with larger land-based regions. Most IOS have small populations concentrated in capital centers, limited local food resources, a reliance on fishery and tourism sectors, high transportation and communication costs, and dependencies upon international trade and economic trends [7]. IOS can also be viewed as microcosms of 'social ecological systems', where the interplay of internal and external dynamics is highly coupled, with the pace and impact of economic and environmental change and societal responses concentrated in space and time [8,9]. This intensity of environmental and social pressures can result in island nations being considered more at risk to economic and climatic events, resulting in debates around their resilience, in particular with regard to food security, economic security, population growth, and climate security [10].

Traditional development theory has framed IOS as vulnerable in light of their socio-economic inter-dependencies. However, this is being re-examined with views that strong socio-cultural ties and regional leadership can foster innovative economic opportunities, inspire local capacity and contribute towards greater resilience to both economic and climatic challenges [11,12]. With regard to economic opportunities, advances in ocean-based technologies and blue growth (e.g. marine renewable energy, aquaculture and fisheries) are contributing towards shifting power dynamics and greater economic benefits for island nations [5,7,13,14]. One example is the 2010 Nauru Agreement (NA) for regional management of tuna stocks by eight Pacific island nations [15]. In recent decades, large marine areas were leased to foreign states for fishing with limited direct revenue flow to island states. The NA now restricts fishing of inshore waters to only national fleets. However, as most IOS have limited capacity to fish their offshore areas, foreign fishing license agreements are still useful, and through the NA are now structured to ensure resource rents flow directly to IOS, contributing to their economic development [16]. Interestingly, many of the same ocean-based technologies and economies that underpin blue growth, are also catalyzing support for large-scale marine protected areas within the EEZs of IOS, focusing on deep sea marine biodiversity and migratory species protection [17,18].

As these advances in ocean knowledge, blue growth and conservation foster more robust IOS economies, impacts from climate change remain paramount in both the short and long-term. Small islands contribute less than 1% to global green-house gases, yet they are on the front lines of diverse climate change impacts, ranging from: sea level rise (SLR), ocean acidification, species range shifts, increasing air and sea-surface temperatures, and extreme weather events [3]. Given most IOS societies reside and depend upon the coastal margins of their islands, it is critical that near-shore marine ecosystems be of sufficient scale, biophysical health and integrity to provide physical protection from storms, waves and SLR. Mangroves, seagrasses and coral reefs are near-shore marine ecosystems which dominate the coasts of most tropical islands. The dense root systems and reef frameworks of these ecosystems provide a range of services, including fisheries, fuelwood, carbon sequestration, biodiversity and tourism [19]. However, of these services, coastal protection is one of the most immediate and tangible [20]. In spite of the diverse services these near-shore marine ecosystems provide, they have been dramatically altered over time and remain highly threatened from direct and indirect impacts: including deforestation, dredging and filling for coastal development, shrimp farming, over-fishing and pollution from land and sea [21,22].

Replacement of the physical and coastal protective functions of mangrove, seagrass and coral reef ecosystems through engineered, hard-infrastructure solutions is costly and can result in a loss of ecosystem diversity and complexity that can compromise other services and co-benefits, e.g. fisheries and biodiversity. Management strategies, including marine protected areas (MPAs), coastal zone management (CZM) and marine spatial planning (MSP), remain an essential first priority for the protection of these ecosystems and attempts to balance conservation and development. However, in light of IOS development pressures and climate change impacts, both in the past and future, there is also a critical need to consider the restoration of degraded mangroves, seagrasses and coral reefs as a critical component of both conservation and development strategies.

This paper contributes to a special issue of Marine Policy exploring synergies across the SDGs, focusing on SDG Goal 14, and its relationship to broader policy, legal instruments for more holistic and effective interpretation of this Goal [23]. The special issue is part of an inter-disciplinary research project examining global to local legal approaches to marine ecosystem services for poverty alleviation [24]. Articles in this issue examining SDG 14 perspectives that are most relevant to this paper on SIDS, include: co-benefits and trade-offs with other SDGs [25], marine spatial planning [26], marine protected areas [27], other area-based conservation measures [28] and technology transfer [29].

Noting the timeliness and relevance of SIDS to SDG 14, in particular target 14.7 on enhancing economic benefits to SIDS [2], the starting point for this paper is consideration of international policies from which SIDS (IOS) could optimize local capacities through the SDGs. As noted the recent analysis by Singh [25] on Goal 14 in relation to all SDGs, Target 14.7 has the highest positive alignment with all of the goals. This is not surprising given the inter-linkages that characterize IOS, yet this also highlights there are numerous ways to conceptually align SIDS, SDG 14 and other SDGs. Taking into account priorities emerging from recent SIDS processes (e.g. the SAMOA pathway) and the *Call to Action* from the 2017 UN Oceans Conference [30], this paper seeks to examine SIDS and SDG synergies which could achieve the following objectives in both the near and long-term: i) enhance ecological integrity, ii) inspire local capacity building, and iii) accelerate climate change adaptation.

This paper begins with a review of entry points in international policy to explore how near-shore marine ecosystem restoration is considered within the SDG goals, the Convention on Biodiversity (CBD), and the UN Framework on Climate Change (UNFCC). We then draw upon academic literature and local examples of practice to consider how restoration of tropical near-shore marine ecosystems can contribute to climate change adaptation and security, in particular for low-lying islands. We conclude with recommendations and policy considerations to more effectively integrate IOS focused near-shore marine restoration into broader climate change adaptation and ecosystem conservation policies.

2. Near-shore marine restoration in SDGs and international processes

To examine to what degree IOS and near-shore marine restoration are profiled in strategic environment and climate processes, the following international conventions and policy plans were reviewed:

- UN Sustainable Development Goals, in particular SDGs: 13 (climate), 14 (oceans), 15 (land).
- CBD Aichi Targets and National Biodiversity Action Plans.
- UNFCC National Climate Action Plans, and Intended Nationally Determined Contributions (INDCs).

These were selected as they highlight SIDS (IOS) from various perspectives and have mandates to address biodiversity loss and climate adaptation. Consideration of these conventions through a lens of IOS near-shore marine restoration, potentially provides a way to explore synergies which could result in more effective ecosystem-based action on the ground and joined-up engagement with local stakeholders and communities. For example, signatory commitments to the CBD and UNFCC are typically responded to by national level ministries, yet the conventions and corresponding action plans may be compiled and managed through different agencies, including NGOs. In addition, a more in-depth look at CBD national biodiversity action plans, UNFCC climate adaptation plans and UNFCC INDCs are considered for two low-lying atoll nations (the Republic of Kiribati, and the Republic of the Maldives). These further explore alignment across international processes and translation into national and local actions.

2.1. UN Sustainable Development Goals

With regard to IOS considerations for climate security and links with other ecosystem services and benefits, it is worth reflecting how IOS marine restoration could contribute to all the SDGs in some way. Taking into account that near-shore marine restoration has the potential to enhance ecological integrity, local capacity building, and climate change adaptation, there are several conceptual alignments between SIDS and all SDGs. One example is provided below to illustrate how restoration can contribute to both environmental and social goals of SIDS (IOS).

- *Maintain natural capital*: 13 (climate), 14 (oceans), 15 (land).
- *Inspire social capital*: 4 (education), 8 (economic growth), 9 (innovation, knowledge), 17 (partnerships).
- *Support sustainable livelihoods*: 6 (water), 7 (energy), 9 (infrastructure), 11 (cities, communities), 12 (consumption).
- *Access, benefit sharing across generations:* 1 (no poverty), 2 (no hunger), 3 (health, well-being), 5 (gender equality), 16 (peace and justice).

Given the ecosystem based focus of this paper, SDGs 13 (climate), 14 (oceans), 15 (land) are the most relevant to IOS (SIDS) and are summarized in the Table 1 with regard to near-shore marine restoration. While Goal 13 on climate change does not explicitly refer to restoration of ecosystems, it can be viewed as supporting healthy marine ecosystems and provision of near-shore coastal protection (SDG 13) [31] in the context of climate change mitigation and adaptation. It directly mentions enhancing capacity building in the context of planning for SIDS. Goal 14 is the most immediately relevant for near-shore marine restoration even though restoration is noted only twice in all of the SDG 14 targets (SDG 14) [32]. This goal is particularly relevant to coral reefs and seagrasses with regard to ocean acidification. Like SDG 13, Goal 14 highlights the importance of sustainable marine resource use and technology transfer for SIDS. Restoration is mentioned only once in Goal 15, yet the intention of several targets can be interpreted as relevant to near-shore coastal restoration and ecosystem service co-benefits of climate and food security (SDG 15) [33]. This goal is particularly relevant to restoring mangroves and linkages with inland and other coastal marine island ecosystems.

The preparation for the 2017 UN Oceans Conference [34] included position papers or 'Partnership Dialogues' [35] reflecting on SDG14 and linkages to other processes. Relevant to IOS marine restoration and climate adaptation is: paper 2 on managing, protecting, conserving and restoring marine and coastal ecosystems, paper 3 on ocean acidification, paper 4 on sustainable fisheries, paper 5 on economic benefits to SIDS and small-scale fishers, and paper 6 on increasing science, research capacity and marine technology transfer. Only paper 2 mentions restoration in the context of MPAs, zoning, ecosystem services, livelihoods, and partnerships. Another preparatory report for the Oceans conference relevant to IOS marine restoration and climate is a UN Department of Economic Affairs (UNDESA) report, mapping linkages between SDG 14 and the other SDGs [36]. While restoration is noted with regard to fish stocks and healthy ecosystems, numerous points highlight the linkages between climate change and healthy marine ecosystems regarding societal dependencies. The paper by Singh in this issue [25] also highlights the relevance of all SIDS to all the SDGS and explicitly notes the relevance of SDG 14.2, for environmental restoration.

2.2. The Convention on Biological Diversity

Article 8(f) in the text of CBD convention itself (and respective international legally binding obligations) consider restoration as a means of in-situ conservation. *Each contracting Party shall, as far as possible and as appropriate, rehabilitate and restore degraded ecosystems and promote the recovery of threatened species, inter alia through the development of and implementation of plans or other management strategies* [37]. The 2010 CBD Strategic Plan [38] outlines four high-level goals (A–D) and 20 "Aichi Targets" to be achieved by 2020. These goals address biodiversity loss, the need for conservation actions, yet do not explicitly mention restoration. However, Target 14, states: *By 2020, ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods and well-being, are restored and safeguarded, taking into account the needs of women, indigenous and local communities, and the poor and vulnerable*". In addition, Target 15 states "*by 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks has been enhanced, through conservation and restoration, including restoration of at least 15% of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification.*" Targets 18 and 19 make the connection with traditional knowledge and technology transfer respectively.

Table 1
Relevance of SDGs 13, 14, 15 to near-shore marine IOS restoration.
Source: Adapted from UN SDG Goals [2].

SDG 13: Take urgent action to combat climate change and its impacts	
13.1	Strengthen resilience, adaptive capacity to climate-related hazards and natural disasters;
13.2	Integrate climate change measures into national policies, strategies and planning;
13.3	Improve education, awareness, human, institutional capacity on climate change mitigation, adaptation, impact reduction and early warning;
13.A	Mobilize $100 billion by 2020 to support mitigation actions benefiting developing countries and
13.B	Promote mechanisms for raising capacity for climate change planning and management in LDCs and SIDS, including focusing on women, youth and local and marginalized communities
SDG 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development	
14.2	Management of coastal marine ecosystems to avoid adverse impacts, strengthen their resilience, restoration actions for healthy productive oceans *[all IOS near-shore ecosystems]*
14.3	Minimize and address ocean acidification *[coral reefs and seagrasses]*
14.4	Regulate overfishing, science-based management plans to restore fish stocks [*all IOS near-shore ecosystems]*
14.5	Marine protected areas *[all IOS marine, complement, reference, supply areas for restoration]*
14.7	Increase economic benefits to SIDS, LDCS sustainable use marine resources *[restoration contribution to livelihoods via coastal protection, fisheries]*
14.a	Enhance scientific knowledge and technology transfer in particular SIDS *[local knowledge, co-production with experts]*
SDG 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss:	
15.1	Ensure conservation, restoration, sustainable use of…ecosystems, services…with international agreements *[all IOS near-shore ecosystems]*
15.2	Promote implementation of sustainable management forests, halt deforestation, restore degraded, increase afforestation and reforestation globally *[relevant to mangroves]*
15.5	Urgent action to reduce degradation of natural habitats, halt biodiversity loss, protect, prevent extinction of threatened species *[all island near-shore ecosystems]*
15.9	Integrate ecosystem and biodiversity values into national and local planning, development *[all island near-shore ecosystems]*

Table 2
Republic of Kiribati: comparison of CBD Biodiversity Strategies, UNFCC Climate Adaptation Plans and INDCs (Adapted from sources [47–49]).

Kiribati 2016–2020: CBD National Biodiversity Action Plan	Kiribati 2014: UNFCC National Framework for Climate Change and Climate Change Adaptation	Kiribati 2015: UNFCC Intended Nationally Determined Contribution Report
Actions so far: – Phoenix Islands Protected Area (PIPA), 408,250 sq mi, no commercial fishing – as of 2013 MPA exceeds marine targets of 12% protected – managing control over extraction marine resources *By 2020* - Protected areas: equitably manage 17% land, 10% marine areas for: biodiversity, ecosystem services; ecologically representative, links to other area-based conservation measures and wider landscape and seascapes. – Ecosystem resilience: enhance biodiversity conservation as contribution for carbon stocks, restore 15% of degraded ecosystems towards climate change mitigation and adaptation. – Traditional knowledge: respect, innovation indigenous practices of local communities for sustainable customary use of biological resources; engage with national, international obligations. – Coastal erosion: develop coastal management plan by 2017, for vulnerable coastal areas (flooding, hazard risks), protect existing key biodiversity areas; expand soft measures with coastal vegetation. – Habitat Loss: reverse unsustainable use, destruction of ecotourism resources; restore destroyed ecotourism resources by 2017; restore and rehabilitate marine, terrestrial habitats by 2020.	*Kiribati Adaptation Program (KAP):* – KAP supports government National Adaptation Program of Action and Kiribati Development Plan, targeting improved management water resources and strengthening coastal resilience as national priorities. – KAP III is US$10.8 expansion phase from 2012 – 2016, extending achievements of KAPI, KAPII, which piloted adaptation measures, e.g. mangrove planting, sea walls. *KAP III aims to:* – Water use: strengthen ability for safe water, resilient coastal infrastructure; install ground, roof rainwater, systems; reduce leakages, waste in existing systems; protect water reserves, improve long-term plans local water management for cleaner, safer drinking water – Coastal erosion: protect against erosion with seawalls investments, mangrove planting at priority sites – Climate change: – strengthen government, community capacity to manage effects of climate change, natural hazards with adoption National Coastal Management Policy; – strengthen institutions, build, maintain stronger infrastructure. – Build community skills to address climate change, natural hazards with education programs for preparation, implementation locally managed adaptation plans.	*Mitigation:* – Five year periods, starting in 2020, ending 2030 – To proactively protect and sustainably manage mangrove resources, – protect, enhance coastal vegetation and seagrass beds. – Together above actions represent effective stewardship of more than – 6 million tons of carbon dioxide stored, – more than 100 times the current annual national emissions inventory.

Countries which are signatory to the CBD are also required to provide National Biodiversity Strategies and Action Plans (NBSAPs) highlighting their status and changes to biodiversity, transposition into national plans, and progress towards the Aichi Targets. A recent UNDP report [39] analyzing pathways for NBSAPs to support the SDG goals, includes restoration as one of eight core themes, noting the linkages between restoration and ecosystem service provision for livelihoods (Target 14) and climate security (Target 15). Over 500 restoration actions are listed across 60 countries, with many focusing on marine and coastal ecosystem restoration, including ecological or nature-based infrastructure.

2.3. National Climate Action Plans (NCAPs) and Intended Nationally Determined Contributions (INDCs)

Through the UN Framework Convention on Climate Change (UNFCC), countries prepare and implement national climate adaptation plans (NCAPs) to identify medium to long-term adaptation needs, and implementation strategies around a 2010–2020 window [40]. For many IOS the emphasis is on adaptation rather than mitigation given their low green-house gas emissions (GHGs), although they are directly impacted by climate change from social and physical perspectives. The NCAPs are therefore key processes to identify connections across different types of IOS, in terms of ecosystem status and change, impacts of infrastructure, livelihoods and decision-making, and incorporation into economic accounting strategies. The 2016 Paris Agreement on climate change and adaptation has been ratified by 153 out of 197 parties [41] representing over 95% of GHGs and the 97% of the world population. Most have now submitted pledges and plans which declare 'intended nationally determined contributions (INDCs) [42], noting respective climate action commitments, until at least 2020. INDCs are required every five years and are envisaged to become more ambitious over time. As discussed in Magnan et al. [43] on ocean scale implications of the Paris Agreement, there are considerable connections between the health of the planet, the ocean and global society. The authors place particular emphasis on small island nations, stressing the need for greater dialogue between the ocean and climate science communities to address the impacts of a 2 °C rise in average global temperature in island contexts. They highlight concerns about rising temperature impacts on reef building corals, mangroves and seagrasses, noting the roles of coastal protection and other ecosystem service provisions. They make direct connections between these issues and the pledges needed by countries through INDCs.

Several other key reports and papers discuss wetland ecosystems, including mangrove and seagrasses with regard to their 'blue carbon' potential, referring to carbon sequestration and the carbon stored in root systems and sediments with these ecosystems [21]. In this light, mangroves and seagrasses ecosystems have the capacity potential to be considered in global climate change mitigation actions such as the UNFCC REDD+ [44,45]. REDD+ provides economic incentives for countries to decrease deforestation in light of the role forests play in carbon capture and storage. However, to date REDD+ is predominately terrestrial in orientation, focusing largely on above ground biomass and large-scale forests, so this remain an arena requiring policy change to consider the full carbon sequestration and storage potential context of these ecosystems [21]. The science and policy community continues to make advances on the need to integrate near-shore marine conservation and restoration as part of climate change mitigation in terms of 'blue carbon' and linkages to the INDCs, through the Paris Agreement mentioned above. In this light, INDC pledges provide a policy pathway for countries to conserve and restore coastal marine ecosystems for nature-based climate adaptation, as well as other ecosystem co-benefits, such as fisheries [46].

2.4. Policy synergies across the CBD and UNFCC

As discussed above, most nations are signatories to the CBD and UNFCC, providing corresponding national action plans for biodiversity and climate adaptation and mitigation, yet these are often executed through different convention specific pathways and agencies at both international and national levels. To consider to what degree IOS relevant near-shore marine restoration is reflected in these pathways, in particular low-lying atoll states, Tables 2, 3 provide a comparison of CBD National Biodiversity Action Plans (NBAPs), UNFCC National Climate Adaptation Plans (NCAPs), and UNFCC Intended Nationally Determined Contributions (INDCs) for the Republic of Kiribati [47–49],

Table 3
Republic of the Maldives: comparison of CBD Biodiversity Strategies, UNFCC Climate Adaptation Plans and INDCs (Adapted from sources: [50–52]).

Maldives 2015 National Biodiversity and Action Plan	Maldives 2010–2020 Strategic National Action Plan for Disaster Risk Reduction and Climate Change	Maldives, 2015 Intended Nationally Determined Contribution Report
By 2025 - Develop policies to minimize climate change impacts, balancing anthropogenic activities with conservation. - Integrate Strategic Environmental Assessments into developmental projects, amend EIA processes. - Reduce pressure on reefs, vulnerable ecosystems from anthropogenic activities. - Reverse loss rate of key habitats by 1/2, if feasible to zero. - Conduct programs to restore key ecosystem functions through alternative solutions, preventing destruction, overuse - Prepare list vulnerable ecosystems, risks and threats. - Ensure impacted ecosystems restored to support human health, wellbeing and livelihood, e.g. water, restoration of mangroves, terrestrial vegetation, reefs, other marine ecosystems. - Increase income generated by biodiversity, ecosystem services and number of community conservation initiatives. - Increase number of local land use plans addressing restoration of essential ecosystems. - Restoration programs, beach vegetation zones per island - Per atoll, protect, manage: 10% coral reef area, 20% wetlands and mangroves, 1 sand bank, 1 uninhabited island - Increase number of islands with improved potable water.	*Recovery and resilience:* - Address climate change disaster risks from weather, climate (1998 El Nino devastated reefs, fishing industry) - Noting vulnerability of communities to natural hazards from ecosystem degradation, reduction in water and food availability, and changes in livelihoods. - Restore and improve facilities for disaster-affected communities, reduce disaster risk factors. *Pollution:* - Enhance waste management to prevent marine pollution. - Formulate, implement oil pollution contingency plans. - Acquire appropriate sewage treatment technologies. *Coral reefs*: - Reliance on healthy reefs for island stability, resilience. - Tourism and fisheries with livelihoods link to coral reefs. - Provide alternatives to coral, sand construction materials. - Monitoring, research to prevent diseases, rehabilitate reefs. - Establish information base on reefs and climate change. *SDG goals:* - Translate SDGs into policies, strategies for climate change adaptation, disaster risk reduction: - Adapt to climate change - Establish marine protected areas and protect coral reefs - Achieve carbon neutrality in energy and transport - Ensure food security.	*Coastal Protection* - Beach erosion widespread, loss of land and costal infrastructure. - Prioritize protection for human settlements (infrastructure of inhabited and resort islands) - Include shore protection and reclamation as adaptation measures to increase island resilience of vulnerable islands. *Safeguarding coral reefs, biodiversity* - Coral reefs key for tourism, fisheries. - Reefs support biodiversity for food, livelihoods to islanders. - Reefs sensitive to SST, other climatic factors, leading to coral bleaching. - Reefs around islands stressed from land based pollution. - Reef conservation as ecosystem based adaptation measure to increase reef resilience. - Reduce pollution as adaptation measure to protect reefs: sewage treatment systems, safe disposal solid waste.

and the Republic of the Maldives [50–52]. These tables explore synergies across the international processes and translation into national and local actions, taking into account biodiversity, climate and sustainable development.

Key themes that were highlighted across the CBD-NBAPs, the UNFCC-NCAPs and UNFCC-INDCs, for Kiribati and the Maldives are summarized below, noting an explicit focus on coral reef and mangrove ecosystems for coastal protection, with most actions targeted for achievement by 2020:

- protect island and marine ecosystems, in particular the coastal margins;
- actions to change development practices that degrade these ecosystems and reverse the decline of loss;
- restore those areas that are already degraded;
- need for healthy coastal ecosystems to minimize climate related disaster risks, and focus on nature-based infrastructure;
- acknowledgement of ecosystem services as directly linked to social and economic benefits;
- linkages of marine near-shore ecosystems with income generation through tourism and fisheries;
- measures to prevent pollution, increase potable water capacity;
- recognition of traditional knowledge and building local capacity for all of the above; and
- need to include local communities in the development and implementation of coastal management policies and plans.

As shown in Tables 2, 3, achieving climate adaptation and security may be more feasible when efforts across international and local spheres align. They also illustrate how near-shore marine restoration, when taking into account both biodiversity and climate adaption can more effectively: i) enhance ecological integrity, ii) inspire local capacity building, and iii) accelerate climate change adaptation.

3. Near-shore marine restoration and climate adaptation

3.1. Ecosystem based adaptation

Appreciating the physical characteristics of IOS near-shore marine ecosystems is fundamental to realizing the values they provide to island societies. Typically, the near-shore areas of high-islands support extensive mangrove forests, seagrasses and coral reefs, while low-lying atolls are characterized by large-scale coral reef systems along the outer island margins and smaller patch reefs in interior lagoons [53]. Forbes et al. [54] provide a useful overview on island typologies in terms of associated physical vulnerability to climate change. Mangroves are salt-tolerant trees, providing marine biodiversity, food, timber and charcoal. Their roots can trap sediment and stabilize land, providing protection against waves and storms [55,56]. Mangrove restoration is predominately relevant to high islands with extensive coastal forests. Seagrasses are marine plants found in sandy shallow lagoons, bays and reef flats of both high and low-lying islands. They also have sediment-binding roots that can form extensive meadows, supporting fisheries, biodiversity and coastal protection [57,58]. Tropical coral reefs are associated with near-shore margins of tropical islands, requiring sunlight to build reef frameworks which support high biodiversity, fisheries and coastal protection [59,60]. Such reefs create natural buffers that can reduce flooding, minimize erosion impacts and attenuate the impact of storm waves and surges [61]. Coral reef restoration may be the most challenging, but also the most important action from coastal protection and livelihood perspectives, especially for low-lying atolls.

As noted earlier, near-shore marine ecosystems continue to be threatened from deforestation, dredging, coastal development, overfishing and pollution, with critical implications for IOS states due to strong dependencies upon these coastal ecosystems. Globally, 20% of mangroves are estimated to have been lost since the 1980s [6,21,55,56,62]. Global rates in seagrass decline have increased almost tenfold in the past 40 years [64,65]. By 2011, 60% of the worlds coral reefs were estimated to be directly threatened from local human-based impacts. This goes up to 75% when taking into account climate impacts of warming sea surface temperatures and ocean acidification [66]. In addition, there is limited understanding of the incremental and synergistic impacts of ecosystem losses through time and at different scales [67–71].

The context of IOS vulnerabilities to sea level rise may be the most studied arena in terms of climate change impacts for small islands. Projections for 2100 range from 0.35 to 0.70 m, depending upon assumptions of models, location, shorelines changes over time [3]. There are increasing studies looking at long-term historical shoreline change, focusing on erosion and accretion for Pacific atolls. However, distinguishing natural cycles of shoreline change from other large-scale coastal alterations (e.g. ports, development) makes future predictability difficult [72,73]. Sea level rise can influence the capacity for mangroves and seagrasses to tolerate increased exposure to saltwater and submersion along their seaward margins, which can affect sedimentation and growth rates, and resulting wave attenuation capacity [63]. Long-term geological studies indicate that healthy coral reefs can keep pace with the rates of sea level rise predicted for the coming century and beyond, but unhealthy reefs and intertidal reef flats that surround many atoll islands, may not have this capacity [74].

In addition to SLR, rising sea surface temperatures and ocean acidification can also influence the physical integrity and service provision of mangroves, seagrasses and coral reefs. For example, warmer ocean temperatures are causing widespread bleaching to coral reefs [59]. Overly acidic ocean conditions can reduce reef calcification, compromising reef building capacities [75], while the impact of ocean acidification on seagrasses is less understood. The potential situation of SLR on low-lying islands, and atoll settings (whose coral communities are compromised by increasing SST, storm damage and disease) may become untenable if land areas of islands become submerged to such a degree that island communities need to consider migration options [76,77].

Incentives to reduce risks to island ocean states from weather related disasters and climate change are leveraging large sums of financial support from governments and business [78]. In recent climate negotiations, developed nations pledged between 2011 and 2014 up to US$ 100 billion per year by 2020 to support mitigation and adaptation in developing countries many of which are tropical and coastal [60,79]. Often funds largely support hard engineering or gray-infrastructure, such as seawalls, dredging and coastal land reclamation as coastal defenses. Coastal protection as detailed in a World Bank report [61] on nature-based solutions for adaptation to climate change, provides evidence that the costs for ecosystem based restoration are far less when compared to hard-structure engineering approaches. In addition, hard structures can result in extreme changes to coastal geomorphological and ecological dynamics which can degrade the functioning of the near-shore ecosystems and compromise coastal protection capacities. For example, changes in sediment transport can accelerate erosion, and vertical seawalls increase the steepness along the coastal margin which can heighten wave impacts, combined with loss of a wide habitat buffer. Such impacts are catalyzing research on hybrid solutions which rely on incorporating coastal biophysical processes into engineering designs [80]. It is against this backdrop that restoration of mangroves, reefs and seagrasses is proposed as a critical component of climate adaptation portfolios for IOS settings.

3.2. IOS restoration implementation considerations

In light of sustained declines in the condition of near-shore marine ecosystems there is increasing attention to best practices for effective restoration. There are different restoration strategies and recovery trajectories depending upon starting points, or baseline conditions, and desired outcomes, resulting in spectrum of strategies ranging from: complete restoration, to ecosystem re-creation, or simply ecological enhancement [60]. For this paper, restoration is envisaged as a means to achieve positive ecological trajectories and net gains in ecosystem function, as well as provide multiple ecosystem benefits, e.g. coastal protection, biodiversity and fisheries [81]. While detailed guidance on restoration of IOS near-shore marine ecosystems is beyond the scope of this paper, key considerations relevant to restoration in the context of climate resilience and coastal protection are reviewed and summarized below.

Mangroves, particularly species with large aerial roots can attenuate wave height and storm surge peaks from 13% to 100% depending upon forest density, tree morphology, water depth, wave height and topography. On longer time scales mangroves can build-up land through sedimentation and minimize erosion, as well as maintain creeks and channels that disperse flood waters [61]. Since the 2004 Indian Ocean tsunami there has been an increase in mangrove restoration for coastal protection and fisheries [56,82]. McLeod and Salm [55] summarize mangrove restoration strategies to promote climate resilience, noting the need for: protection or restoration of areas proven to be resilient to storms and SLR, acquisition of baseline data to monitor changes, and establishment of buffer areas to minimize adjacent development impacts and ensure habitat connectivity. Barbier [56,83] provide more recent reviews on economic valuation methods and lessons learned from mangrove restoration projects globally. Highlights include: the importance of overall time frames and baseline ecological condition status, costs of nature-based versus built infrastructure solutions, cautious optimism around success and failure, and the need for monitoring, treating projects as long-term collaborative experiments with diverse stakeholders.

Seagrasses also contribute to coastal protection. As subtidal marine plants, they bind sediments, build-up shoreline elevation, influence erosion and accretion processes, dissipate wave energy, and can reduce current velocity in subtidal areas [84,85]. Restoration of seagrasses have generally received less attention than mangroves and coral reefs, in spite of their roles in coastal protection and fisheries. However, more recent research on the distribution, status and restoration of seagrasses at different scales, highlight their roles in supporting climate change resilience and the carbon storage potential in their submerged root systems [57,58,86]. Katwijk et al. [65] provides an overview of the contribution of seagrasses to coastal protection in terms of optimal conditions for establishment and restoration, summarizing 1786 trials of seagrass planting experiments for restoration. The authors note the importance of: site specific conditions, removing stressors (water quality), suitable planting environment (light, shelter wave conditions), need for adjacent donor beds and sufficient density of initial plantings with trials of larger areas performing better.

Intact, healthy coral reefs can dissipate wave energy up to 97% with reef crests dissipating up to 86% and can function as low-crested natural breakwaters, and supply carbonate sediment to beaches [61]. The degree to which reefs dissipate waves varies with water depth, cross-shore profile and reef topographic complexity. As noted earlier, healthy reefs can usually keep pace with sea level rise which is critical for low-lying atoll islands. Yet, their capacity to keep pace with sea level rise and grow in increasingly warmer and acidic ocean conditions may reduce their overall functionality. This is more critical if the reef framework has been damaged and fragmented through impacts such as dynamiting, dredging and filing. Research on reefs as a coastal defense service are still limited, with most studies to date focusing on coral reefs and fishery benefits [60]. Although reef restoration is in its infancy, the costs of reef restoration are lower than hard infrastructure alternatives, and should be a consideration for both conservation and development planning. Based on a large study of reef projects it was estimated that the average cost to build breakwaters was US$19,791m, while the average cost of reef restoration projects was US$1290m. These numbers indicate only the construction costs associated with rebuilding damaged reefs, not the value of lost benefits associated with the multiple ecosystem services that coral reefs provide in both the short and long-term [60].

The restoration of coral reefs is potentially more challenging in comparison to mangroves and seagrasses, given the biophysical complexity of reefs, requiring interdisciplinary teams of ecologists, geologists, oceanographers and engineers, as well as sustained collaboration with local communities and planners for long-term success. In most instances, full restoration of a coral reef is impossible. In many cases the incentive for reef restoration has been to offset habitat losses from a development project [87], achieving only partial restoration through nature-based engineered, artificial reefs [88,89]. The scientific literature on reef restoration is expanding, driven in part by climate and SLR concerns. Fabian et al. [90] conducted an extensive review and survey of reef restoration and artificial reef projects, looking at biological restoration and those targeting coastal defense and climate adaptation. Most projects focused on biodiversity and fisheries enhancement rather than coastal defense, with the exception of breakwater projects using “Reef Balls”. Most active reef restoration projects involved transplants of small coral fragments on supporting structures, also known as coral gardening [91,92]. Similar to mangroves and seagrasses above, reef restoration guidance highlights include: the importance of site condition and removal of stressors and status of starting condition; challenges in restoring reefs at scale; need for MPAs as reference benchmarks and knowledge on species and ecological dynamics; value of locating reef projects near mangrove and seagrasses for ecological connectivity; and the need for local support and commitment to long-term monitoring [90–92].

3.3. The importance of local knowledge, and long-term perspectives

As illustrated above, near-shore marine restoration for coastal protection and climate security in IOS contexts may be the most successful when stakeholders with local, long-term and expert knowledge are part of the restoration projects. Comparative success and failure can be shared when there are similarities in habitat, scale and socio-economic contexts. Site-based knowledge is fundamental to understand and anticipate biophysical changes in time and space; taking into account cumulative changes, and the nature of the change, e.g. episodic weather events, incremental SLR, or coastal development. Forbes [54] examines the physical aspects of coastal adaptation across a spectrum of island typologies noting the importance of understanding a site in terms of local scale and larger scale dynamics. Choosing the wrong site, or not having the right starting conditions and realistic time frames for restoration can be costly and lose momentum [93]. Recent assessments of coastal protection and adaptation strategies in the Republic of Kiribati, and the Republic of the Marshall Islands discuss the complexity of evaluating historical and future change taking into account existing coastal protection infrastructure [94–96]. Also noted are challenges in balancing priorities between international aid for infrastructure loans which may provide more immediate solutions, with nature-based solutions that may be less costly, foster local capacity building, but take longer for results [60,97,98].

With regard to IOS restoration in terms of the different starting points and implications for future trajectories, multi-generational knowledge is also key. In this light, there is recognition of the importance of, not only local knowledge, but also traditional and indigenous knowledge especially with regard to climate, vulnerability and resilience over time. The scholarship on traditional knowledge is expanding in the context of marine protected areas and ecosystem services, in particular locally managed marine areas [99], and issues of access and benefit sharing [100], yet has been less considered for restoration. Marine traditional knowledge has generally focused on fishers’ knowledge and traditional conservation practices [101–105], and women's roles in fishing [106], yet there is little discussion explicitly on restoration. Papers on reef recovery in Hawaii introduce the concept of historical ecology [107] and the engagement of local communities in restoration projects [108]. Thornton and Sheer [109] provide a review over 200 articles examining to what degree is local and traditional knowledge considered in the context of marine restoration, conservation and climate adaption. They highlight that over 40% of the articles focus on North America, and 22% Oceania, both areas where indigenous leadership is increasingly engaged in current politics and policies around environmental stewardship.

There is also recognition of the need for increased engagement between academic and indigenous communities highlighting the concept of co-production of knowledge [110]. This concept can be relevant to restoration in supporting ecosystem-based adaptation and provision of multiple ecosystem benefits as compared to hard infrastructure solutions which may provide fewer benefits overall and be costly. One project in the Solomon Islands used the community construction of a simple physical model of their island as a starting point for discussion on environmental change in the past, and adaptation solutions for the future [111]. Marshall et al. [112] provide useful frameworks for integrating social adaptation into climate change, while McLeod et al. [113] directly addresses the need for conservation organizations who are increasingly advising national and local communities on climate adaptation of the importance of local input and the primacy of their knowledge and engagement. Another dimension is not only the concept of knowledge transfer, but also technology transfer, as new tools and technologies develop in the arena of near-shore marine restoration, e.g. seagrass planting, coral transplants. Training and facilities need to be provided in ways that can be taken-up and implemented by local communities for sustained management of restoration projects. All of these studies highlight the importance of local knowledge and leaders, who have a collective memory of environmental and social change, as well as what is culturally acceptable, and the need for knowledge exchange between external experts and local leaders to ensure local capacity building and stewardship in the long-term.

4. Policy recommendations and conclusion

In returning to the overall goal of considering how near-shore marine restoration can help IOS states realize the SDG goals, Table 4 summarizes indicative strengths, weaknesses, opportunities and threats towards achieving restoration, with a particular emphasis on coastal protection and climate adaptation. This is considered across political, economic, environmental, social and technological perspectives. The table also draws upon insights from the literature and practice noted above, as well as priorities noted earlier in the CBD biodiversity action plans, the UNFCC climate action plans and the INDCs. In brief, the key strengths of near-shore marine restoration are that it can: encourage partnerships, enhance provision by ecosystems of multiple benefits, facilitate knowledge exchange and capacity building between local communities and experts, support traditional and generational knowledge over time, and enhance scientific understanding to support nature based solutions. Challenges include: long time frames required for restoration, specific site and species requirements, sustainable funding, limited local expertise, and continued demands for urbanization for coastal development.

As the SDG goals, the CBD biodiversity and UNFCC climate action plans illustrate, it is essential to consider near-shore marine restoration in concert with other ecosystem protection strategies, such as: MPAs, development and zoning plans, biodiversity offsetting, alternative livelihoods to reduce pressure; and diverse partnerships for local, technical and financial support. Examples of policy considerations to

Table 4
Marine restoration linkages across the SDGs for island ocean nations.

IOS marine restoration	Political	Economic	Environmental	Social	Technological
Strengths	Encouraging partnerships between countries (SDG 17).	SDGs 8,10,12,17	Restoration can enhance ecosystem services (most SDGs).	All of the SDGs, linking into ecosystem services.	SDG 4, 8, 9, 10 Education, industry, innovation and infrastructure, knowledge transfer.
Weaknesses	Restoration timeframes may not align with political horizons; Resistance to restoration due to costs and knowledge gaps.	Restoration projects typically dependent on funding, foreign investment.	Proper site selection for project to be successful -External environmental factors can damage projects.	All local communities need to involved, valuable knowledge and opportunities may be missed.	Restoration knowledge and technology may not exist in some SIDS/IOS, opportunity for other countries to become involved.
Opportunities	Restoration profile environmental issues into forefront.	Restoration can assist with the development of other businesses eg tourism, fisheries	Restoration of one site may have benefits for adjacent sites/other habitats and species	Community involvement, empowerment, knowledge exchange, alternative livelihoods	New restoration techniques can be tried.
Threats	Changeable political situations can hamper environmental momentum and focus.	Lack or sudden cut offs of, time and funds required for both start up and maintenance.	Ecosystem may already be too degraded to be restored. Restoration may cause further damage.	Some stakeholders jeopardize restoration projects.	High initial investment; some restoration technologies and techniques may not be transferrable between different sites, countries.

incorporate restoration into a portfolio of solutions for IOS sustainable development and ecosystem-based adaptation are summarized below:

- *Integrate marine restoration into strategic planning processes (Marine Spatial Planning and Integrated Coastal Management)*: Restoration and planning needs to be considered at scales relevant for the respective ecosystem and goals, e.g. whole island, coasts, ocean domains. Restoration can build on lessons and laws that underpin 'integrated coastal zone management', applied to island settings since the 1990s, as well as contribute to emerging policy options through 'marine spatial planning' (MSP). MSP has developed in parallel with geo-spatial technologies (GIS and remote sensing), and the need to map, zone, manage activities further offshore in EEZ domains. The potential relevance for ICZM and MSP concepts is to provide an overarching process to balance conservation and development through time, for which restoration areas can be identified and planned at various stages and scales. Ntona and Morgera [26] in this issue provide further discussion on MSP and SDG linkages.
- *Ensure near-shore marine restoration is considered as a complement to, not a replacement, for marine protected areas*: Marine protected areas (MPAs) are fundamental to prevent ecosystem decline and biodiversity conservation from the outset, with healthy sites providing reference areas, and recovery areas. See Rees et al. [27] in this issue for a full discussion on SDG 14 and Aichi Target 11. The scholarship around MPAs relevant to IOS settings is growing as MPAs span across island to oceanic scales. Near-shore scale MPAS are increasingly taking into consideration alternative livelihood strategies, noting the need to link conservation with income generation (e.g. ecotourism, small-scale fisheries), placing an emphasis on local leadership and 'locally managed marine protected areas' (LMMAs), to all of which restoration contributes. In parallel, is the establishment of large-scale MPAs which can extend from IOS coasts to further offshore, with many of the near-shore sites providing critical breeding, nursery and feeding sites for migratory species, and for which recovery of these sites is essential to their survival.
- *Consider near-shore marine restoration along with "other effective area-based conservation measures" (OECMs)*: In addition to biodiversity-focused MPAs, international and national targets for marine conservation and ecosystem based management, there is increasing appreciation of a broader scope of measures that can help maintain and restore biodiversity. Many have broader sectoral and sustainable development objectives and provide policy mechanism for which restoration can be integrated. Diz et al. [28] in this issue elaborate on the considerable scope of OECMs, from fishery closures to prescribed areas of particular environmental interests.
- *Integrate restoration in ecologically positive ways through environmental impact assessment processes*: There is a need to more directly incorporate restoration with different scales of development projects, both Strategic Impact Assessments (SIAs) and Environmental Impact Assessments (EIAS). This would include restoration as part of infrastructure projects, ranging from creating soft-engineered seawalls to biodiversity offsets, where if an area is to be altered from a project, others could be restored and/or protected depending on site similarities. Additionally, permit conditions, supporting restoration can be applied to development projects.
- *Evaluating restoration options through scenario planning and economic analysis of alternative strategies for coastal protection*: In complement with use of spatial planning and measures to balance conservation and coastal development, is the need to consider restoration as ecosystem-based adaptation. This includes financial evaluation of restoration-focused, nature based solutions, e.g. replanting mangroves and enhancing coral reefs, as compared with predominately built environment solutions (e.g. seawalls). This requires taking into account financial sources and repayment of loans, local capacity and benefits, as well as long-term effects that infrastructure versus nature enhancement will have on future development and

livelihood options.

- *Incorporate the value of near-shore ecosystems services into economic valuation of trade-offs and into national accounting strategies*: As detailed by Barbier [56], another dimension is to ensure the full benefits spectrum of nature-restoration be taking into account in various economic valuation trade-offs, both in the long-term and short term, e.g. not only for coastal protection functions, but also other benefits, e.g. small-scale fisheries that mangroves, seagrasses and reefs support. For example, the value of stored carbon in well-functioning mangrove and seagrass beds is significant and needs to be factored not only into the calculation of national accounts, but into possible REDD+ eligible activities. Crooks et al. [21] and Herr and Landis [46] provide further elaboration on this policy direction.

As illustrated, there is considerable scope for near-shore marine restoration to contribute to both maintaining and rebuilding the coastal margins of small island and large ocean states to enhance their capacity for long-term coastal protection. As impacts from climate change (e.g. sea-level rise and storminess), population growth and economic opportunities expand, the need to protect, restore and monitor coastal mangrove, seagrass and coral reef ecosystems remains fundamental. Near-shore marine restoration is not simple and requires input from multiple spheres of knowledge across different disciplines, different generational points of view and value. It takes time and resources. It is hoped that by considering near-shore marine restoration as a critical complement to both marine conservation and sustainable development, it can contribute to achieving climate security for generations of ocean islanders to come.

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