Marine and coastal accounts for Small Island Developing States: A case study and application in Grenada

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Abstract

In recent decades, a concerted effort has been made to define methodologies and frameworks to account for the contribution of the natural environment to national wealth and its role in fulfilling societal and economic needs. The linkages between natural capital and human well-being are even stronger in low-income and vulnerable countries, such as Small Island Developing States (SIDS). This is particularly true for coastal and marine ecosystems and for SIDS, considering that a large portion of their population live along the coast. Therefore, SIDS would greatly benefit from systematically assessing and recording the condition and services provided by marine and coastal habitats in ecosystem accounts. Applications of accounting frameworks to marine and coastal habitats, however, are still under development. Through a case study in the Caribbean Island of Grenada, we explore SIDS readiness to develop marine and coastal natural capital accounts, in particular framed within the guidelines of the United Nations System of Environmental-Economic Accounting Ecosystem Accounting (SEEA-EA). We find that, while data to compile accounts of ecosystems extent exist and may be suitable for accounting, data related to ecosystem condition are very limited. Data gaps significantly constrained the potential approaches to estimate the ecosystem services supply provided by the coastal and marine environment in our natural capital accounts for Grenada. Our case study investigation brings us to suggest initial steps for the development of ecosystem accounts in SIDS, including potential methodologies and approaches and discuss how developing a set of coherent accounts can play a key role in incorporating nature into decision-making.

Keywords

natural capital accounting, small island developing states, ecosystem services, sustainable development, marine and coastal habitats, ocean accounting, ecosystem accounting

Introduction

Natural capital (NC) is defined as the stock of natural assets (e.g. the ocean) providing a wide range of ecosystem services (e.g. wild fish) which, in combination with manufactured and human capital, enhance the well-being of humans (e.g. the food we eat) (Costanza et al. 1997, Convention on Biological Diversity 2018). It is nowadays broadly acknowledged that NC is declining globally under the pressure of challenges, such as increasing impacts from anthropogenic activities (Banerjee 2020). Policy solutions and targeted investments mainstreaming natural capital approaches are a requisite to mitigate and adapt to various environmental problems (e.g. ecosystems degradation, climate change) while promoting societal well-being (Hein et al. 2020, Banerjee 2020).

For these reasons, there is a recognised need to assess and monitor the status of NC, its ecosystems and the changes in ecosystem services they supply over time and space (Millennium Ecosystem Assessment 2005, Costanza 2020). Ecosystem Accounting (EA) can support and facilitate this assessment and monitoring processes and help to track the sustainable use of natural systems and their condition whilst emphasising the contribution to the economy and human well-being (Fenichel 2020a, Banerjee 2020). Several accounting frameworks have been proposed in the last decades to systematically measure and report on stocks and flows of NC (Guerry et al. 2015, Turner et al. 2019). The System of Environmental Economic Accounting (SEEA) (UN 2014a, UN 2014b, UN 2021) has emerged as one of the leading approaches and it is the international statistical standard for measuring the contribution of the environment to the economy, as well as the impact of economic activities on the environment (Vardon et al. 2018, Turner et al. 2019, Pirmana et al. 2019, Banerjee 2020, La Notte 2020, Grilli et al. 2021b, Vysna 2021). The SEEA framework builds on the principles of national accounting as delineated in the System of National Accounts (SNA) (Obst and Vardon 2014). The SEEA Central Framework (SEEA CF) (UN 2014a), adopted by the UN Statistical Commission in 2012 as the international standard for environmental-economic accounting, provides a statistical framework which incorporates measurement of environmental flows (both physical and monetary), stocks of environmental assets, such as water, timber, minerals etc. and monetary flows linked to economic activities related to the environment (Chen et al. 2020, Edens 2022). The SEEA Ecosystem Accounting (SEEA EA) (UN 2021) complements the SEEA CF by looking at ecosystems; it provides a statistical framework*[1] to organise spatially-explicit data on ecosystem stocks and flows and measure ecosystems and their contribution to the economy and to sustaining human well-being (Edens 2022).

Whilst several applications of the SEEA framework for EA exist for terrestrial ecosystems (see, for example, Vallecillo et al. 2019, Hein et al. 2020, Grunewald et al. 2020), applications to coastal and marine habitats are limited (Chen et al. 2020). The marine realm is complex and there are still several shortcomings to be addressed. For example, key challenges are the lack of ownership rights over the ocean and its productive resources beyond territorial waters and the scarcity and suitability of spatial data (Townsend 2018, Fenichel 2020b). Recently, some of the work developed by the Global Ocean Accounts Partnership (GOAP), which is looking into the challenges of natural capital accounts in the marine environment, has been incorporated in the Ocean Accounts Framework within the thematic accounts of the SEEA EA (UN 2021). The Ocean Accounts Framework provides a comprehensive approach to account for marine and coastal ecosystems in a consistent and comparable manner (UN 2021). In the UK, the Office for National Statistics (ONS) published their marine natural capital accounts in line with the SEEA guidelines (Office for National Statistics 2021). Some countries including China, Malaysia, Thailand, Vietnam and Canada have been testing applications of Ocean Accounts under the guidance of the United Nations and the GOAP. Two ocean accounts pilot studies have been taking place, under the GOAP technical guidance, in Pacific SIDS: Fiji and Samoa. The pilot in Fiji (GOAP 2022) focused on the development of mangroves satellite accounts, while the pilot project in Samoa (UNESCAP 2022) was aimed at scoping the development of a Tourism Satellite Account.

Accounting for the contribution of marine and coastal ecosystems to human well-being through consistent, coherent and integrated EA tools to systematically organise and present statistics on their ocean resources is of paramount importance for Small Island Developing States (SIDS) to mainstream the natural environment into decision-making. SIDS face a number of common challenges due to their small size, institutional weaknesses, vulnerabilities to natural disasters and economic shocks and small economies of scale which hamper effective environmental governance (Briguglio 1995, Mycoo 2020). SIDS are highly dependent on their natural resource base, especially marine and coastal ecosystems (World Bank and United Nations Department of Economic and Social Affairs (UNDESA) 2017, Recuero Virto et al. 2018). Natural resource dependence increases SIDS vulnerability to environmental and economic shocks which, coupled with the burden caused by the Covid-19 pandemic, risks to further hindering a sustainable and equitable development*[2] of their blue economy sectors (e.g. fisheries, aquaculture, tourism, renewable energy and shipping) (Bennett 2019, Palacios et al. 2021).

The development of ecosystem accounts, ideally in line with the approach set out in the SEEA, would facilitate international comparability of environmental and economic statistics between countries, thus giving SIDS a more effective voice in relevant international forums, as well as access to international financing resources needed to build resilience. By tracking SIDS environmental asset extent, condition, services and benefits,*[3] ecosystem accounts could, for example, assist decision-making regarding the implementation of financial mechanisms that have the potential to invest in natural capital, such as parametric insurance, payment for ecosystem services (PES), blue bonds, resilience bonds and microfinance. PES, for instance, can be utilised to motivate coastal communities to maintain and repair local habitats, such as mangrove trees (e.g. Mohammed 2012). Additionally, ecosystem accounts could be used by SIDS as tools to track and report on progress in meeting sustainability and equity indicators of global conventions and agreements, such as the UN Framework Convention on Climate Change, Convention on Biological Diversity and Sustainable Development Goals (Nature 2020, Bagstad 2021). However, is it possible to develop a full set of marine and coastal ecosystem accounts for SIDS using data already available to government officials and decision-makers? We use a case study approach to test whether it is possible to develop NC accounts for Grenada coastal and marine environments considering the SEEA EA (UN 2021) framework. We then discuss the challenges encountered in the testing and suggest possible solutions to address them. The results of our work are relevant for policy-makers and stakeholders across SIDS to provide information on priorities for development of ecosystem accounts aligned with the SEEA EA (UN 2021) and highlight how tools for ecosystem accounting can support investments in nature-based management and conservation of natural capital (see Russell et al. 2020) for the sustainable development of SIDS ocean economies. We believe that the results of our work may also support a strategy to promote a more sustainable and equitable development of SIDS marine and coastal economies, taking into consideration complex economic, environmental, social and governance trade-offs as advocated by Bennett (2019).

The reminder of this paper is organised as follows. Section 2 describes the SEEA EA framework and the steps for the compilation of accounting tables according to SEEA EA guidelines. Section 3 provides some background information on the case study area, Grenada and outlines the approaches used to pilot test the SEEA EA. Challenges, limitations and relevant data gaps surrounding the SEEA EA pilot test in Grenada are highlighted in Section 4, as well as opportunities for moving forward. Finally, Section 5 presents our conclusions to facilitate the development of EA in SIDS.

Constructing marine and coastal ecosystem accounts: An overview

This study aims to test, through a pilot study, whether SIDS are prepared to develop marine and coastal ecosystem accounts, specifically considering potential alignment with the SEEA EA framework. The SEEA EA (UN 2021) is an integrated and comprehensive accounting framework to organise ecosystem data and to regularly measure their contribution to the economy and society, their condition and the services they provide, coherently with national economic accounts (Obst and Vardon 2014, Hein 2015, Obst et al. 2015, Czúcz 2021, La Notte et al. 2022).

The development of coastal and marine ecosystem accounts in line with the SEEA EA guidance (Fig. 1), requires the structured compilation of a first set of core accounting tables, which provide information on extent and condition of ecosystem assets in biophysical terms. Ecosystem assets are areas that contain individual ecosystem types and form the conceptual base for accounting. For example, ocean assets are formed by individual ecosystem types which include mangrove forests, coral reefs, seagrass beds and sandy beaches. It is necessary for the asset extent account table to be linked to ecosystem asset conditions, which relates to the quality of the asset mapped in the extent account, in order to understand the capacity of the ocean asset to supply ecosystem services. For example, potential condition indicators could relate to primary production, marine food web functioning, concentration of pollutants, habitat fragmentation, abundance and diversity of marine species etc. (Thornton 2019). Once extent and condition accounts are developed, a second core set of accounting tables needs to be developed recording the supply and use of ecosystem services (e.g. fish and shellfish provision, coastal protection, blue carbon etc.) in physical and monetary terms. For the latter, the SEEA EA provides standard and recommended methodologies which are aligned with the accounting structure of the SNA and based on exchange values (i.e. pricing and cost approaches), which means that ecosystem assets, services and goods are valued at the price for which they could be exchanged if a market existed (Badura T. 2017). Monetary ecosystem asset accounts are designed to record information on ecosystem stocks values, as well as stock changes (additions and reductions) of the ecosystem assets, based on the monetary valuation of the ecosystem services. This account encompasses also measurement of ecosystem degradation, enhancement and revaluation.

However, application of the SEEA EA to coastal and marine ecosystems has proved complex and a limited number of attempts exist to date. With the exception of the national-level accounts developed in the UK (Office for National Statistics 2021) and those piloted in China, Malaysia, Samoa, Thailand, Vietnam and Canada under the GOAP supervision, most of the examples in the marine realm are related to small scale implementations. Some local pilot projects of the SEEA EA framework have been carried out in the Netherlands (Graveland 2017), Australia (Australian Bureau of Statistics 2017), the US (Dvarskas 2019) and Norway (Chen et al. 2020).

Testing the application of marine and coastal ecosystem accounts in SIDS: the case study of Grenada

Grenada is a tri-island country of volcanic origin in the eastern Caribbean (Fig. 2), which is comprised of the main island of Grenada and the smaller islands of Carriacou and Petite Martinique (Elgie et al. 2021). A large portion of Grenada's population, similarly to other SIDS, live on or near the coast (Thomas et al. 2020). Therefore, people are highly dependent on marine and coastal ecosystems, such as coral reefs, seagrasses and mangroves and the resources they provide for their economic and social well-being (Day 2016).

Following the process outlined in the SEEA EA (UN 2021), we started by developing the extent and condition accounts, followed by ecosystem services accounts for selected Grenadian marine and coastal ecosystems.

Ecosystem extent accounts

Based on habitat mapping data availability and considering that there is not a single internationally agreed classification for coastal and marine habitats, we focus on the ecosystems that are most relevant for Grenada and that allow a plausible level of spatial detail. The selected ecosystems for our case study are: seagrass meadows, mangrove forests, coral reefs, sandy beaches, littoral forests, shelf sea habitats and deep-sea habitats. Table 1 shows the extent of the selected ecosystem assets, the year (if known) of data collection and data source.

Data used to compile the ecosystem extent account were retrieved from various sources. The data used to map and estimate the extent of seagrass, mangroves and coral reefs, provided by The Nature Conservancy (TNC) via the Government of Grenada in 2017, were a collation of data collected over several time periods (1999, 2007 and 2012) from different sources including field surveys and aerial and satellite images. Retrieving data for habitat extent from different sources poses limitations in terms of data harmonisation in space and time. For example, regarding the data on seagrass habitat, the methodology used for digitisation of aerial images and mapping exercises is unknown, as is the quality and resolution of most of the aerial images used. Most of the aerial images used were from 1999, so are over 20 years old. From the information provided by TNC, it seems that no ground-truthing of the image digitisation was conducted. As for mangroves habitat (Figs 3, 4), the methodology used for digitisation of aerial images and classification of dominant vegetation type is unknown, as is the quality and resolution of most of the aerial images used. From the information provided, it appears only three of the regions of mangrove were ground-truthed. The same applies for coral reef habitats (Figs 5, 6). The methodology used for digitisation of aerial images is unknown, as is the quality and resolution of most of the aerial images used. From the information provided by TNC, it seems that no ground-truthing of the image digitisation was conducted.

Data on the extent of beaches and littoral forests are based on the land-use and land-cover data layer provided by TNC via the Government of Grenada in 2017. The extent of littoral forest was estimated by assuming that the whole forest extent in coastal enumeration districts is composed of littoral forest, likely resulting in an overestimation of habitat extent. Moreover, there is no information available on what data were used to create land-use and land-cover layer, nor what date those data are from.

Extent of the shelf and deep-sea habitats were estimated from the Food and Agriculture Organisation (FAO) country report (FAO 2018).

Ecosystem condition accounts

In relation to our case study, the only condition indicator we were able to assess in Grenada relates to seagrass bed density (Figs 7, 8) which can be considered a proxy for some of the ecosystem services supplied by seagrass habitats (e.g. climate regulation, coastal protection, fish nursery etc.) (Weatherdon et al. 2018, Oreska et al. 2020). Other indicators for seagrass condition include: estimates of canopy height, below-ground biomass and carbohydrate content (Weatherdon et al. 2018).

No condition indicators or information were available for the other considered marine and coastal ecosystems. Building on data, as shown in Table 1 and Table 2, shows the extent of the selected ecosystem assets, as well as the seagrass bed condition proxied by its density to provide an example about how condition indicators should be recorded.

Additionally, the SEEA EA guidance advises to include in the extent and condition accounts both the opening and closing variation in extent and condition of habitats during the accounting period. This was, however, not possible for this case study, based on the data available. As stated in Grilli et al. (2021b), systematically mapping marine and coastal habitats through field surveys is challenging due to technical and financial limitations. Ecosystem mapping information, which is repeated over time and would allow to account for opening and closing ecosystem extent and condition, is usually not available, especially for SIDS countries.

Ecosystem services physical and monetary accounts

Exploring the potential for developing marine and coastal ecosystem accounts in SIDS required the compilation of the ecosystem services supply accounting tables in biophysical and monetary terms. We focused on the most frequently identified ecosystem services in SIDS which include: food provision (benefit of fish and shellfish provision); carbon sequestration and storage (benefit of climate regulation); natural hazard protection (benefit of erosion prevention and coastal protection); natural hazard protection (benefit of erosion prevention and coastal protection); and outdoor recreation (benefit of recreational use). Tables 3, 4 show trends in the yearly supply of the selected ecosystem services in Grenada, expressed in biophysical and monetary terms, respectively*[4]. The timeframe considered for this accounting application covers the period 2010-2016.

Nonetheless, our attempt to adhere to the SEEA EA to compile the ecosystem services supply tables presented a number of challenges, particularly with regard to monetary valuation approaches.

Provisioning Services

The fishing sector in Grenada relates to the wild seafood provisioning service and plays an important role in the Island economy, supporting the livelihoods of local communities and ensuring food security (Trade and Export Development Division, Ministry of Foreign Affairs, Environment, Foreign Trade & Export Development 2011). Data for the biophysical and monetary supply of the seafood provision service (Tables 3, 4) were derived from the Fishstat FAO database (FAO 2018). Biophysical data relate to nominal fish catch, crustaceans and molluscs, caught for commercial, industrial, recreational and subsistence purposes from marine waters within the country's Exclusive Economic Zone (EEZ). Data include all quantities caught and landed for both food and feed purposes, but exclude discards since they were not available through official statistics, although technically, physical accounts should include all fish that are discarded (UN 2014b). Only data for vessels from Grenada are considered. Data to estimate the monetary value of the ecosystem service (Table 4) relate to the value of fish landings in Grenada landing sites. Whilst the monetary values of landings in Table 4 show the economic impact of a sector which is of paramount importance for Grenada and SIDS, in general, a limitation of the approach used here is that the benefits generated by the wild seafood provisioning service are already embodied within the System of National Accounts (SNA). Consequently, the valuation approach used here raises issues of double counting (Vallecillo et al. 2019). Alternative and more appropriate methods which could be considered for valuing the contribution of provisioning services consistently with the SEEA EA framework, are the residual value and resource rent approaches (UN 2021, p. 193). Resource rent type approaches are used also by the ONS (2021): in their UK marine natural capital accounts, they calculated the monetary value of the service by using estimates of the net profit per tonne landed for various marine fish species (Office for National Statistics 2021). If appropriately applied, resource rent approaches can be a plausible solution to value seafood provision for ecosystem accounting purposes in Grenada and more broadly in SIDS. However, information needed to apply this approach in SIDS, in particular fleet costs, might not be readily available. It is also difficult to disaggregate between industrial and small-scale fisheries (Porras 2019). This is mainly caused by lack or inaccuracy of data on small-scale and subsistence fisheries available through official national statistics and capacity constraints in national statistics offices (Porras 2019, Fenichel 2020a). As pointed out by Gill et al. (2019), the lack of fisheries data in SIDS, due to scarcity of fisheries monitoring tools, hinders the robustenss and effectiveness of management interventions. Likewise, residual value and resource rent approaches have limitations as they may result in very low or negative residual estimates which are not likely to capture the appropriate value of the associated provisioning service (Obst et al. 2015, UN 2021). Additionally, consideration should be given to the value of recreational fisheries in a broader context. Indeed, the recreational value of fisheries does not only depend on fish catch, but also on other attributes provided by fishing sites (Scheufele and Pascoe 2021) and, therefore, there is also a connection to recreation related services which should be recorded and quantified (see section on cultural services).

Regulating Services

Carbon sequestration and storage is a relevant service supplied by Grenada’s marine and coastal habitats (in particular, mangroves and seagrasses). The key function of this service is to regulate climate, thus providing local and global-scale benefits. The extent of mangrove and seagrass habitats is directly extracted from the ecosystem assets extent account in Table 1. We assumed that the extent of both habitats did not change in the time period considered in this application, i.e. between 2010 and 2016*[5]. To calculate the total quantity of carbon sequestered and buried beneath sediments by mangroves and seagrasses, two different carbon burial rates are used. For mangroves, a rate equal to 1.3 tC ha^{-1} yr^{-1} is used (Breithaupt 2012); for seagrasses, a rate equal to 0.06 tC ha^{-1} yr^{-1} is used (Miyajima et al. 2015). In both cases, the lower bound of estimated carbon burial rates is used due to the high level of uncertainty regarding the capture and storage rates from vegetated marine habitats.

Finding an appropriate method to estimate the exchange value of blue carbon in SIDS is complex and conditional to the uncertainty surrounding global and local carbon value estimates (Ricke et al. 2018, World Bank 2020, McHarg et al. 2022). Approaches to derive monetary estimates for carbon in line with the SEEA EA rely on observed prices from emission trading systems (ETS) and carbon taxes or, alternatively, on the abatement cost. However, at the time of compiling the accounts, an abatement cost or carbon tax for Grenada was not available and the Island is not linked to any ETS, as also reported in McHarg et al. (2022). Global carbon prices could be another alternative, but they show large variability and sensitivity to exogenous shocks and geographical factors (World Bank 2020) resulting in increased uncertainty which limits their use in EA applications. In our case study, then, a social cost of carbon (SCC) is used to estimate the monetary value for the carbon sequestered by Grenadian mangrove and seagrass habitats*[6]. In particular, a value of US$51 per tonne of CO_2 as provided by the US Environmental Protection Agency (EPA) is used (Carbon 2021). The rationale for using the US EPA value of carbon relies on the geographical proximity and the consistency with SCC values reported in literature (e.g. Nordhaus 2017).

Information used in Table 3 for the natural hazard protection service only relates to coral reefs. Natural hazard protection, expressed as the extent, in hectares, of coral reef habitat providing protection to Grenada's coastal areas (Table 3), remains constant throughout the timeframe, as we only had data for a single year and assume that habitat extent (therefore, the physical flow of service provided) has not changed. The monetary values used in the accounting tables (Table 4) are derived from secondary information, in particular from a preliminary flood-depth damage function developed by the Centre for Environment Fisheries and Aquaculture Science (Cefas) to estimate the coastal protection benefits of coral reefs in Grenada (for details, see Beraud 2018, Posen 2018). A damage cost avoided method is employed to assess the damage to manufactured capital as a function of potential inundation resulting from storm surge scenarios for Grenada. Infrastructure' costs (roads, bridges, airports, dams etc.) are estimated by reviewing Grenada's infrastructural projects over the last three decades. The modelled inundation scenarios are based on historic storm data and likely variations are calculated for a range of predicted sea level rise scenarios. Here, we use a conservative approach by considering the damage cost avoided following an event similar to hurricane Lenny, resulting in an inundation scenario characterised by a 0.5 m storm-induced water level increase.

Cultural Services

As for most SIDS, tourism is an important sector for Grenada's economy, accounting for around 41% of the country's GDP and 23.8% of total employment in 2019 (World Travel and Tourism Council 2021). Data used to record provision of the tourism and recreation service in biophysical and monetary terms relate to the total number of tourists visiting Grenada and the relative total tourist expenditure, as recorded by the Grenada Tourism Authority. A substantial limitation of this approach is that it uses information that is already recorded in the standard SNA and, thus, as in the case of seafood provisioning, it is subject to double counting issues. The approaches recommended in the SEEA EA for the valuation of cultural services include the use of revealed preference methods, based on the travel cost method or hedonic pricing to estimate local house prices. In other SEEA EA applications (e.g. Vallecillo et al. 2019, Hein et al. 2020), there was an attempt to separate the proportion of nature-related tourism and recreation revenues due to ecosystem services or to capture daily recreation values applying the travel cost method. Vallecillo et al. (2019), for example, used a spatial modelling approach to assess the contribution of nature to the tourism sector and quantify the actual recreation flow. Similarly, Fitch et al. (Fitch et al. 2022) in their study disaggregated the specific contribution of natural capital to tourism and outdoor leisure expenditure from other forms of capital in Great Britain. Currently, there are several pilot projects in different countries (Thailand, Vietnam, Samoa and Canada) under the GOAP umbrella which are testing and applying the methodologies suggested in the draft technical guidance specifically looking at the inclusion of sustainable tourism in their national accounts, which can pave the way towards a more robust inclusion of tourism and recreation in ecosystem accounting.

Challenges in the construction of marine and coastal ecosystem accounts in SIDS and the way forward

The aim of this work was to test, through a case study, if and how ecosystem accounts following the SEEA EA guidance could be developed in SIDS using available data and information. To the best of our knowledge, this work is the first marine and coastal EA pilot in a SIDS context examining different ecosystem types and the related ecosystem services. Our pilot study includes the most recent data publicly available at the time of compilation. However, several challenges currently hinder the development of a full set of ecosystem accounts in SIDS and, consequently, their use for policy decisions and natural capital finance (Ruijs et al. 2018). This is consistent with previous work where the compilation of ecosystems accounts has been attempted within a marine and coastal context (e.g. Dvarskas 2019, Chen et al. 2020).

Some initial takeaways from this pilot study regarding the possibility to develop marine and coastal ecosystem accounts in Grenada, which can extend to SIDS, in general, include a thorough review of existing environmental and economic data that may have been generated in Grenada and may be held by the government of Grenada, as well as their suitability for a baseline assessment and subsequent use for the development of EA. Data should then be collected and recorded systematically and coherently. The resulting tables and maps should be periodically produced to track dynamics of ecosystem changes and forecast future trends. As pointed out by Singh (2014), the unavailability of data common to all SIDS due to limited human and technical capacity, may translate in policy decisions made with scarce or no sceintific evidence, which, conversely, is vital for resource management and environmental governance.

The most recent data available on some of the extent of ecosystems considered were collected over 20 years ago. In addition, the collection of these data was fragmented in terms of methods, years and geographical locations. Opening and closing variation in extent and condition of habitats during the accounting period were not considered due to lack of data. Additionally, condition indicators were available only for seagrasses. The selection of condition indicators specific for marine and coastal ecosystems is challenging due to scarcity of data readily available and the scientific complexity to assess suitable condition indicators that affect ecosystem functions and related ecosystem quality (Hatziiordanou et al. 2019;Grilli et al. 2021b). Certainly, good quality, up-to-date and detailed ecosystems spatial extent and condition data constitute a key building block of ecosystem accounting (European Environment Agency 2016). However, as shown in this work, the inconsistencies between different data sources, as well as data gaps, constitute a significant challenge for Grenada to fulfil all the data quality requirements which encompass factors, such as relevance, timeliness, accuracy, coherence, interpretability, accessibility, as well as the quality of the institutional environment where the data are collected (UN 2021).

Trends in the supply of selected ecosystem services in Grenada expressed in biophysical and monetary terms, as shown in Tables 3, 4, are also subject to limitations and shortcomings. In particular, data availability significantly limited potential valuation approaches to populate monetary supply tables in line with the SEEA EA.

Consideration must be given to how the values of ecosystem services and natural assets are connected to those already accounted within national accounts or outside national accounts in satellite accounts (Vallecillo et al. 2019). The reported monetary values of the selected provisioning and cultural services in Table 4 must be interpreted with caution since, from an accounting perspective, both monetised services (fish and shellfish, as well as tourism and nature watching) are already embedded in national accounts. The seafood provisioning services could be monetarily valued using residual value and resource rent methods derived from exchange type values. Furthermore, in case of fish caught for recreational purposes, there is a connection to the measurement of cultural services which should be taken into consideration. Prior to the compilation of the monetary supply tables, however, the focus should be on organising appropriately relevant biophysical data needed for the accounts.

Recreational values for accounting purposes could be obtained using data on estimated visits, specifically to marine and coastal areas and on disaggregated expenditure types. Such information would, ideally, be obtained through a visitors' survey and subsequent estimation of an exchange value for the ecosystem service, based on a travel cost method. Otherwise, a simulated exchange value approach (Caparrós et al. 2017) could be considered as an alternative method to be applied to extract the exchange value of cultural ecosystem services in a small-scale context and consistent with SEEA valuation principles. However, simulated exchange values have limitations in practical applications (Grilli et al. 2021a) and their suitability in SIDS context has yet to be tested. Moreover, cultural benefits derived from the coastal and marine environment do not only refer to the direct value of using an ecosystem for recreational opportunities it provides, but encompass as well the non-use dimension of ecosystems, such as existence, bequest and option values (Chan 2011, Milcu 2013,Small et al. 2017). In the case of benefits that are often non-tangible and non-material and which can be associated with a plurality of values (Small et al. 2017), exchange value approaches are not able to fully capture all the welfare values (Turner et al. 2019). Hence, other valuation methods or development of complementary accounting could be explored (Turner et al. 2019). Complementary accounts, instead, can enable the use of a range of different data and approaches (including non-monetary methods), whilst also better capturing a full range of values, thus providing additional information on the importance of ecosystems services (Turner et al. 2019). Further research and discussion with national stakeholders and other countries working on developing SEEA EA for the marine and coastal environment are needed to advance the valuation of nature-based tourism and recreation (Hein et al. 2020).

The valuation of climate regulation services provided by marine and coastal environments, as well as the valuation method to be used to more appropriately represent the value of this service, are subject to scientific uncertainty. Extensive and more frequent habitat surveys, together with the use of new technological and analytical methods (e.g. Earth Observation, artificial intelligence), would allow a better assessment of both baseline and trends in the extent of relevant habitats. Concerning the estimation of carbon burial rates, biogeochemical research has greatly improved our knowledge in the last decades, but a degree of uncertainty still remains. Seafloor sediments may also be added to the carbon sequestration and storage estimation of a country (Luisetti et al. 2019); excluding this habitat is likely to result in an underestimation of the actual service which would be a relevant disadvantage for SIDS considering the extent of their shelf-sea area. With regards to the monetary value of climate regulation services provided by blue carbon resources, in this study, the SCC was used as monetary metric to estimate the avoided damage costs; the SEEA EA now supports the use of the SCC in those situations, like our case study for Grenada, where other methods more in line with the exchange value approach are not possible.

The damage cost avoided approach used for estimating the natural hazard regulating service provided by coral reefs surrounding Grenada in monetary terms, despite being coherent with the SEEA EA guidance, has several limitations. For example, it is likely to result in an overestimation of the actual service in monetary terms, even though only the service provided by coral reefs is considered. The impact of storm-induced water levels is assumed to be the same for each of the reporting years. Additionally, the built capital costs are calculated using costs from different years and assuming no change in infrastructure endowment of coastal areas. Moreover, no capital depreciation is applied. Finally, estimation does not account for different flooding levels and simply calculates the total area affected by storm surge inundation. As recognised also in the SEEA EA, most regulating services vary substantially in their supply potential which depends on local contexts. More accurate valuation should be grounded on complex bio-economic and spatial modelling, coupling characteristics of marine and coastal environment with social and economic attributes. This is essential to robustly estimate the monetary value of the service, as it would allow the obtaining of a credible estimate of the economic and social damage that would occur if natural habitats did not provide protection. Data granularity is relevant to spatially link the value of land protected to different natural habitats.

Our pilot study focused on biophysical and monetary ecosystem services supply. Ecosystem services use and possible approaches to compile biophysical and monetary use tables have not been included since they are beyond the scope of our research and given the paucity of required data. The role of the use tables in environmental accounting is to make the contribution of ecosystem services to economic and human activities explicit, including household, businesses and government. The use tables should be harmonised with national accounting frameworks and, in the case of SIDS, could be further divided into policy-relevant sub-categories (e.g. commercial fisheries vs. small-scale fisheries). This would enable policy plans to be tailored around specific sectoral needs. The compilation of an ecosystem services use table was not possible under existing data limitation. Previous applications of EA accounting in marine and coastal ecosystems also show that the compilation of a use table is particularly difficult (see Thornton 2019). Furthermore, EA applications in SIDS should be supplemented by and interlinked with specific social descriptors (e.g. poverty and inequality, education, health and well-being etc.). It is argued, in fact, that we should not solely rely on Gross Domestic Product (GDP) to measure the sustainability of ocean economies (Fenichel 2020a, Dasgupta 2021). The inclusion and integration of measures of social capital in EA would help SIDS stakeholders and decision-makers to better capture the complex relationships amongst environment, human well-being and poverty, thus complementing information on trade-offs, costs and benefits of targeted environmental interventions, as well as financial investments on natural capital.

Conclusions

The fundamental role of the oceans for the planet and humankind is emphasised in the 2030 Agenda for Sustainable Development (UN 2015). There is an acknowledged need to account for the benefits that ocean and coastal habitats provide to humans, especially in SIDS, in order to achieve the targets set by SDG 14 “Conserve and sustainably use the oceans, seas and marine resources for sustainable development” (UN 2015), as well as to meet the targets under other SDGs interlinked to SDG 14 (e.g. SDG 1 on poverty reduction, SDG 2 on food security, SDG 13 on climate change mitigation and adaptation etc.) (Palacios et al. 2021). The SEEA EA (UN 2021) now provides an Ocean Accounting Framework and an Ocean Technical Guidance for the compilation of Ocean Accounts is in development through the GOAP. Evidence shows that the use of EA in developing countries is scarce (Recuero Virto et al. 2018). EA is data intensive and a relatively new concept for SIDS, but with significant potential to support the sustainable development of a blue economy as it is gaining traction on the international scene. The inclusion of ecosystem accounts in real world policy decision-making needs to be embedded in the institutional settings and policy dynamics of SIDS. Areas where EA can assist decision-making in SIDS in order to promote sustainable development and to make their economies resilient, inclusive and sustainable include: i) evaluation of appropriate level of investment for environmental programme and project appraisal, ii) identification of opportunities and trade-offs between environmental, economic and social priorities and iii) implementation of financial mechanisms that have the potential to invest in natural capital. Moreover, developing ecosystem accounts using the SEEA would be beneficial for SIDS as it could facilitate the report on progress in meeting sustainability targets (i.e. SDGs) and international agreements (Hein 2016).

By using Grenada as a case study to test SIDS readiness for the development of ecosystem accounts, we showed that, overall, it is currently difficult to compile a full set of marine and coastal accounts for SIDS with readily available data. Appropriate data to compile natural capital accounts, both biophysical and monetary (e.g. spatial, environmental or economic), may be already available to governmental departments, agencies and local and Non-Governmental Organisations (NGOs), but it is necessary to pragmatically consider how to regularly collect, organise and use that information, as well as ensure coherence and consistency across information sources over time. Regular collection of biophysical data and indicators in SIDS is usually hampered by limited resources across governmental and non-governmental organisations. Furthermore, considerable work is also required to adapt and test approaches, particularly for monetary valuation, that can be applied consistently with international accounting frameworks, such as the SEEA and allow the full integration of ecosystem values (Capriolo et al. 2020).

It is necessary to strengthen national and international cross-government and cross-departmental collaboration and communication. At the SIDS national level, engagement with diverse stakeholders, including local communities, private sector and NGOs, is key in EA development. It is also required to build national capacity and technical expertise and knowledge through closer collaboration between SIDS and the wider international NC accounting community, for example, by expanding the pilot applications already undertaken under the GOAP and UN supervision. The need for cooperation, increased synergies through collaboration and capacity building development emerged also during a consultation held in June 2019 with relevant Grenadian stakeholders, undertaken within the Commonwealth Marine Economies Programme (CME). Despite limited familiarity with natural capital accounting concepts, stakeholders widely recognised that incorporating natural capital into national accounts would be beneficial for the sustainable development of Grenada. Therefore, the construction of a full set of accounts in SIDS necessitates enhanced awareness and understanding of natural capital and ecosystem services concepts and, most importantly, greater cooperation to promote synergies between institutions and key actors involved in natural capital management. A pragmatic way forward, based on closer collaboration between SIDS national organisations and continued mobilisation or access to international funding and knowledge exchange opportunities*[7], is indispensable. This would create opportunities for stakeholders to share knowledge, participate in policy decision-making processes, review, manage and link available data and information and move to a systematic approach for future ecosystem accounting development in SIDS.

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Conflicts of interest

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Endnotes

*1 The UN Statistical Commission adopted the SEEA-EA (UN 2021) chapters from 1 to 7 as an international statistical standard, whereas chapters 8-11 "present internationally recognized statistical principles and recommendations for valuation of ecosystem services and assets". Source: SEEA Ecosystem Accounting is adopted! | System of Environmental Economic Accounting

*2 The authors refer to the most frequently cited definition of Sustainable Development that is “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED, SWS 1987). Equitable development in the context of SIDS is intended as development which aims to reduce disparities amongst vulnerable populations and communities through policies and programmes that foster equal distribution of the wealth generated through the ocean economy (Bennett 2019, EPA: Equitable Development and Environmental Justice | US EPA).

*3 There has been an active debate over the definition, interpretation and classification of ecosystem services and the need to distinguish between ecosystem services and benefits for economic valuation and for accounting purposes (see, for example, La Notte et al. 2017). The SEEA EA (UN 2021, p.121) refers to ecosystem services as " *contributions of ecosystems to the benefits that are used in economic and other human activity*”, while benefits are (p.122) “*the goods and services that are ultimately used and enjoyed by people and society*”.

*4 Monetary values are normalised in 2016 prices using Grenada’s Consumer Price Index.

*5 While we recognise that keeping the extent of some ecosystem types constant is a strong working assumption, for the purpose of this work, it is considered appropriate to illustratively display endowment of ecosystems that are important to SIDS and it is also supported by other applications in the marine realm (e.g. Thornton 2019). In addition, the fragmentation and typology of information available do not allow us to make any assessment on whether changes in the extent of those ecosystem types have happened in the timeframe considered as also reported in McHarg et al. (2022) , even if such changes are, in reality, plausible.

*6 While social cost of carbon is listed in the SEEA EA (UN 2021) as a method, this metric includes consumer surplus, which is not included in the exchange value required for the SEEA EA. The uncertainty around carbon values adds up, in this work, to the uncertainty around the assessment of the biophysical provision of regulating services due to the fragmentation and typology of data collection as reported in Table 1. However, monetary valuation is important for decision-making and our results aim to illustrate the importance of compiling monetary accounts including regulating services which are crucial for SIDS.

*7

Examples include: the Official Development Assistance (ODA) grants and funds, direct research investments and science support, such as the UK FCDO funded CME Programme, the German Gesellschaft für Internationale Zusammenarbeit (GIZ) projects and programmes in the Caribbean, including Grenada and the EU funded Caribbean Investment Facility (CIF).

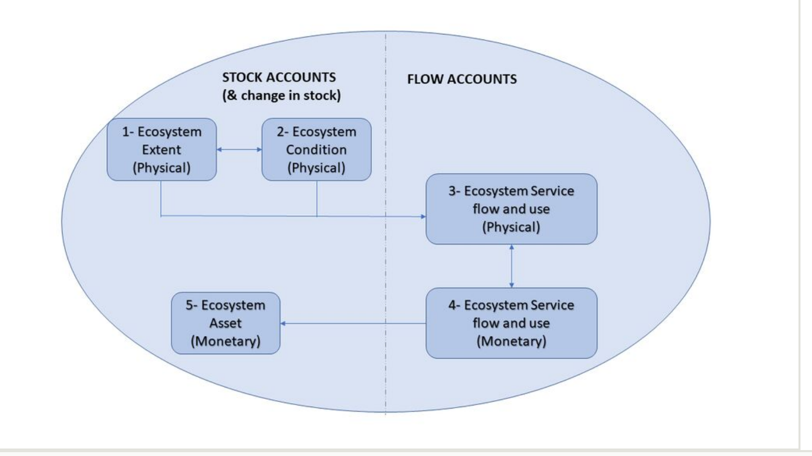

Figure 1.

Steps for the compilation of a full set of ecosystem accounting tables in line with the SEEA EA guidelines. Adapted from SEAA EA (UN 2021).

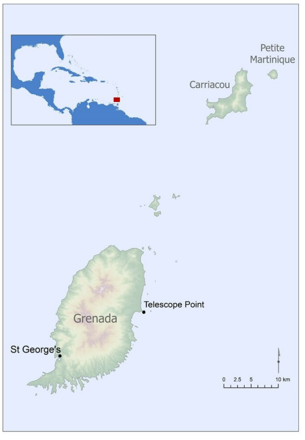

Figure 2.

Map of Grenada.

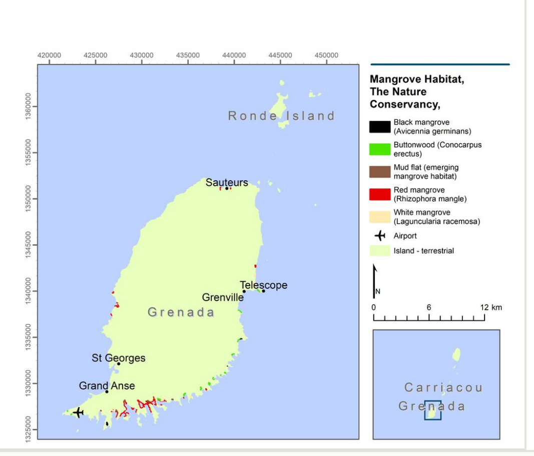

Figure 3.

Grenada Mangroves habitat.

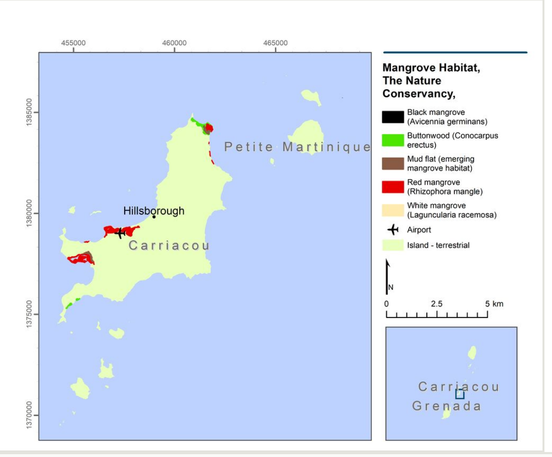

Figure 4.

Grenada (*Carriacou and Petite Martinique)* Mangroves habitat.

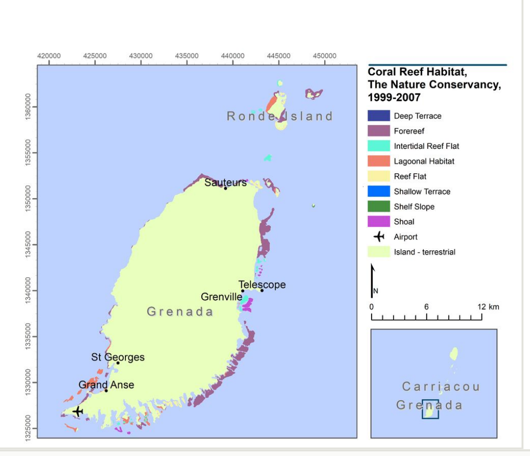

Figure 5.

Grenada Coral reefs habitat.

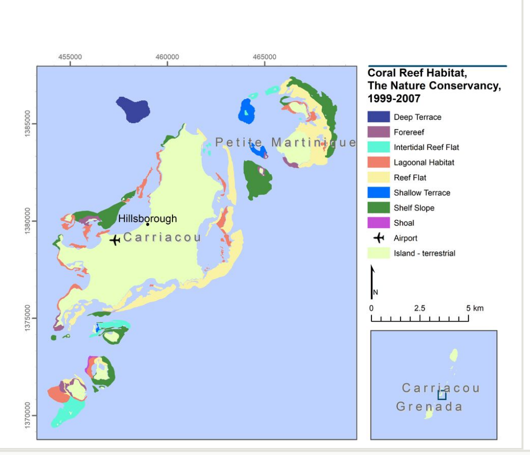

Figure 6.

Grenada (*Carriacou and Petite Martinique)* Coral reefs habitat.

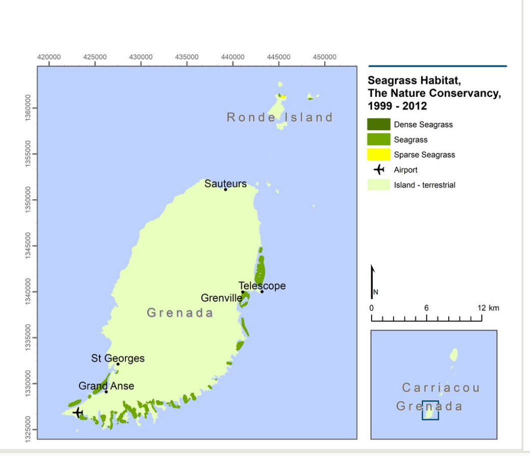

Figure 7.

Grenada Seagrass habitat.

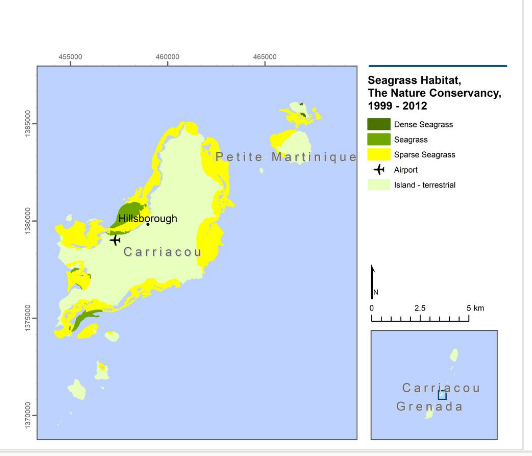

Figure 8.

Grenada (*Carriacou and Petite Martinique)* Seagrass habitat.

Table 1.

Selected ecosystem types extent account.

Ecosystem Type	Extent (Ha)	Year	Source
Seagrasses	2622	The dataset was compiled from six different datasets with images captured in **1999, 2007** and **2012**	Data provided by The Nature Conservancy (TNC) via the Government of Grenada in 2017
Mangroves	205	The dataset was compiled from four different datasets with images captured in **2007** and **2010**	
Coral reefs	5460	The dataset was compiled from four different datasets with images captured in **1999** and **2007**	
Coasts and Beaches	6	Unknown	
Littoral forests	2730	Unknown	
Shelf sea	270900	Unknown	FAO (2018)
Deep sea	2342400	Unknown	
Total	2624323		

Table 2.

Selected ecosystems types extent and condition. Condition indicators only available for seagrasses.

Ecosystem type	**Extent (Ha)**	**Characteristics of ecosystem condition**		
		Sparse Seagrass - *Low vegetation density (Ha)*	Seagrass - *Medium vegetation density (Ha)*	Dense Seagrass - *High vegetation density (Ha)*
Seagrasses	2622	1519.2	1101.3	2.3
Mangroves	205			
Coral reefs	5460			
Coasts and Beaches	6			
Littoral forests	2730			
Shelf sea	270900			
Deep sea	2342400			
Total	2624323			

Table 3.

Grenada marine and coastal ecosystem services, provision of selected ecosystem services in biophysical terms, 2010-2016.

[a]: Ecosystems extent assumed to be constant in the considered period.

Type of service	Ecosystem service	Indicator	2010	2011	2012	2013	2014	2015	2016
Provisioning	Fish and shellfish	Fish landings (Mt)	2.4	2.3	2.3	2.7	2.8	2.7	2.8
Regulating	Natural Hazard Protection	Coral Reef Extent (Ha)[a]	5460.7	5460.7	5460.7	5460.7	5460.7	5460.7	5460.7
	Climate regulation	Carbon stored (tCO_2eq)[a]	1551.2	1551.2	1551.2	1551.2	1551.2	1551.2	1551.2
Cultural	Outdoor recreation	Tourist arrivals (‘000 arrivals)		425.1	357.1	311.8	370.3	421.9	462.7

Table 4.

Grenada marine and coastal ecosystem services, provision of selected ecosystem services in monetary terms, 2010-2016 (EC$ million, 2016 prices).

Type of service	Ecosystem service	Indicator	2010	2011	2012	2013	2014	2015	2016
Provisioning	Fish and shellfish	Value of landings	37.1	33.9	32.5	39.2	39.5	39.2	40.4
Regulating	Natural Hazard Protection	Reef coastal protection benefit	1313.3	1313.28	1313.28	1313.28	1313.28	1313.28	1313.28
Climate regulation	Carbon stored	Social Cost of Carbon US EPA	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Cultural	Outdoor recreation	Recreational expenditure		337.6	327.9	419.8	400.5	398.1	408.0