Chapter 8: Natural Capital Considerations for an Extension of the U.S. Marine Economy Satellite Account

Jeffrey Wielgus[1], Monica Grasso[1], Charles Colgan[2], Jennifer Zhuang[3], Sarah Siegel[1], Joseph Conran[1], Tadesse Wodajo[1]

Abstract

In an effort to measure and track marine-dependent economic activities, the United States National Oceanic and Atmospheric Administration (NOAA) has developed two statistical tools: The Economics: National Ocean Watch (ENOW) and the Marine Economy Satellite Account (MESA). In both efforts, the focus has been on activities in selected sectors of the economy. MESA is developed within the framework of the System of National Accounts (SNA) and includes only economic activities that use essential marine inputs, produce goods or services to be used predominantly in the marine environment, take place in the marine environment, or need to be placed in proximity to the coast to take place. In addition, MESA only employs data on the annual flows of market-based values related to the marine activities. As an SNA-based tool, MESA also lacks a systematic tracking of the contribution of the environment to the economy by properly accounting for changes in the values of environmental capital stocks.

This paper proposes an initial extension of MESA to include natural capital considerations by employing key elements of the System of Environmental-Economic Accounts Central Framework (SEEA-CF). In addition to reporting the economic activities captured by the SNA structure, the SEEA-CF requires measuring both additions to the environmental capital stocks (due to natural growth or improved resource management) and reductions in these stocks (resulting from depletion from use in the production process or removal of resources from the natural stock). Considering the complexity involved in the measurement of the natural capital foundations of the marine-related economy, the paper proposes to launch the MESA extension as pilot projects focusing on relatively data rich marine activities defined in MESA: offshore oil and gas, commercial fishing, and beach recreation.

1. Introduction

The marine environment provides space and resources for a large number of economic activities. Some countries have developed satellite accounts[4] for the ocean based on the United Nations System of National Accounts (SNA), which provides valuable information on the role of oceans as providers of products for the economy. For example, the United States National Oceanic and Atmospheric Administration (NOAA) has developed the Marine Economy Satellite Account (NOAA, 2022), or MESA, in collaboration with the United States Bureau of Economic Analysis

[1] National Oceanic and Atmospheric Administration (NOAA)
[2] Middlebury Institute of International Studies
[3] Integrated Systems Solutions, Inc.
[4] Satellite accounts provide statistics for a particular aspect of the economy. Data presented in satellite accounts are consistent with BEA's core statistics.

(BEA); and the Economics: National Ocean Watch (ENOW) data set.[5] These efforts are a substantive improvement in our ability to understand how marine industries and activities contribute to society.

However, these efforts do not account for specific environmental inputs and ecosystem services that support economic activities, or the manner and degree to which natural capital stocks are consumed or adversely affected by those economic activities (Colgan, 2016; Fenichel et al., 2020; Hoagland et al., 2020). Applying the United Nations System of Environmental-Economic Accounts (SEEA) framework to understand the contributions of natural capital to activity in the marine environment would be a logical next step in characterizing the U.S. marine economy. Other countries, including Portugal[6], Norway[7], and Canada[8], are beginning the process of developing ecosystem accounts for the ocean by building upon efforts to create marine satellite accounts.

MESA identifies the activities of the marine economy and measures the output, value added, compensation, and employment associated with these activities at the national level. To make the contributions of natural capital to the marine economy visible, MESA can be extended by following the guidelines of the SEEA Central Framework (SEEA-CF)[9], which is an internationally agreed standard for accounting for environmental assets and their supply to and use in the economy. SEEA-CF provides guidance for accounting for non-produced, non-financial assets[10], such as minerals and fisheries, in greater detail than the System of National Accounts (United Nations et al., 2014).

This paper proposes an initial extension of MESA to include natural capital considerations by adopting key elements of SEEA-CF in pilot activities of the marine economy. It contributes to the implementation of the National Strategy to Develop Statistics for Environmental-Economic Decisions: A U.S. System of Natural Capital Accounting and Associated Environmental Economic Statistics, which was released in 2023 by the White House Office of Science and Technology Policy, the White House Office of Management and Budget, and the Department of Commerce[11].

The paper is organized as follows. Section 2 discusses MESA, and Section 3 provides a general discussion of dependencies and impacts related to natural capital in MESA activities. The fourth section outlines a general plan for extending MESA based on elements of SEEA-CF to three pilot sectors. Finally, section 5 concludes and discusses possible challenges to the MESA extension as well as theoretical issues that will need to be addressed.

---

[5] See https://coast.noaa.gov/digitalcoast/data/enow.html.

[6] See https://www.ine.pt/ngt_server/attachfileu.jsp?look_parentBoui=569531189&att_display=n&att_download=y.

[7] See https://www.ssb.no/nasjonalregnskap-og-konjunkturer/nasjonalregnskap/artikler/progress-on-ocean-accounting-in-norway/_/attachment/inline/df99d004-df1a-4839-9639-aa4ca55e3705:742aef3b1dae70b406bc98831670f3d0d1143371/NOT2023-28.pdf.

[8] See https://www.oceanaccounts.org/canadian-ocean-accounts-pilot.

[9] See https://seea.un.org/content/seea-central-framework.

[10] These assets are defined as existing without human production, but can be used in production. Examples are natural resources such as land, mineral and energy reserves, and non-cultivated biological resources.

[11] See https://www.whitehouse.gov/wp-content/uploads/2023/01/Natural-Capital-Accounting-Strategy-final.pdf.

2. The U.S. Marine Economy Satellite Account

An interest to create international statistical standards that would allow comparisons between national economies followed the formation of the United Nations (UN). The UN Statistical Office released the first System of National Accounts (SNA) in 1953 and has released multiple updates, with the most recent one in 2008, with support and input from other statistical agencies (European Commission et al., 2009).[12] The SNA provides standard recommendations to compile measures of economic activity and includes a strong statistical setup with internal consistency checks which allow for robust statistics. The recommendations describe a "coherent, consistent, and integrated" set of macroeconomic accounts that provide an overview of economic processes (European Commission et al., 2009: p. 1). The most well-known measure from the SNA is gross domestic product (GDP), but the accounts provide much more information about the economic state of a country at a certain point in time.

The SNA provides guidance for four types of accounts: (1) production accounts (to measure how much producers make and sell); (2) consumption and expenditure accounts (to measure how much households buy and consume); (3) accumulation accounts and balance sheets (to measure the change in assets and their value, i.e, wealth); and (4) supply and use or input-output tables (to describe the interconnections of how goods and services flow through the economy). The SNA also provides guidance to adjust for changes in price through time (United Nations et al., 2009).

The SNA does not explicitly focus on the marine-dependent portions of a nation's economy. In the United States, efforts to measure marine economic activities date back to the 1970s (e.g., Nathan Associates, 1974). The National Ocean Economics Program (NOEP) has produced time series data on marine economic activities since 1999 (Colgan, 2013). Building upon the NOEP's methodology, the National Oceanic Atmospheric Administration (NOAA) started to develop and maintain the ENOW dataset in 2011. ENOW focuses on six economic sectors: Living Resources, Marine Construction, Marine Transportation, Offshore Mineral Resources, Ship and Boat Building, and Tourism and Recreation.

The ENOW/NOEP approach provides a regional focus but gives limited detail on marine industries. To get a more comprehensive view of the marine economy, Congress directed NOAA and BEA to develop a satellite account for the U.S. marine economy in 2017. First released in 2021 with data from 2014-2019, MESA is published annually in June. MESA provides data for a wide array of ocean activities because it uses the detailed input-output tables produced by BEA.

The United States is not the only country moving to the satellite accounts approach. Portugal (Statistics Portugal, 2016), the United Kingdom (Stebbings et al., 2020), China (Wang and Wang, 2019), and Norway (Randen et al., 2022) have also rolled out experimental satellite accounts recently. The Organization for Economic Co-operation and Development (OECD) is also currently exploring an international ocean economy satellite account aiming to provide global totals and comparisons across countries (Jolliffe et al., 2021).

MESA captures economic activity in the marine environment (Figure 1), which is defined to

[12] For the historical updates of the SNA, see https://unstats.un.org/unsd/nationalaccount/HistoricSNA.asp.

include the U.S. Exclusive Economic Zones of the Atlantic, Pacific, and Arctic oceans (approximately 200 nautical miles off the U.S. coast); the Gulf of Mexico;, the Great Lakes (up to the international boundary with Canada); and major estuaries and embayments (e.g., the Chesapeake Bay and Puget Sound); as well as segments of inland river downstream from the major seaports that accommodate ocean-going vessels, even though they are located far from the coast (e.g., Portland, Oregon, New Orleans and Baton Rouge, Louisiana). The geographic scope is derived from the Coastal Zone Management Act of 1972, which assigned NOAA management of coastal resources and the Great Lakes (Nicolls et al., 2020).

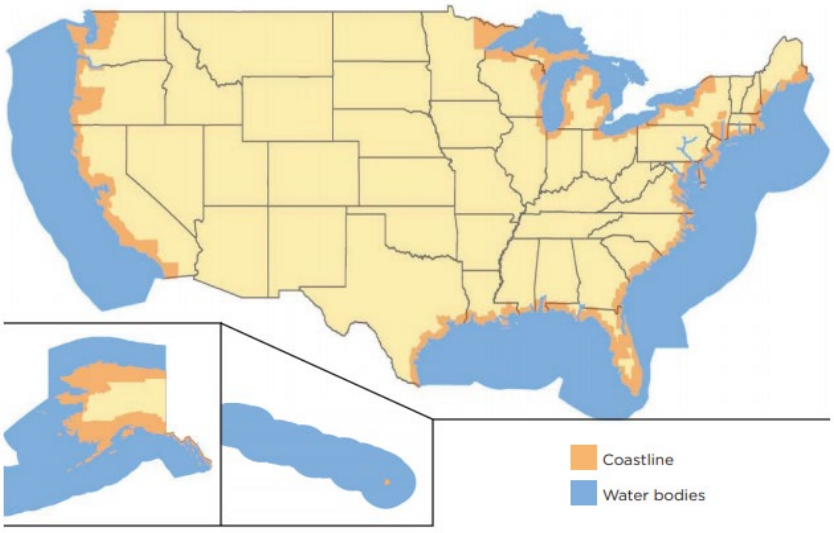

Figure 1: Geographical extent of the marine environment, whose contribution to the United States economy is captured in the Marine Economy Satellite Account. Coastline areas capture shore-adjacent zip codes. (From Nicolls et al, 2020).

There are four criteria as to whether an economic activity is included in MESA: (1) the activity takes place in the marine environment, as defined above (e.g., marine transportation); (2) it uses essential inputs from the marine environment (e.g., seafood processing); (3) it produces goods/services predominantly for use in the marine environment (e.g., marine navigational equipment); (4) it would not take place if not located in proximity to the coast (e.g., beach vacation rental property). Economic activities in the SNA that meet any of the four criteria above are identified and categorized into 29 marine industries in the following 10 sectors: Living Resources, Construction, Research and Education, Transportation and Warehousing, Professional and Technical Services, Offshore Minerals, Coastal Utilities, Ship and Boat Building, Tourism and Recreation, and National Defense and Public Administration.

Many activities along the coast are not solely marine related, and MESA uses a set of coefficients, or “partials”, to estimate the portion that is specifically marine-dependent. Partials are applied to the seven final demand categories of each good and service class in BEA’s supply-use framework: personal consumption expenditure, exports, imports, intermediate inputs, government expenditure, inventory changes, and private fixed investment (Nicolls et al., 2020). If a good or service is not marine-related, a partial of “0” is assigned to the category and it is excluded from

MESA; if a good or service is entirely marine-related, a partial of "1" is assigned to the category; finally, if one category includes both marine and non-marine components, a percentage is estimated to partially include the category in MESA. For example, for electric power generation, output is defined by identifying all electric power production within the national shoreline and calculating the gross megawatt hour (MWh) output for this as a share of the national MWh generated.

Data to estimate partials are collected by the private sector or government agencies, and sources include NOAA, BLS, Census Bureau, Department of Energy, Department of Defense, National Marine Manufacturers Association, the Baker Hughes oil field service company, and the DK Shifflet travel performance research firm, among others. To maximize consistency, the same sources are consulted from year to year. When data are available from more than one source, data released by government agencies are prioritized.

MESA reports statistics for both the customized set of groupings (the sectors and activities) that align better with natural "breakpoints" in the marine economy and the standard BEA industry groupings in the national accounts. The latest release of MESA[13], in June of 2023 with 2021 data, showed that the U.S. marine economy contributed $432 billion to the national GDP in 2021, generated $730 billion in gross output, and supported more than 2.3 million jobs. The marine economy accounted for 1.8% of national total gross output, 1.9% of total GDP, and 1.3% of total employment. Recovering from the effects of COVID-19 in 2020, the marine economy bounced back strongly in 2021 with 7.4% growth from 2020 to 2021 in real GDP, larger than the overall U.S. economy's growth of 5.9%. The marine economy sectors with the highest growth in 2021 were Tourism and Recreation (27.3% growth in gross output to a level of $231.8 billion); Transportation and Warehousing (16.8% growth to $57.1 billion); and Living Resources (13.5% to $31.0 billion).

3. Natural Capital in MESA

Although the SNA has been in use for over half a century, there has long been criticism that the accounts, and especially GDP, do not provide a full representation of a society's well-being, including that linked to a healthy environment (Nordhaus and Tobin, 1973). Alternatives have been proposed that help provide a greater context to societal welfare, including the Human Development Index and the Gross National Happiness Index, among many others (Fleurbaey, 2009).[14] Nonetheless, in many of these proposed indicators there is no consideration of the economy's impact on the environment nor a systematic process to keep track of the environment's contribution to the economy. Furthermore, it is important to develop measures tracking changes and potential depletions of natural capital.

Initiatives to account for natural capital in the measurement and reporting of economic performance culminated in the development of SEEA in 1993, but it took two more decades for

[13] See https://www.bea.gov/sites/default/files/2022-06/mesa0622.pdf.

[14] The Human Development Index is discussed in https://hdr.undp.org/data-center/human-development-index#/indicies/HDI, and the Gross National Happiness Index is discussed in https://www.grossnationalhappiness.com.

SEEA-CF to be adopted as a statistical standard by the United Nations Statistical Commission (United Nations et al., 2014). The goal of the framework is to provide a comprehensive view of the stocks and changes in stocks of environmental assets. SEEA-CF generally follows the SNA's accounting structures, which allow the integration of information on economic and environmental assets. MESA and ENOW provide SNA-consistent data on the annual flows of market-based values related to ocean activities. The investment part of the SNA's National Income Accounts include both additions to capital stocks and reductions in capital stock values through consumption of fixed capital (depreciation) (BEA, 2022). Extending concepts from the SNA framework, SEEA-CF requires measuring both additions to capital stocks and reductions in the stocks.

The marine economic sectors captured in MESA can be classified into 4 types (with some overlapping categories) according to their connections with natural capital (Table 1): 1) Living Resources and Offshore Minerals are sectors that depend on the extraction of natural resources from the ocean; 2) Living Resources and Tourism and Recreation are sectors that directly benefit from a healthy and sustainable marine environment; 3) Offshore Minerals, Transportation and Warehousing, Construction, Ship and Boat Building, and Coastal Utilities are sectors that do not heavily rely on the health of the natural ecosystems but may bring potential significant impacts to the environment; and 4) National Defense and Public Administration, Research and Education, and Professional and Technical Services are sectors that provide regulation, management, scientific and technological advances, and education on the uses of marine resources.

Table 1: Major relationships or dependencies of MESA sectors with the marine environment.

MESA Sector	Resource Extraction	Ecosystem Health	Ecosystem Impacts	Ecosystem Management
Living Resources	X	X		
Offshore Minerals	X		X	
Tourism and Recreation		X		
Transportation and Warehousing			X	
Construction			X	
Ship and Boat Building			X	
Coastal Utilities			X	
National Defense and Public Administration				X
Research and Education				X
Professional and Technical Services				X

4. Proposed Pilots for an Initial Extension of MESA

An expansion of MESA to incorporate natural capital will help fill in the gaps to include the value of the stocks and the flows between economic activities and the natural environment. Consistent with SEEA-CF, this will include accounting for investments needed to reduce the damages to natural capital caused by each of the economic activities, as well as the value of damages attributable to other economic activities (residual damages). However, these measurements of the natural capital foundations of the ocean-related economy require a more complex process than the estimation of MESA. The data, for the most part, are not nearly as readily available, and the specific measure of natural capital is unique to each type of good or service in the ocean economy. Therefore, the MESA extension will start from major marine economic activities with a known relative abundance of statistics and an explicit relationship to environmental stocks and flows. The pilot marine activities considered here are offshore oil and gas exploration and production (a component of Offshore Minerals), commercial fishing (a component of Living Resources), and beach recreation (a component of Tourism and Recreation).

Offshore oil and gas exploration and production is one of the largest ocean related contributors to the U.S. GDP in the offshore mineral extraction sector (NOAA, 2022). The value of the mineral reserves extracted and sold in the market is monitored in BEA's national accounts, statistics from the Department of Energy, and the private sector. The valuation of mineral reserves is a well-established field in mining and mineral economics, and the methodology is fairly straightforward.

Commercial fishing is the one economic activity that is found in virtually all the marine waters of the United States, from the Bering Sea to the Caribbean. For more than 50 years, NOAA has been maintaining a variety of time-series data on fisheries in the U.S., including harvests, stocks, spawn and mortality rates, and overfishing status, and conducting in-depth research studies on both deep sea and coastal ecosystems that support fisheries. Some of these statistics, such as fish landing values, have been incorporated into BEA's models for the national accounts. Internationally, the SNA framework uses fish stocks as an example of natural assets that are in scope for the non-produced non-financial balance sheet. The basic approach for measuring fisheries-related natural capital is also well defined in the SEEA-CF.

While oil and gas is the largest contributor to GDP among ocean sectors, the largest sector in terms of employment is Tourism and Recreation (NOAA, 2022). Beach recreation, extending from Maine to Hawaii, is the primary activity underlying this sector. The natural capital value of beaches is a function primarily of the value of beach use for recreation. This value has been studied using various versions of stated and revealed preference methods. For the purposes of promoting their coastal economies, some state and local tourism bureaus and industry associations keep active track of beach visits and consumer behavior statistics through regular surveys and tax reports in some areas, which provide a foundational understanding on the value of the natural environment for tourism and recreation.

The following discussion provides the conceptual basis for measuring natural capital in the three proposed pilots and examples of data sources that we have identified to build pilot accounts.

4. Conceptual Basis for Pilot Accounts

4.1 Offshore Oil and Gas

4.1.1 Physical account

Offshore oil and gas lying under the seabed between the seaward extent of the states' jurisdiction and the seaward extent of federal jurisdiction belongs to the national government under the Law of the Sea Conventions (LOSC)[15] of 1958, 1964, and 1982. Under the U.S. Outer Continental Shelf (OCS) Lands Act of 1954, as amended in 1978 (43 USC 29), the steward of that resource is the Department of the Interior, specifically the Bureau of Ocean Energy Management (BOEM). BOEM divides its jurisdiction into four areas: Atlantic, Gulf of Mexico, Pacific, and Alaska. The OCS Lands Act is based on the premise that the seabed oil and gas resources will be developed and sold in the market and that the private oil and gas industry is authorized to explore, develop, produce, and sell the oil and gas.

The offshore oil and gas accounts will be structured following guidance for mineral and energy asset accounts from SEEA-CF. The framework provides guidelines for developing physical and monetary accounts and focuses on clearly organizing the relevant information to highlight flows of extraction, depletion, and discoveries (SEEA-CF 5.169).

The scope of deposits included in the SEEA-CF mineral asset accounts are based on the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009, and are classified in three classes: Class A - commercially recoverable resources; Class B - potentially commercially recoverable resources; and Class C - non-commercial and other known deposits.[16] The scope and classifications of BOEM are aligned in spirit with SEEA's classifications. BOEM's resource classification includes undiscovered resources (equivalent to class C), contingent resources (class B), and reserves (class A).[17]

BOEM releases annual reports for reserves found in the Gulf of Mexico and Pacific OCS areas. There are also intermittent data on contingent resources as well as five-year reports on undiscovered resources. Thus, annual tables for the Gulf of Mexico and Pacific OCS areas can be developed for Class A (reserves) resources, and Class B and C data will be added as available.

Table 2 provides an example of an annual physical asset account using the 2013 estimates of oil in the Gulf of Mexico OCS area. The table matches the format of the physical account tables of SEEA-CF, but it has two additional rows: "unknown additions" and "unknown reductions." These rows were added to ensure transparency when fitting BOEM data into the SEEA format, as BOEM does not fully release information specifying the different reasons for additions and reductions in the stock. The exception is with production data, which is published annually and will be included under extractions.

[15] Although not yet a party to the treaty, the U.S. observes the LOSC as reflective of customary international law and practice.

[16] See https://unece.org/DAM/energy/se/pdfs/UNFC/unfc2009/UNFC2009_ES39_e.pdf.

[17] See https://www.boem.gov/oil-gas-energy/resource-evaluation/classification-and-methodology-reserves-calculations for more information on BOEM's classification and methodology for reserves calculations.

Table 2: 2013 Oil Gulf of Mexico OCS physical asset account (billion barrels)[18].			
	(A) Commercially Viable	(B) Potentially Commercially Viable	(C) Non-Commercial Other Known Deposits
Opening stock	4.33	4.61	
+ Discoveries			
+ Upward reappraisals			
+ Reclassifications			
+ Unknown additions			
Total additions	0	0	
- Extractions	0.46		
- Catastrophic losses			
- Downward reappraisals			
- Reclassifications			
- Unknown reductions	0.19	1.32	
Total reductions	0.65	1.32	
Closing stock	3.68	3.29	35.01

4.1.2 Monetary account

The monetary account of the mineral asset account is limited in scope to class A of minerals, which are those that are commercially recoverable. Thus, we are interested in valuing the offshore plots in which a lease has been sold and there is confirmed commercial progress in. BOEM handles the sale and management of leases and has developed an auction system that works pursuant to the OCS Lands Act, which requires that winning bids must be considered "fair market value."[19] The Department of Interior develops a 5 year program which sets a schedule under which BOEM offers for sale a defined group of 9 mi^2 blocks within an OCS planning area. The auction is called a lease sale because the winning bidder is given lease hold rights to the designated block; ownership of the undersea lands remains with the government, but the oil and gas becomes the property of the firm producing the resource. A lease gives the winner the right to drill for oil or gas (subject to environmental reviews) for up to 5 years, and this period may be

[18] Data sources for the table include are from the following reports, which are available on BOEM's website (www.boem.gov): Estimated Oil and Gas Reserves Gulf of Mexico OCS Region December 31, 2019 (data for column A); Reports on Estimated Oil and Gas Reserves Gulf of Mexico OCS Region December 31, 2012 and 2013 (data for column B); and the Assessment of Technically and Economically Recoverable Hydrocarbon Resources of the Gulf of Mexico Outer Continental Shelf as of January 1, 2014 (data for column C).

[19] See https://www.boem.gov/oil-gas-energy/resource-evaluation/fair-market-valuation-methodology for a description of BOEM's fair market valuation methodology.

extended. The use of the sealed bid auction processes is used to assure that the bids are received in a fair market.

If oil and/or gas are discovered, the lease owner has the right to install development wells to extract oil or gas. Once the field development is complete, the lease owner may produce and sell the oil and gas. The lease owner is also responsible for transporting the oil and gas to shoreside processing via pipelines or tankers. The terms of the lease ownership call for three payments to be made to the government. A rental fee is charged per acre for each 5,700-acre block. The rental fee is paid regardless of any discoveries or drilling activity. A royalty is charged as a percentage of the gross value of all oil and gas sold. The royalty is charged only if oil or gas are found.

The bids in the sealed bid auction are for what amounts to an up-front payment of a share of the value of oil and in excess of the royalty and rental payments. Because it is a competitive market, the optimal bid for the company wishing to have the right to explore for and perhaps acquire producible reserves are considered remaining rents. The oil company, in other words, must pay to the government a substantial amount for an unknown (and at the time unknowable) right to possibly produce and sell oil. The only rational maximum bid is an amount that just leaves the company with the likelihood of a minimum return if oil is present. The lease sale system using bonus bidding identifies and measures the resource rent which is transferred from the oil company to the government as a competitive market price. Tracts that receive no bids or that receive bids below the BOEM minimum bid are not considered in the valuation of oil and gas resources. Any oil and gas they may contain is accounted for as undiscovered (unconfirmed) resources.

BOEM records provide a means to measure the capital value of the currently leased OCS lands.[20] Currently, there are no active leases in the Atlantic, nor any plans to sell land there, and Alaska reserve and leasing data are not available to the public. However, data are available for the Gulf of Mexico and Pacific regions.

This measure of the capital stock of offshore oil and gas can be updated every year to show changes in the stocks' values. This update will reflect changes in expected physical levels of oil and gas and expectations of prices as reflected in bonus bids.

The use of the bonus payments as a measure of capital value of offshore oil and gas raises a definitional question. Only some areas sold for exploration will actually yield oil and/or gas; the majority in fact will not. The bonus bid can be considered the market value of blocks with oil and gas (at the time of sale), while the payments where no hydrocarbons are found can be considered a capital value of the seabed. Accounts need to separate the minerals from the lands. It should be noted that the lands may also have other capital value as habitat for fisheries, which should also be estimated in a complete capital account. These challenges are currently being investigated in the oil and gas pilot research phase.

4.1.3 Environmental expenditures account

[20] This information may be retrieved from the website https://www.data.boem.gov, "Leasing Information" subsite. Data are available for deposits that are being produced and the value of bonus payments paid for leases.

The method above meets many of the needs for a capital asset valuation for oil and gas, but it lacks a consideration of important environmental issues. SEEA-CF environmental accounts ensure that goods and services that protect or improve the environment are identified and their value recognized. The environmental accounts cover two broad categories of environmental expenditures: resource management and environmental protection.

Expenditures on environmental protection are generally internal expenditures within organizations that are accounted for as "inputs" to the final produced goods. SEEA-CF calls for these expenditures to be separated from the standard accounts to explicitly measure environmental protection as a good or service. The environmental protection aspects of natural capital should include both those investments needed to reduce the extent of environmental damage caused by extraction of the oil and gas, and the value of residual damages that cannot be avoided. In the case of oil and gas, these can be grouped as operational environmental effects and investments and catastrophic effects.

Environmental impacts of oil and gas operations are well understood because of decades of experience in managing these effects under the authority of the OCS Lands Act, the Clean Air and Clean Water Acts, the Oil Pollution Act, and other federal (and state) environmental laws. Major effects of concern include small scale oil spills (from transferring fuels), air emissions from venting and flaring of natural gas, and the impacts of disposal of drilling materials. There are also solid and domestic wastes typical of ship-bound operations. In general, all of these impacts are managed by the oil companies to the extent required by their permits of operation. The physical extent of possible versus actual pollutants should be documented from permitting records. It is unclear if the monetary expenditures on environmental protection are routinely accounted for.

While regulation of the environmental effects of OCS exploration and production results in extensive investment in environmental protection, there are known to be uncontrolled residual effects. These include oil spills that are small individually but are cumulatively quite significant. This is particularly the case in the transportation subsystems of OCS oil and gas. These residual effects have been extensively studied and to the extent possible will be accounted for in the pilot.

The final major element is the possibility of catastrophic oil spills. These are quite rare, as the most frequent causes of such events are understood and controls are put in place. However, as the Deepwater Horizon oil spill of 2010 showed, the right combination of individually low probability events can still result in a large disaster. The damages to the environment as well as to the fishing and other ocean industries were of an order of magnitude to exceed total bonuses paid in some years. Measuring the losses in environmental capital value from catastrophic oil spills is a major challenge for this project. The events are too large to be ignored but too infrequent to forecast. The development of an appropriate methodology will be an important part of the prototype project. An initial approach may be to adapt the stochastic simulation methodology that is used by DOI to estimate the probability of oil existing within a designated area, but this would be highly experimental research.

In addition to environmental protection expenditures, SEEA also calls for spending on resource management to be included in the accounts. For purposes of the prototype account, the OCS program management expenditures by BOEM can serve as a measure of resource management

expenditures. Expenditures by other public agencies at the federal and state levels may also be included to the extent that distinct budgetary lines and expenditures can be identified.

4.2 Commercial Fishing

4.2.1 Physical account

The commercial fisheries pilot will begin with the selection of an initial fishery to examine. NOAA recognizes over 450 distinct fish stocks, of which some 250 are designated as "high value."[21] Some stocks are shared with other countries and spread between state and federal waters. The natural capital estimate will attempt to determine the economic value of some subset of these stocks. It is expected that a portion of the capital stock will be removed each year as depletion from both natural and man-made causes. In a renewable resource such as fisheries, the critical natural capital question is whether there is a long-term reduction in exploitable stocks and output in the fishing industry. The usual assumption is that this reduction in the physical size of fisheries stocks is brought about by overfishing, that is, fishing beyond the biological reproduction rate such that removal exceeds population growth.

This question of sustainable exploitation of the resources is clearly an important issue. U.S. fish stocks support a mix of unsustainable and sustainable fisheries, so this will become an additional criterion in selecting the stocks to be examined. However, traditional issues of over exploitation are not the only source of possible long-term change in capital stocks. Climate change is expected to reduce the size of fish populations in some areas and increase populations in other areas as populations respond to changes in thermal and chemical properties of the ocean. In addition, indirect impacts across multispecies fisheries (e.g., prey responses when fishing for predatory species) commonly result in stock changes. Because capital value is the discounted present value of some future flows of values, incorporating expected impacts of climate change and ecological relationships will be important considerations across fisheries.

Due to these complexities, the initial commercial fisheries pilot will likely focus on a single-fishery, sedentary species fishery with a history of sustainable exploitation and harvest data. We will use data from NOAA's Stock SMART database[22], which provides biomass estimates for fishery stocks as well as data on recruitment and fishing mortality. Stock assessment information from NOAA can be used to supplement Stock SMART data (Table 3).

[21] These stocks make up about 80% of total landed value; see https://www.fisheries.noaa.gov/topic/population-assessments/fish-stocks.
[22] See https://apps-st.fisheries.noaa.gov/stocksmart?app=homepage.

Table 3. Illustration of some of the data available to build pilot physical and monetary natural capital accounts for the Atlantic scallop (*Placopecten magellanicus) fishery*.[23]

Physicial Account Data				Landings Data		
Year	**Catch (MT)**	**Abundance (MT)**	**Fishing Mortality**	**Revenue ($US)**	**Landings (MT)**	**Unit ($/MT)**
2022	-	-	-	426,491,119	12,873	33,131.34
2021	-	-	-	560,882,635	16,670	33,646.70
2020	-	-	-	347,202,577	15,916	21,814.89
2019	27,647	147,073	0.34	434,337,168	20,796	20,885.17
2018	26,433	173,494	0.23	411,546,653	20,179	20,394.80
2017	23,458	193,441	0.23	369,604,286	16,446	22,474.09
2016	18,439	188,876	0.23	303,898,576	11,235	27,048
2015	16,207	175,263	0.26	286,546,638	10,559	27,137.83
2014	15,343	132,925	0.25	297,522,810	10,645	27,950.13
2013	18,664	108,533	0.35	366,369,379	14,538	25,201.61
2012	25,915	113,215	0.40	389,320,756	17,776	21,901.69

4.2.2 Monetary account

Fish stocks from which fish are caught and sold are primary inputs to commercial fishery industries, but one which are generally unpriced. The economic conceptual challenge with fisheries is to identify this unpriced value.

The discussion of asset valuation for fisheries in SEEA-CF focuses on market-based transactions used to secure the right to fish. Such transactions could include tradable fisheries permits or individual transferable quotas, the prices of which can be assumed to represent the resource rents that fishing enterprises are willing to surrender for the right to fish (Newell et al., 2005). For commercial fisheries in federal waters that are managed this way, quota prices, where available, will be used to estimate rents (e.g., see Holland et al., 2015).

In the absence of a market-based resource allocation system, or in cases where quota prices are not available, the method recommended is the residual value approach, which estimates the Net

[23] Stock SMART was used for stock data, and NOAA's National Marine Fisheries Service provided scallop fishery landings data. The latest stock data available is from 2019, which is the data year for the most recent stock assessment, published in 2020. Catch refers to the total amount harvested by fishing vessels or gear, while landings refers to the portion of the catch that is brought to port or landed for commercial use.

Present Value of the implied resource rents accruing from holding or using the asset (Obst, 2010). This method starts with the gross output value (i.e., the landed value) and works backward to remove the costs of inputs such as fuel, bait, and labor to yield an approximate value of the profits of fishing. These profits are a combination of the return to the capital invested in fishing activities and the return to the natural capital.

The empirical issues associated with a residual estimate of value for a specific fishery begin with data on the gross output values. These data are regularly maintained by state and federal fisheries agencies and are generally of high quality. However, the same is not true of the values of the various purchased inputs, which are not regularly measured in any economic statistics series. Labor in commercial fishing, for example, is not measured by standard wage data because crew on fishing vessels are, with some exceptions, treated as individual contractors and their labor compensation computed as a share of the catch value. Data on other variable costs such as ice, fuel, and bait may or may not be available, and there are limited data on the value of fishing vessels and gear. Some of these data may be available on an episodic basis for specific fisheries through various studies by NOAA's Fisheries Office in support of management decisions. Some fisheries such as the Atlantic scallop are relatively data-rich, but we are investigating potential ways of addressing challenges in data-sparse fisheries, including exploring if information from the National Accounts could be used to fill in gaps.

The residual value approach to estimate resource rent should be applied with caution, as there are potential estimation challenges that could include the vertical integration of companies that transfer profits to elsewhere in the supply chain, and barriers to entry that may produce quasi-rents that could be confounded with resource rents (Obst, 2010). A comparison with values obtained through the analysis of quotas, where available, would help shed light on these potential drawbacks.[24]

4.2.2 Environmental expenditures account

Eight Regional Fishery Management Councils, established in 1976 under the Magnuson-Stevens Fishery Conservation and Management Act, oversee the management of fishery resources in federal waters of the United States.. Each council develops region-specific management plans to prevent overfishing, rebuild fish stocks, and ensure the long-term health of U.S. fisheries[25].

For example, the New England Fisheries Management Council manages the Atlantic sea scallop under a variety of measures provided in the fishery's Management Plan. Allowable catch is determined based on stock estimates, and fishing permits are allocated to different fishing groups depending on historical catch. Additional management measures include crew-size limits, closures of certain areas to protect young scallops and reduce bycatch, and mandatory use of vessel monitoring systems. Certain fishing groups are allowed to participate in a program of

[24] We thank Andrew Scheld for drawing attention to these potential challenges with the approach.
[25] See https://www.fisherycouncils.org.

individual catch quotas[26]. Management plans are publicly available and can be used to estimate resource management expenditures for fisheries[27].

4.3 Beach Recreation

4.3.1 Physical account

The physical account will help track changes due to natural erosion and accretion, and human impacts such as beach nourishment, which will increase beach areas, and infrastructure developments that could reduce beach extent. High-resolution remote sensing (e.g., see Addicott, this volume) as well as existing beach physical data can be used to measure the linear extent and area of the stock of beaches. Stock will be defined in the pilot in both linear extent and surface area from the top of the dune to mean low water.

4.3.2 Monetary account

The natural capital value derived from recreational use of beaches accrues in part to the recreational users and in part to the businesses that supply services, such as lodging and recreational equipment sales and rentals. The recreational user value is normally taken as an unpriced benefit since few beaches have entrance fees, and other variables included in the willingness to pay for recreation need to be estimated. This unpriced benefit has been extensively studied by economists using both stated and revealed preference methods, as discussed below. The majority of these studies have been done in a few states, including Florida, California, and New Jersey, but estimates have tended to fall within a narrow enough range to be useful. The share of the beach value accruing to businesses supporting tourists is, like the value of fish stocks, a portion of the profits of the relevant businesses.

Although the estimation of beach values for recreational users has a substantial theoretical foundation in the literature, data on the number of users of beaches are not widely collected. The same public access that creates the unpriced benefit that has been so extensively explored also makes it difficult to measure the number of beach visitors (and visits). A further complication in estimating user values is that a significant portion of the studies of user benefits are done with stated preference studies using different methods (e.g., Landry et al., 2020; Lew et al., 2022). Such studies are well grounded in economic theory and methods, but the diversity of approaches raise questions about comparability of results (De Valck et al., 2018; Glenk et al., 2020). These validity issues led the SEEA-CF and SEEA-Ecosystem Accounting standards to recommend against using stated preference studies and instead using market-price based valuation methods such as travel cost (e.g., Pascoe, 2019).

The producer side of the capital value may be estimated from industry data in the national income accounts for selected industries. The Tourism and Recreation industries in the ENOW and MESA data provides basic information. For industries such as hotels, ENOW data includes

[26] See https://www.fisheries.noaa.gov/species/atlantic-sea-scallop.

[27] For illustration, the Fisheries Management Plan and supplementary information for the Atlantic sea scallop can be found at https://www.nefmc.org/management-plans/scallops.

establishments located in shore adjacent zip codes, which will permit some localization of the relevant data.

Like commercial fisheries, natural capital estimation for beaches will require selection of case studies to estimate natural capital. In this case, the choice of case studies will be made from beaches for which adequate user volume data is available or where user benefit studies have been done, and where there is adequate localized data on relevant businesses.

4.3.3 Environmental expenditures account

Beach use is occasionally affected by closures related to water quality issues and business cycle reductions in tourism spending. The COVID-19 pandemic also generated beach closures. Like commercial fisheries, climate change is a threat to beach recreation through erosion of beaches or, in the case of some activities such as surfing, changes in water levels that alter recreation. The economic value of erosion on beaches, which reduces the available area and increases congestion, will be reviewed to determine if user values decline with changes in the physical nature of the beach. Beach clean-up expenditures, such as daily raking, may also be considered, and data availability is being investigated.

5. Discussion and Conclusions

In the United States, the development of the Marine Economy Satellite Account (MESA) and the Economics: National Ocean Watch (ENOW) database has provided a focus on the contribution of the ocean to the national and regional economies. Both of these efforts are based on conventional measurements for assessing relationships between the economy and the environment, and thus are limited in their assessment of the contribution of natural capital accounting to the economy. This paper has outlined a plan to extend MESA so that it begins to incorporate key aspects of the United Nations System of Environmental-Economic Accounts Central Framework (SEEA-CF) as a foundation to gain an understanding of the contributions of natural capital to economic activities in the marine environment.

Standard national income accounting based on the United Nations System of National Accounts (SNA), including MESA, measures flows of economic activity in a specific period. In contrast, accounting based on SEEA-CF includes measures of both stocks and flows of economic values. An extension of MESA would allow expanding the definition of “capital assets” to include natural resource assets and to account for their depreciation and depletion. Measurement of the natural capital foundations of the marine-related economy requires a significantly more complex process than the estimation of MESA because the data and methods are much more complex and, for the most part, not nearly as readily available. Thus, this paper proposes to begin the MESA extension by developing pilots for three sets of ocean activities defined in MESA that are relatively data rich: offshore oil and gas, commercial fishing, and beach recreation. However, a number of challenges will need to be addressed. Table 4 summarizes links to MESA, analytical challenges, and environmental connections related to the proposed pilots.

Table 4: Links to the Marine Economy Satellite Account (MESA), analytical challenges, and environmental connections associated with the three proposed pilots for extending MESA to include natural capital considerations

Pilot	Links to MESA	Analytical Challenges	Environmental Connections
Offshore Minerals	Oil and Gas: - Resource Extraction - Ecosystem Impacts	Capturing geographic and quality extent; Difficulties in measuring additions and reductions in stock; Monetary valuation limited to subset of minerals; Value of stock contingent on expected value at auction	MESA does not account for activities that protect or improve environment; protective expenditures not explicit; Measuring losses of environmental capital due to catastrophic events is challenging
Commercial Fishing	Living Resources: - Resource Extraction - Ecosystem Health	Must consider both fishing and ecological reductions in stock; Climate change projections should be integrated into forecasts to help properly value fish stocks	Fish stocks sensitive to ocean climate change and ecological interactions
Beach Recreation	Tourism and Recreation: - Ecosystem Health	MESA provides producer side of value but does not represent unpriced recreational user benefits; Use and comparability of diverse valuation studies; Need to include adjacent areas to account for lodging and other relevant producer surplus	Climate impacts may degrade usable area and quality of beaches; Potential increase in cleanup costs subject to ocean and weather variability

Challenges in the oil and gas pilot include capturing the extent of oil and gas resources, navigating contract complexities, and accurately valuing stocks. In addition, measuring the probabilistic risk of environmental factors, such as pollution, proves challenging. The government lease sale system introduces uncertainty, requiring SEEA to encompass environmental resource management in its accounting framework.

There are a number of questions that will need to be considered in the commercial fishing pilot. Changes in ocean chemistry and other climate-related impacts should be included in the stock-assessment process. In addition, fish stocks are sometimes well defined from a biological perspective, but traditional ideas of fish stocks have been significantly undermined by the presence of multi-species fisheries in which complex predator-prey and ecosystem conditions have more influence on the total amount of fish available to be caught than the simple process of natural population change adjusted for the amount of fish caught. Trophic interactions can be captured in the shadow prices of prey and predator species (Yun et al., 2017). This will be explored further as part of the pilot.

Additional issues will need to be addressed for natural accounting in the commercial fisheries sector as a whole. Unique valuations will be required for a large number of fisheries that in some cases are shared with other countries and spread between state and federal waters. Discount rates present a number of theoretical and empirical issues, and resource dynamics are important in calculating effective discount rates (Fenichel and Abbott, 2014, Fenichel et al., 2016, Hoagland et al., 2020). For fisheries, conservation that leads to stock increases for a renewable resource would lower the effective discount rate.

In the beach recreation pilot, recreational value for some of the case studies may need to be taken as an unpriced benefit since few beaches have entrance fees. Although methods for the estimation of beach values for recreational users have a substantial foundation in the literature, data on the number of users of beaches are not widely collected. A further complication in user values is that a significant portion of the studies of user benefits are done with stated preference studies, which are not recommended in SEEA.

There are now efforts to create SEEA accounts across 90 countries, including efforts in a number of them to develop ocean accounts[28]. Australia recently released experimental estimates for a National Ocean Account[29], which include measures of extent, condition, and carbon stocks for mangroves and seagrasses. Also recently, Norway published a pilot ocean satellite account in the spring of 2022 and has released information on plans for developing an ocean account[30]. In January 2023, the United States launched the National Strategy to Develop Statistics for Environmental-Economic Decisions: A U.S. System of Natural Capital Accounting and Associated Environmental Economic Statistics, which provides guidelines to create a national system for natural capital accounting. The work proposed in this paper will contribute to the National Strategy and will benefit from the lessons learned by countries that are already conducting natural capital accounting for the oceans. The extension of MESA will be a first step to account for the contribution of marine natural capital to the economy. It will also provide essential information for industries relying on the ocean.

The pilots we propose in this paper will shed light on data and research needs for the development of a consistent accounting system for marine natural capital. They will offer exploratory work to identify challenges and identify solutions to advance the implementation of the aforementioned U.S. National Strategy. Lessons learned in the pilots will be applicable to sectors of MESA that have similar uses and dependencies in regards to marine natural capital. Conceptually, the natural capital underlying each of these economic uses of the ocean is the same: the value that the natural environment contributes to creation of valuable goods and services through the application of labor and capital. But the nature of that capital is very different among the three, and this will necessitate further exploring how natural capital that supports one activity can be reduced or augmented by other activities, and how this interaction is reflected in the different accounts[31].

[28] See https://seea.un.org/content/2022-global-assessment-results.

[29] See https://www.abs.gov.au/articles/towards-national-ocean-account.

[30] See https://seea.un.org/sites/seea.un.org/files/lg28_d1_s2_2_randen.pdf.

[31] An example from the pilot activities is oil spills, which can be a byproduct of oil and gas extraction and can damage natural capital that supports recreation.

The data gleaned in the MESA extension will also be useful for the eventual development of accounts for specific ecosystems, which will provide another layer of information to marine-dependent industries. A reduction in the health of ocean ecosystems will affect key industries such as commercial fishing and tourism. A decline in the healthy cover of coastal ecosystems such as mangroves will make coastal communities more prone to damages from natural disasters. Decision makers at all levels will benefit from marine natural capital accounting data in helping to make a wide range of policy decisions.

Acknowledgements: We are grateful to Mary Bohman, Eli Fenichel, Nick Muller, Andrew Scheld, Arnab Acharya, Jeff Adkins, and Doug Lipton for insightful suggestions that helped improve earlier versions of the manuscript. Errors and omissions remain solely the responsibility of the authors. We thank Alissa Miller-Gonzalez for compiling the data in Table 3.

References

Addicott, E.T. (this volume). The Value and Configuration of Coastal Natural Capital.

BEA (Bureau of Economic Analysis). 2022. Concepts and Methods in the U.S. National Income Accounts (Chapters 1-13) (December). Also available from: https://www.bea.gov/resources/methodologies/nipa-handbook.

Colgan, Charles S. 2013. "The ocean economy of the United States: Measurement, distribution, & trends." *Journal of Ocean and Coastal Management* 7:334-343,

Colgan, Charles S. 2016. "Measurement of the ocean economy from national income accounts to the sustainable blue economy." *Journal of Ocean and Coastal Economics* 2.

De Valck, Jeremy, and John Rolfe. 2018. "Spatial heterogeneity in stated preference valuation: Status, challenges and road ahead." *International Review of Environmental and Resource Economics* 11(4): 355-422.

European Commission, International Monetary Fund, Organisation for Economic Co-operation and Development, United Nations and World Bank. 2009. System of National Accounts 2008. New York. United Nations Publication, Sales No. E.08.XVII.29. https://unstats.un.org/unsd/nationalaccount/docs/SNA2008.pdf.

Fenichel, Eli P., and Joshua K. Abbott. 2014. "Natural capital: from metaphor to measurement." Journal of the Association of Environmental and Resource Economists 1(1/2):1-27.

Fenichel, E.P., Joshua K. Abbott, Jude Bayham, Whitney Boone, Erin M. Haacker, and Lisa Pfeiffer. 2016. "Measuring the value of groundwater and other forms of natural capital." Proceedings of the National Academy of Sciences 113(9):2382-2387.

Fenichel, Eli P., Ethan T. Addicott, Kristine M. Grimsrud, Glenn-Marie Lange, Ina Porras, and Ben Milligan. 2020. "Modifying national accounts for sustainable ocean development." *Nature Sustainability* 3(11): 889-895. https://www.nature.com/articles/s41893-020-0592-8

Fleurbaey, Marc. 2009. "Beyond GDP: The quest for a measure of social welfare." *Journal of Economic literature* 47(4): 1029-1075.

Glenk, Klaus, Robert J. Johnston, Jürgen Meyerhoff, and Julian Sagebiel. 2020. "Spatial Dimensions of Stated Preference Valuation in Environmental and Resource Economics: Methods, Trends and Challenges." *Environ Resource Econ* 75:215–242. https://doi.org/10.1007/s10640-018-00311-w.

Holland, Daniel S., Eric Thunberg, Juan Agar, Scott Crosson, Chad Demarest, Stephen Kasperski, Larry Perruso, Erin Steiner, Jessica Stephen, Andy Strelcheck, and Mike Travis. 2015. "US Catch Share Markets: A Review of Data Availability and Impediments to Transparent Markets." Mar Pol 57:103-110. https://doi.org/10.1016/j.marpol.2015.03.027.

Hoagland, Porter, Di Jin, and Stace Beaulieu. 2020. "A primer on the economics of natural capital and its relevance to deep-sea exploitation and conservation." In *Natural Capital and Exploitation of the Deep Ocean*, pp. 25-52. Oxford University Press. https://doi.org/10.1093/oso/9780198841654.001.0001.

Jolliffe, James, Claire Jolly, and Barrie Stevens. 2021. "Blueprint for improved measurement of the international ocean economy: An exploration of satellite accounting for ocean economic activity. *OECD Science, Technology and Industry Working Papers 2021/*04. https://dx.doi.org/10.1787/aff5375b-en.

Jolliffe, James, Claire Jolly, and Barrie Stevens. 2021. "Key Considerations for the Development of Internationally Comparable Statistics on Ocean Economic Activity," *Journal of Ocean and Coastal Economics* 8(2), Article 6. https://doi.org/10.15351/2373-8456.1140.

Landry, Craig E., J. Scott Shonkwiler, and John C. Whitehead. 2020. "Economic Values of Coastal Erosion Management: Joint Estimation of Use and Existence Values with recreation demand and contingent valuation data." *Journal of Environmental Economics and Management* 103.

Lew, Daniel K., Leif E. Anderson, Douglas W. Lipton, Tammy B. Murphy, and Kristy Wallmo. 2022. "Adherence to Best Practices for Stated Preference Valuation within the U.S. Marine Ecosystem Services Literature." *Journal of Ocean and Coastal Economics* 9(1), Article 3. https://doi.org/10.15351/2373-8456.1159.

Nathan Associates, 1974. Gross Product Originating from Ocean-Related Activities. Washington DC, Bureau of Economic Analysis

Newell, Richard G., Kerry L. Papps, and James N. Sanchirico. 2005. "Asset Pricing in Created Markets for Fishing Quotas. Discussion Papers 10639. *Resources for the Future*, Washington, D.C.

Nicolls, William, Connor Franks, Teresa Gilmore, Rachel Goulder, Luke Mendelsohn, Edward Morgan, Jeffery Adkins, Monica Grasso, Kate Quigley, Jennifer Zhuang, and Charles Colgan. 2020. Defining and Measuring the U.S. Ocean Economy. Bureau of Economic Analysis, U.S. Department of Commerce. https://www.bea.gov/system/files/2021-06/defining-and-measuring-the-united-states-ocean-economy.pdf

NOAA (National Oceanic and Atmospheric Administration). 2022. "NOAA Report on the U.S. Marine Economy." NOAA Office for Coastal Management. Charleston, SC. http://coast.noaa.gov/digitalcoast/training/econreport.html

Nordhaus, William D. and James Tobin. 1973. "Is growth obsolete?" In *The measurement of economic and social performance*, NBER pp. 509-564.

Obst, Carl. 2010. Outcome Paper for Global Consultation Issue #12: Valuation of Assets: A Case Study on the Valuation of Fish Stocks. United Nations Statistics Division, Department of Economic and Social Affairs. https://unstats.un.org/unsd/envaccounting/seearev/OCdocs/Outcome12.pdf.

Pascoe, Sean. 2019. "Recreational beach use values with multiple activities." *Ecological Economics* 160: 137-144.

Randen, Trine H. B., Kristine Grimsrud, Tarik Ogbamichael, and Tor Kristian Ånestad. 2022. "Progress on ocean accounting in Norway." Paper for the 28th London Group meeting. Siegburg, Germany. https://seea.un.org/sites/seea.un.org/files/randen_1.pdf

Statistics Portugal. 2016. Satellite Account for the Sea - 2010-2013, Methodological Report. Department of National Accounts (December). https://www.ine.pt/ngt_server/attachfileu.jsp?look_parentBoui=300613867&att_display=n&att_download=y.

Stebbings, Emily, Eleni Papathanasopoulou, Tara Hooper, Melanie C. Austen, and Xiaoyu Yan. 2020. "The marine economy of the United Kingdom." *Marine Policy* 116. https://doi.org/10.1016/j.marpol.2020.103905

United Nations, European Union, Food and Agriculture Organization of the United Nations, International Monetary Fund, Organisation for Economic Co-operation and Development, and The World Bank. 2014. System of Environmental-Economic Accounting 2012— Central Framework. New York. United Nations Publication, Sales No. E.12.XVII.12. https://unstats.un.org/unsd/envaccounting/seearev/seea_cf_final_en.pdf

United Nations, European Union, Food and Agriculture Organization of the United Nations, International Monetary Fund, Organisation for Economic Co-operation and Development, and The World Bank. 2009. The System of National Accounts, 2008. New York. Available from: https://unstats.un.org/unsd/nationalaccount/docs/sna2008.pdf.

Wang, Yixuan and Nuo Wang. 2019. "The role of the marine industry in China's national economy: An input–output analysis." *Marine Policy* 99. https://doi.org/10.1016/j.marpol.2018.10.019.

Yun, Seong Do, Barbara Hutniczak, Joshua K. Abbott, and Eli P. Fenichel. 2017. "Ecosystem-based management and the wealth of ecosystems." *Proceedings of the National Academy of Sciences of the United States of America* 114: 6539-6544.