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Relating Mandates in the United States for Managing the Ocean to Ecosystem Goods and Services Demonstrates Broad but Varied Coverage

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HIGHLIGHTS

- A complete catalog is presented of the legislative, executive and international mandates related to NOAA, as well as the subset of these relevant to NOAA-Fisheries.
- The ecosystem goods and services addressed by each NOAA mandate were assessed, as well as the overlap between the major mandates.
- The collective coverage across the suite of ecosystem goods and services is shown in comparison to the portfolio of mandates; differences in these profiles indicate a continued need for ecosystem-based management.

There are numerous ecosystem goods and services (EGS) provided by the ocean. There are also multiple mandates to address this suite of EGS. What facets of the ocean EGS does this portfolio of mandates collectively address? How are these mandates interrelated? Are there gaps in their coverage of EGS? Are there areas of reinforcement? To elucidate this set of issues, we characterize the portfolio of mandates that a leading governmental ocean agency, the National Oceanographic and Atmospheric Administration (NOAA), and the subset of those that one of its Line Offices, the National Marine Fisheries Service (NOAA-Fisheries), is responsible for implementing. We link these mandates to a suite of EGS, evaluating the relative degree that each mandate addresses each EGS. The weighted overlap across mandates with respect to EGS was also estimated. Of the nearly 100 NOAA mandates, and the subset of 50 NOAA-Fisheries mandates, there was broad coverage of ocean EGS. Food production, habitat provision, genetic resources, recreation, tourism, historical and heritage value, and knowledge and science value were the EGS that had the highest degree of coverage. All EGS had at least some mandate coverage, although some had a limited number of mandates associated with them. There was some reinforcement across mandates, particularly for the top EGS, suggesting that the multiple facets of these EGS are being reasonably well addressed. The large number of mandates and the importance of EGS they address suggest that some form of coordination is warranted, particularly via adoption of an ecosystem-based approach to management.

Keywords: policy analysis, ecosystem-based management, decision analysis, portfolio approach, provisioning service, regulating service, supporting service, cultural service

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INTRODUCTION

The oceans provide numerous ecosystem goods and services (EGS; MEA, 2003, 2005; Halpern et al., 2008). The term "goods and services" has been used to identify those benefits people obtain from ecosystems, either directly or indirectly (MEA, 2003). These reflect the derived benefits for and from human activities that are based on the function, structure, resilience and production of the ocean. This suite of EGS includes provisioning (e.g., food, oil and gas production), supporting (habitat), regulating (carbon sequestration to reduce green-house gases), and cultural (recreation, aesthetic value) facets of what ocean ecosystems provide (MEA, 2003, 2005; Halpern et al., 2008). To maintain these EGS, some form of management of the ocean and its component features is required (Christensen et al., 1996; Leslie and McLeod, 2007; Link, 2010).

Managing natural resources in the ocean is an important trust. Countries have traditionally addressed management of ocean ecosystems on an issue-by-issue basis for particular EGS (Slocombe, 1993; Crowder et al., 2006; McLeod and Leslie, 2009). The result is a plethora of mandates that are independent of one another, and are usually implemented in similar fashion by distinct agencies that focus on specific goods and services. Considering agency resources are limited, the large number of objectives and authorities that any agency is responsible for implementing can be quite difficult to manage, and necessitates the prioritization of some objectives over others. Increasingly the fulfillment of these mandates, and specific objectives within each of them, requires an understanding of and trade-offs between multiple facets of EGS. There are myriad legislative actions, executive orders, conventions, treaties and related authorities, collectively termed mandates, which address various facets of management of the ocean and its EGS. There are nearly 100 (McFadden and Barnes, 2009; Link, 2010) such mandates in the U.S. However, there is very little analysis of the facets of the ocean EGS that these mandates may collectively address. That type of analysis is necessary to determine if there are gaps in their coverage of EGS, and how these mandates are interrelated.

This myopic approach to managing EGS through a suite of uncoordinated mandates has several disadvantages, which has led many countries to adopt a more holistic, ecosystem-based management approach (EBM) (Christensen et al., 1996; FAO, 2003; Pitcher et al., 2009). At its core, EBM is about recognizing that many EGS, and uses thereof, are competitive in nature (Link, 2010), to the point that progress toward one objective (e.g., food production) can often be at the expense of another (e.g., conserving habitat or genetic resources). The tradeoffs inherent in the implementation of EBM mandates should be elucidated in order to ensure that they align with current national priorities. Identification and characterization of these mandates is a critical first step as we continue the dialogue on authorities to better adopt EBM toward the end of wise, effective management of our ocean EGS.

To elucidate this issue, here we characterize the portfolio of mandates that the National Oceanographic and Atmospheric Administration (NOAA) and the subset of these mandates that one of its Line Offices, the National Marine Fisheries Service (NOAA-Fisheries), is responsible for implementing. As one of the leading agencies dealing with ocean resources, NOAA's mission is critical for identifying, forecasting, maintaining, conserving and protecting a diverse set of goods and services provided by the oceans of the United States. NOAA-Fisheries focuses on one sector of ocean uses but has a wide range of mandates as well. This Line Office is particularly exemplary in that, although it has a focused mission of managing living marine resources, the scope and breadth of those resources encapsulates a wide range of ocean processes, dynamics and functioning. Thus, the portfolio of mandates that NOAA and the subset that NOAA-Fisheries are required to implement should both be instructive and illustrative to examine in relation to a suite of EGS. To that end we address four objectives in this work: (1) to catalog and characterize all the ocean-oriented mandates that drive NOAA's mission; (2) expressly link these mandates to a suite of EGS that they inform; (3) evaluate the collective coverage of the suite of EGS by these mandates; and (4) explore the overlap among mandates for NOAA and NOAA-Fisheries according to the various EGS they address.

METHODS

Applicable Mandates and Estimation of Relative Effort

To characterize the mandates of NOAA, we first compiled a comprehensive list of mandates that apply to this organization (**Table 1**), and the subset relevant to NOAA-Fisheries. The initial list of mandates was provided by NOAA's Office of General Counsel which maintains a catalog of the mandates affecting NOAA. That list was compared to and augmented from the literature that explored more limited facets of the topic (McFadden and Barnes, 2009; Fluharty, 2014). It was further augmented from discussions with several NOAA personnel, where corrections, additions and removals were made (Link, pers. comm.). The final list of mandates was evaluated and characterized based on the relevant EGS they protect. For each of these mandates, the major tasks and requirements are synthesized.

The relative effort that the mandates require of NOAA or NOAA-Fisheries in order to comply with it was estimated with a score of 1–10. These scores were informed by examining several years of budget allocations within the agency, strategic plan documents, and discussions with some NOAA planning personnel. An effort score of 1 indicated that the mandate requires minimal effort, while an effort score of 10 indicated that a major emphasis of agency resources is needed to meet the requirements of the mandate. The scale was purposefully intended to be ordinal but imprecise; we acknowledge that the distinction between any set of contiguous scores (i.e., difference between a 2 and 3) is apt to be indistinguishable, but the distinction between scores at different parts of the scale should be (i.e., the difference between a 2 or 3 and 6 or 7, and certainly 9 or 10). For example, for NOAA the relative effort required to comply with the MSA was considered to be a 9. All of these scores were reviewed by NOAA experts (L. Letson, D. Lipton, R. Methot, R.

TABLE 1 | A listing of NOAA relevant mandates

Legislation	Mandated task(s)	Requirements
Magnuson-Stevens Fishery Conservation and Management Act (MSA)	National program for the conservation and management of the fishery resources of the United States: •To prevent overfishing •To rebuild overfished stocks •To insure conservation, and •To realize the full potential of the Nation's fishery resources	•Establish annual catch limits (ACL) •Establish accountability measures (AM) •Implement Fishery Management Plans (FMPs) •Any subsequent FMP amendments, and fishery regulations
Endangered Species Act (ESA)	Conserve, protect, and recover protected marine life	• List species •Consider species for listing •Issue protective regulations for threatened species •Develop and implement recovery plans for endangered and threatened species •Review/Issue take permits •5 year review of listed species
Marine Mammal Protection Act (MMPA)	Conserve, protect, and recover marine mammals	•Review/Approve take permits •Enforce laws •Review species •Conservation plans for depleted species •Prepare annual marine mammal stock assessment reports
*Migratory Bird Treaty Act	Protect migratory birds and their habitat during the time that the birds are within the United States	(Partnership agreement) • Identify where actions may harm bird populations • Conduct seabird bycatch analyses • Assess vulnerability of seabirds to shipping operations • Implement habitat restoration programs • Research species and share info with FWS
Federal Ocean Acidification Research and Monitoring Act (FOARAM Act)	Establishes Interagency Working Group on Ocean Acidification that will prepare a strategic plan for ocean acidification monitoring and research •Plan creates ocean acidification program (OAP)	OAP (NOAA) to •Develop implementation plan •Manage federal OA research •Establishing an OA information exchange •Produce\reports
Fish and Wildlife Coordination Act (FWCA)	Requires all federal agencies to consult with NOAA fisheries when action might result in modification of body of water	•Submit comments and recommendations to prevent harm •Collect data on effects of environmental decisions
Oil Pollution Act (OPA)	Directs natural resource trustees to: •Return injured natural resources and services to pre-event condition •Recover compensation for interim losses of such natural resources/services through the restoration, rehabilitation, replacement, or acquisition of equivalent natural resources or services	Promulgate regulations for assessing natural resource damages
*CERCLA	•Establishes liability for hazardous materials release •Authorizes federal cleanup	(Delegated by EO 13016) •Seek damages on behalf of public for resources injured by release of toxic materials •Respond to hazardous releases to protect natural resources not covered by other response actions
National Environmental Policy Act (NEPA)	Requires government agencies to consider environmental impacts when enacting policies	Requires production of: •Environmental Impact Statements (EIS) •Environmental Assessments (EA) OR •Memoranda for Categorical Exclusions for all agency actions covered by NEPA

(Continued)

TABLE 1 | Continued

Legislation	Mandated task(s)	Requirements
Estuary Restoration Act	•Promote coordinated federal approach to estuary restoration •Forge partnerships between public agencies and private sector •Provide financial and tech assistance •Develop research capabilities	•Develop monitoring protocols for estuary restoration projects •Create and maintain national database of restoration projects
Coral Reef Conservation Act	•Grants authority to implement national program for coral reef •Creates coral reef conservation fund;	•Draft and submit national coral reef action strategy •Submit follow-up reports every 2 years •Mapping, monitoring, assessment, research, and restoration that benefit coral reef ecosystems •Enhancing public awareness of such ecosystems •Assisting states to remove abandoned vessels and marine debris from reefs •Conducting cooperative management of coral reef ecosystems •Provide emergency grants for coral reef emergencies to state/local governments •Provide matching grants for coral reef conservation
National Invasive Species Act	Provide for ballast water management to prevent the introduction and spread of non-indigenous species into the waters of the United States, and for other purposes (reauthorization of NANPCA)	•Designates undersecretary of commerce/NOAA to be cochair of aquatic nuisance species task force •Assist states/other agencies in developing management plans
National Aquaculture Act of 1980	Provide for the development of aquaculture in the United States	Create a National Aquaculture Development Plan; assist other agencies/organizations with aquaculture research and development
National Sea Grant College Program Act	Extending and strengthening the national sea grant program (1966) to promote: •Research •Education •Training, and •Advisory service activities in fields related to ocean, coastal, and Great Lakes resources	Administer the National Sea Grant College Program •Yearly reporting
Lacey Act Amendments of 1981 (16 USC 3371-3378)	Makes it illegal to partake in the trade of fish, wildlife, or plants taken in violation of any US or Indian tribal law, treaty, or regulation as well as the trade of any of these items acquired through violations of foreign law	•Enforcement against foreign ships fishing in US waters •Enforcement against US ships fishing in foreign waters •Seafood fraud enforcement/inspections etc
*National Marine Sanctuaries Act (16 USC 1431-1439)	(Delegated by Secretary of Commerce) •Designate/Protect areas of the marine environment with special national significance due to their conservation/recreational/ecological/historical/scientific/cultural/archeological/educational/or esthetic qualities as national marine sanctuaries	•Issue regulations for sanctuarys/system •Prepare and update management plans •Assess civil penalties •Recommend alternatives to federal programs required to consult by the Act
Resources and Ecosystems Sustainability, Tourism Opportunities and Revived Economy of the Gulf Coast Act of 2011 (RESTORE Act)	•Develop comprehensive plan to improve the economies and ecosystems of the Gulf •Establish the Gulf Coast Ecosystem Restoration Science, Observation, Monitoring and Technology Program	•Give grants to centers of excellence •Develop plans for coodinating Program with other research centers in the Gulf
Billfish Conservation Act (October 9, 2012)	Prohibits any person from offering billfish or billfish products for sale, selling them, or having custody, control, or possession of them for purposes of offering them for sale	Enforcement under Magnuson-Stevens

(Continued)

TABLE 1 | Continued

Legislation	Mandated task(s)	Requirements
Atlantic Striped Bass Conservation Act	Support/Encourage the development, implementation, and enforcement of effective interstate action regarding the conservation and management of the Atlantic striped bass	During December of each fiscal year (or any time necessary) the Atlantic States Marine Fisheries Commission shall determine: •Weather each coastal State has adopted all regulatory measures necesarry to implement this plan •Whether enforcement of this plan, by each coastal State, is satisfactory Enforcement shall not be considered satisfactory if the implementation of the plan is substantially and adversely affected The commission shall immediately notify the Secretaries of each negative determination of adoption/enforcement
The Atlantic Coastal Fisheries Cooperative Management Act	Support/Encourage the development, implementation, and enforcement of effective interstate action regarding the conservation and management of Atlantic coastal fishery resources	Secretary of Commerce and the interior shall develop and implement a program which shall include activities to support and enhance: •State cooperation in collection, management, and anaysis of fishery data •Law enforcement •Habitat conservation •Fishery research including biological and socioeconomic research •Fishery management planning
High Seas Driftnet Fishing Moratorium Protection Act	Prohibits the US from entering into international agreements on the conservation and management of living marine resources or the use of the high seas by fishing vessels that would prevent the full implementation of the global moratorium on large-scale driftnet fishing on the high seas; enforcement against US fisheries	•Produce a biennial Report to Congress that lists nations the United States has identified for IUU fishing and/or bycatch of protected species and shark catches on the high seas for nations that do not have regulatory measures comparable to the United States •2-year consultation process to encourage that nation to take necessary measures to address the issue for which it was identified •Following consultations, NOAA Fisheries determines whether to negatively or positively certify the identified nation in the next Report to Congress ○A positive certification is issued if the nation has provided evidence of actions that address the activities for which it was identified ○A negative certification may result in denial of U.S. port access for fishing vessels of that nation, and potential import restrictions on fish or fish products
America Competes Act of 2007	Directs the Administrator to conduct, develop, support, promote and coordinate formal and informal educational activities at all levels to enhance public awareness and stewardship	•Develop a science education plan setting forth education goals and strategies •Programmatic actions to carry out goals and priorities over next 20 years •Evaluate and update plan every 5 years NOAA shall be a full participant in nay interagency effor to promote innovation and economic competitiveness through scientific R&D, science, etc.
Integrated Coastal and Ocean Observation System Act of 2009	Establishes NOAA as the lead Federal agency for the implementation of a national integrated system of ocean, coastal, and Great Lakes observing systems "to support… weather, climate and marine forecasting… improve the Nation's capability to measure, track, explain, and predict events related directly and indirectly to weather and climate change, natural forecasting… climate variability, and interactions between the oceanic and atmospheric environments… "	The System shall be national scope and consist of: •Federal asses to fulfill national/international observation missions •Non-Federal asses, including network of regional information entities •Data management, communication, and modeling systems for integration and dissemination of data and information products •Research and development program with basic/applied research and development as well as large scale computing research to advance modeling
Secure Water Act of 2009	NOAA shall provide the Secretary of the Interior with "access to the best available scientific information with respect to presently observed and projected future impacts of global climate change on water resources"	N/A

(Continued)

TABLE 1 | Continued

Legislation	Mandated task(s)	Requirements
National Integrated Drought Information System Act of 2006	Establish a National Integrated Drought Information System (NIDIS)	Provide an effective drought early warning system that: •Collects and integrates information on indicators of drought to make effective forecasts and assessments •Communicates drought forecasts/conditions/impacts to government, private sector and public •Timely data, info and products that reflect local/regional/State differences in conditions Consult with all levels of government, research institutions and private sector in the development of NIDIS
Inland Flood Forecasting and Warning System Act of 2002	Authorizes NOAA, through the United States Weather Research Program, to conduct: •Research and development •Training, and •Outreach activities relating to improve the capability to accurately forecast inland flooding, including flooding caused by coastal and ocean storms	•Improve the capability to accurately forecast inland flooding through research modeling •Develop/Test/Deploy a new flood warning index to give public and emergency officials better information •Train emergency management, National Weather Service, meteorologists and others in terms of new index and techniques •Outreach and education activities for meteorologists and public regarding dangers/risks •Assess: long-term trends in inland flood severity/frequency and how shifts in climate make regions more vulnerable
Data Quality Act of 2001	Requires that the U.S. government assure the quality of the information disseminated	•Issue data quality guidelines ensuring quality, objectivity, utility and integrity of information •Establish administrative mechanisms for correction of information that does not comply with guidelines •Periodically report to OMB about data quality complaints and how they are handles
Oceans Act of 2000	Led to the Congressionally-mandated report of the U.S. Commission on Ocean Policy and the Executive response	N/A
Consolidated Appropriations Act of 2005	Establishes a Federal research program that examines ocean resources and their applications to human health	N/A
Hydrographic Services Improvement Act of 1998	Promote safe, efficient and environmentally sound marine transportation	•Acquire/disseminate hydrographic data •Promulgate standards for hydrographic data •Promulgate standards for hydrographic services •Ensure comprehensive geographic coverage of hydrographic services •Maintain national database of hydrographic data •Provide hydrographic services in uniform format •Participate in development/implementation of international standards for hydrographic data/services
Coast and Geodetic Survey Act of 1947	Provides the basis for NOS navigation service programs	
Ocean and Coastal Mapping Integration Act	Establish an integrated Federal ocean and coastal mapping plan for the Great Lakes and coastal state waters, the territorial esa, the exclusive economic zone and the Continental Shelf of the US	•Identify all Federal and federally funded programs conducting shoreline delineation and ocean or coastal mapping •Facilitate cost-effective, cooperative mapping efforts that incorporate policies for contracting with private entities •Facilitate the adaption of existing tech as well as foster expertise in new mapping tech •Develop standards and protocols for testing innovative mapping tech •Provide archiving, management, and distribution of data sets

(Continued)

TABLE 1 | Continued

Legislation	Mandated task(s)	Requirements
		•Develop data standards and protocols consistent with Federal Geographic Data Committee •Identify the procedures for coordinating collection of Federal ocean/coastal mapping data •Facilitate collection of real-time tide data and development of hydrodynamic models •Establish plan for acquisition/collection of ocean/coastal mapping data •Set forth timetable for completion/implementation of above
Clean Air Act 1990	•Administrator of NOAA must serve on the Acid Precipitation Task Force responsible for, reviewing current research and identifying gaps, Maintaining monitoring and upgrade models, publication and maintenance of a National Acid Lakes Registry, Submission of unified budget •Participate in conference on air quality monitoring •Submit a report to congress every 3 years on current average tropospheric concentration of chlorine/bromine, level of stratospheric ozone depletion	•Requires that NOAA identify and assess the extent of deposition of atmospheric pollutants to the Great Lakes and coastal waters •Conduct research, in conjunction with other agencies, to improve understanding of the short-term and long-term causes, effects, and trends of damage from air pollutants on ecosystems
Global Climate Change Protection Act of 1990	Provide development and coordination of comprehensive and integrated US research program to assist the nation to understand, assess, oredict and respond to human-induced and natural processes of global change	A Department of Agriculture mandate, which coordinates with other agencies via the Science & Technology Office of the White House
Global Change Research Act of 1990	Ensures the establishment of global measurements and worldwide observations, and requires an early and continuing commitment to the establishment and maintenance of worldwide observations and related data and information systems	Requires research in climate change needed to protect the environment •Must provide representative for committee
National Climate Program Act of 1978	•Authorizes global data collection, monitoring, and analysis activities to provide reliable, useful and readily available information on a continuing basis •Authorizes measures for increasing international cooperation in climate research, monitoring, analysis, and data dissemination	
Coastal Zone Management Act (CZMA) of 1972 (as amended)	Encourage states to preserve, protect, develop and, where possible, restore and enhance valuable natural coastal resources	Programs should at least provide for: •protection of natural resources •management of coastal development to minimize loss of life and property caused by improper development in flood-prone or other hazardous areas •to extent possible, give priority consideration for coastal-dependent uses related to national defense, energy, fisheries development, recreation, ports and transportation, •assistance in development of deteriorating urban waterfronts and ports •coordination/simplification of procedures to expedite govt decision making •inform public about opportunities for public/local government participation in coastal management decision-making •assistance for comprehensive planning •study/development of plans for addressing adverse effects of coastal sea level rise
Federal Records Act of 1950 (as amended)	Responsible for the establishment of the National Weather Records Center which archives and services U.S. weather and climate records, among others	

(Continued)

TABLE 1 | Continued

Legislation	Mandated task(s)	Requirements
National Weather Service Organic Act of 1890 (as amended)	Provides the statutory authority to •Forecast the weather •Issue storm warnings •Provide flood forecast services •Collect and transmit intelligence for the benefit of commerce	
U.S. Weather Research Program (USWRP) Authorization Act	Mandated to accelerate forecast improvements of high impact weather and facilitate full use of advanced weather information	•Provide attention/resources where progress can be made quickly and impact is the greatest •Submit report within to congress and senate including 5 year plan, justifications of plan changes, detailed assessment of the extent to which objectives have been achieved
Harmful Algal Bloom and Hypoxia Research and Control Act	Authorizes funding for research on Harmful Algal Blooms and hypoxia to advance scientific understanding and our ability to detect, assess, predict, control, and mitigate events	Five Interagency Reports: •Assessment of efforts to predict/respond to harmful algal blooms •Assessment of marine harmful algal blooms •Assessment of freshwater algal blooms •Management/Response to harmful algal bloom •Assessment of hypoxia in US coastal waters
Tsunami Warning and Education Act	•Establishes a comprehensive program to operate and maintain a Tsunami Forecasting and Warning Program, Tsunami Warning Centers, Tsunami Research Program, and National Tsunami Hazard Mitigation Program •Provides authority to operate a Tsunami Forecasting and Warning Program which is charged with providing tsunami detection, forecasting and adequate warnings	
Clean Water Act	Governs water quality with the goal is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters	Regulates both the direct and indirect discharge of pollutants into the Nation's waters •Prohibits the discharge into navigable waters of any pollutant by any person from a point source
Ocean Exploration Authority	•Establish a comprehensive and coordinated National Ocean Exploration Program •Establish Undersea Research Technology and Infrastructure Task Force •Establish Ocean Exploration Advisory Board	•Conduct interdisciplinary voyages to explore and survey little known areas of marine environment •Giving priority attention to deep ocean regions •Conducting scientific voyages to locate, define and document historic shipwrecks and submerged sites •Enhancing the technical capability of the U.S. marine science community •Establishing an ocean exploration forum to encourage partnerships •Promote communication among experts to enhance the scientific and technical expertise and relevance of the National Ocean Exploration Program
NOAA Undersea Research Program Act of 2009	Authorizes a comprehensive NOAA Undersea Research Program	Conduct voyages or other scientific activities in conjunction with other Federal agencies or academic partners to explore/survey little known areas of marine environment, emphasis on deep sea
Oceans and Human Health Act	Calls for the coordination of a national research plan by the National Science and Technology Council to study the relationship between human health and the oceans	•Establish, for 10-year period following submission, the goals and priorities for Federal research which most effectively advances scientific understanding of the connection between the oceans and human health •Describe specific activities required to achieve goals/priorities, including funding of research grants, ocean/coastal observations, training/support for scientists

(Continued)

TABLE 1 | Continued

Legislation	Mandated task(s)	Requirements
National Coastal Monitoring Act	Requires the Administrator of the Environmental Protection Agency (EPA) and the NOAA Under Secretary, in conjunction with other Federal, state and local authorities, to develop and implement a program for the long-term collection, assimilation, and analysis of scientific data designed to measure the environmental quality of the nation's coastal ecosystems	Requires the Administrator and the Under Secretary jointly to submit to Congress a report, every other year, on the condition of the nation's coastal ecosystems
High Performance Computing and Communication Act of 1991	NOAA shall conduct basic and applied research in weather prediction and ocean sciences, particularly in: •Development of new forecast models •Computational fluid dynamics, and •Incorporation of evolving computer architectures and networks into the systems that carry out agency missions	
National Ocean Pollution and Planning Act 1978	•Establish a comprehensive 5 year plan for Federal ocean pollution research and development and monitoring programs (The Plan) •Develop the necessary base of information to support, and to provide for, the rational efficient, and equitable utilization, conservation, and development of ocean and coastal resources	The Plan shall contain: •Assessment and ordering of National needs and problems including areas of ocean pollution •Detailed listing of all existing Federal programs relating to ocean pollution research and development and monitoring •Policy recommendations from analysis of existing Federal program effectiveness, given current budget •Review budget review process for the purpose of ensuring interagency coordination/cooperation and eliminate duplicate efforts
Port and Tanker Safety Act 1978	Mandates the Coast Guard to protect life, property and marine environment when dealing with vessels, increase supervision of vessels	Act in consultation with the Coast Guard to determine the desirability and feasibility of possible shore-station systems for monitoring vessels Act in consultation with the Coast Guard to determine current uses of areas deemed necesarry for port access route designation and weigh uses/protection vs. access route
Ocean Dumping Act	•Regulate intentional ocean disposal of materials •Research ocean disposal of materials	A common name given to article I of the Marine Protection, Research, and Sanctuaries Act of 1972 (PL 92-532) NOAA is responsible for long-range research on the effects of human-induced changes to the marine environment
Regional Marine Research Program 16 USC 1447B	Set priorities for regional marine and coastal research in support of efforts to safe-guard the water quality and ecosystem health of each region and carry out said research	•Marine Research board established for 9 regions, NOAA will appoint 3 members for each •Administer a grant program to support the administrative functions of each Board •Evaluate research grant applications from each Board (yearly)
Aquatic Nuisance Species Program 16 USC 4722	Development of an Aquatic Nuisance Task Force, which provides funds to the Department of Interior and Department of Commerce	Funds aquatic nuisance species prevention and control research under section 4722 (i) of this title at the NOAA's Great Lakes Environmental Research Laboratory
Navigation and Navigable Water-Water Resource Development-Great Lakes Water Quality Agreement of 1978 amended 1987 33 USC 2326B	Charges the Secretary of the Army to manage sediment from dredging projects Consultation with interested Federal agencies is encouraged	N/A
Coastal Ocean Program (§ 201(c); PL 102-567)	Created by the "National Oceanic and Atmospheric Administration Oceanography Amendment Act of 2003"	Provides direct financial assistance through grants and cooperative agreements for research supporting the management of coastal ecosystems
Coastal Wetlands Planning, Protection, and Restoration Act	The Secretary of Commerce shall serve on the Louisiana Coastal Wetlands Conservation and Restoration Task Force (The Task Force)	The Task Force shall: •Prepare a list of coastal wetlands restoration projects in Louisiana, in order of priority •List must be produced and transmitted to congress annually

(Continued)

TABLE 1 | Continued

Legislation	Mandated task(s)	Requirements
Establishment of Papahânaumokuâkea Marine National Monument (71 FR 36443/10031; PP 8031/8112)	Establishes ~140,000 sq mi of emergent and submerged lands and waters of the Northwestern Hawaiin Islands as Federal property, to be maintained and protected by NOAA	•Coordinate with Fish and Wildlife Service (FWS) in areas of overlapping protection •Review current plans and modify as appropriate •Establish list of approved vessels that can move through the monument •Protect the monument from natural resource extraction, introduction of species, anchoring or deserting a vessel and discharging any waste
Government Performance & Results Act	Must submit yearly plans: •Strategic Plan •Performance Plan	N/A
Marine Debris Research Prevention and Reduction Act	Establishes the Marine Debris Prevention and Removal Program	•Marine debris mapping, identification, impact assessment, prevention, and removal efforts •Improve efforts to reduce adverse impacts of lost and discarded fishing gear on living marine resources and navigation safety •Outreach and education of the public and other stakeholders (e.g. fishing industry, fishing gear manufacturers, and plastic/waste management industries)
Marine Protection, Research, and Sanctuaries Act (16 U.S.C. § 1431; PL 106-513)	•Identify and designate as national marine sanctuaries areas of the marine environment which are of special national significance •Provide authority for comprehensive and coordinated conservation and management of these marine areas •Maintain natural biological communities in the national marine sanctuaries •Enhance public awareness, understanding, appreciation, and wise/sustainable use of the marine environment •Support, promote, and coordinate scientific research on, and long-term monitoring of, the resources of these marine areas •Facilitate public/private uses of the resources of these marine areas •Develop/Implement coordinated plans for the protection and management of these areas •Create models of, and incentives for, ways to conserve and manage these areas •Cooperate with global programs encouraging conservation of marine resources	
NOAA Chesapeake Bay Watershed Monitoring, Education, Training, and Restoration Act - amendments to Section 307 of the National Oceanic and Atmospheric Administration Authorization Act of 1992 (15 U.S.C. 1511d)	Enhance the protection of the Chesapeake Bay	•Establish Chesapeake Bay Integrated Observing System •Establish Chesapeake Bay watershed education and training program •Establish Chesapeake Bay watershed stock enhancement and habitat restoration program •Submit biennial report to Congress/Secretary of Commerce with respect to progress of Chesapeake Bay
Ocean Exploration Act *PL111-11	Establishes the national ocean exploration program and the national undersea research program	•Conduct interdisciplinary voyages or other scientific activities •Give priority attention to deep ocean regions, with focus on deep water marine systems •Conduct scientific voyages to locate, define, and document historic shipwrecks •Develop/Implement a transparent, competitive process for merit-based peer-review and approval of proposals for activities under the program •Enhance the technical capability of the U.S. marine science community •Establish ocean exploration forum to encourage partnerships and promote communication

(Continued)

TABLE 1 | Continued

Legislation	Mandated task(s)	Requirements
Water Pollution Prevention and Control Act (33 U.S.C. § 1268)	•Provide support for programs for the prevention, reduction, and elimination of pollution •Establishes the Great Lakes Research Office •Consult on comprehensive national survey and assessment of data regarding aquatic sediment quality in the U.S. •Consult with other agencies on The National Contingency Plan, providing efficient, coordinated, and effective action to minimize damage from oil and hazardous substance discharges •Conduct research for one or more estuarine zones -determine baseline state, trend assessment monitoring, water quality sampling, and nutrient, sediment and pullant movements	
Water Resources Development Act of 2000	For projects involving dredged channels, the Army Corps of Engineers provides hydrographic survey data to NOAA who provide final charts at no cost	N/A
MAJOR INTERNATIONAL AGREEMENTS AND PROGRAMS		
The 1995 United Nations Straddling and Highly Migratory Fish Stocks Agreement	•Detailed minimum international standards for the conservation and management of straddling fish stocks and highly migratory fish stocks •Ensuring that measures taken for the conservation and management of those stocks in areas under national jurisdiction and in the adjacent high seas are compatible and coherent •Ensuring that there are effective mechanisms for compliance and enforcement of those measures on the high seas •Recognizing the special requirements of developing States in relation to conservation and management as well as the development and participation in fisheries for the two types of stocks mentioned above	Compliance with minimum international requirements for fisheries management (e.g. data collection, use of precautionary principle)
Convention on International Trade in Endangered Species of Wild Fauna and Flora	Trade regulation (import/export permits) or listed species	Scientific and research support for select marine species to FWS
International Whaling Commission	Serve as lead agency for U.S. in committee	•Review the condition of whale stocks •Modify conservation measures
International Convention for the Conservation of Atlantic Tunas	Providing internationally coordinated research on the condition of Atlantic tuna and tuna-like species, and their environment, as well as for the development of regulatory recommendations	Serving on Commission
Convention on Future Multilateral Cooperation in the Northwest Atlantic Fisheries	•Provide for continued multilateral consultation and cooperation with respect to the study, appraisal, and exchange of scientific information and views relating to fisheries of the Convention Area •Conserve and manage fishery resources of the NAFO Regulatory Area (NRA), i.e., that part of the Convention Area that lies beyond the areas in fishery resources of the NAFO Regulatory Area (NRA), i.e., that part of the Convention Area that lies beyond the areas in which coastal states exercise fisheries jurisdiction The Convention Area is located within the waters of the Northwest Atlantic Ocean roughly north of 35° north latitude and west of 42° west latitude	Member of New England Fisheries Management council must: •Serve on Commission •Issue Permits

(Continued)

TABLE 1 | Continued

Legislation	Mandated task(s)	Requirements
Convention for the Establishment of an Inter-American Tropical Tuna Commission	•Study the biology of the tunas and related species of the EPO with a view to determining the effects that fishing and natural factors have on their abundance •Recommend appropriate conservation measures so that the stocks of fish can be maintained at levels which will afford maximum sustainable catches	NOAA member must serve on Commission
Western and Central Pacific Fisheries Convention	Ensure the long-term conservation and sustainable use of highly migratory fish stocks in the western and central Pacific Ocean in accordance with •The 1982 United Nations Convention on the Law of the Sea •The 1995 UN Fish Stocks Agreement	•NOAA representation on Commission •Develop conservation and management measures (CMM) •Monitor and control
Convention for the Conservation of Antarctic Marine Living Resources	Protecting and conserving the marine living resources in the waters surrounding Antarctica	•Provide advice to US commissioner as a member of delegation •Submitting licensed vessel information to ensure compliance •Collecting electronic catch documentation •Issuing import permits, •Making regulations for IUUs
Inter-American Convention for the Protection and Conservation of Sea Turtles	Prohibition of deliberate take of sea turtles or their eggs •Compliance with the Convention on International Trade in Endangered Species (Convention on International Trade in Endangered Species of Wild Fauna and Flora) •Implementation of appropriate fishing practices and gear technology to reduce incidental take (bycatch) of turtles in all relevant fisheries •Use of Turtle Excluder Devices (TEDs) on shrimp trawl vessels •Designation of protected areas for critical turtle habitat •Restriction of human activities that could harm turtles •Promotion of sea turtle research and education	•Reviews and analyzes information relating to the protection and conservation of populations of sea turtles and their habitats •Examines reports concerning the environmental, socio-economic and cultural impact on affected communities resulting from the measures set forth or adopted pursuant to the Convention •Evaluates the efficiency of the different measures proposed to reduce the capture and incidental mortality of sea turtles as part of Consultative Committee •Scientific support on science Committee
International Plan of Action for the Reducing the Incidental Catch of Seabirds in Longline Fisheries (IPOA-Seabirds)	Create and implement National Plan of Action	•Fishery assessments •Data collection •Prescription of measures, research and development of mitigation measures •Outreach and education •Reporting •Activities at bilateral fishery meetings, RFMOs, collaborative projects, and sharing and exchange of information via reports, meetings, conferences, or other forums
Convention for a North Pacific Marine Science Organization	•Promote and coordinate marine research undertaken by the Parties in the Convention Area •Advance scientific knowledge about the ocean environment, global weather and climate change, living resources and their ecosystems, and the impacts of human activities •Promote the collection and rapid exchange of scientific information on these issues •Creates PICES	Scientific research and advice as part of PICES
Convention for the International Council for the Exploration of the Sea	•Promote and encourage research and investigation for the study of the sea particularly related to the living resources thereof •Draw up programs required for this purpose •Organize, in agreement with the Contracting Parties, such research and investigations as may appear necessary	

(Continued)

TABLE 1 | Continued

Legislation	Mandated task(s)	Requirements
	•Publish or otherwise disseminate the results of research and investigations carried out under its auspices or to encourage the publication thereof	•Scientific research and advice as part of ICES •Recommend representatives
Pacific Salmon Treaty	•Creates Pacific Salmon Commission to coordinate between US and Canada to prevent overfishing and provide for optimum production •Provide for each Party to receive benefits equivalent to the production of salmon originating in its waters	•Provide information to PSC on fishing activities •Review PSC recommendations for implementation in the US
International Scientific Commission (ISC) for tuna and tuna-like species in the North Pacific Ocean	•Enhance scientific research and cooperation for conservation and rational utilization of the species of tuna and tuna-like fisheries which inhabit the North Pacific Ocean •Establish the scientific groundwork for the conservation and rational utilization of these species in the region	•Supplying fisheries data •Scientific support
International Pacific Halibut Commission	Conserve, manage, and rebuild the halibut stocks in the Convention Area to those levels that would achieve and maintain the maximum sustainable yield from the fishery	•NOAA official must serve on commission •Publishing of regulations of catch limits
UN Food and Agriculture Organization Code of Conduct	•Promote research on fisheries as well as on associated ecosystems and relevant environmental factors •(Article 2.i) Promote protection of living aquatic resources and their environments and coastal areas •Promote the contribution of fisheries to food security and food quality, giving priority to the nutritional needs of local communities	(Voluntary) produce and implement an implementation plan based on principles in the code
U. N. Framework Convention on Climate Change (UNFCCC):	Stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system	Climate data collected by NOAA is summarized in the U.S. Department of State's Action Report to the UNFCCC
Montreal Protocol on Substances that Deplete the Ozone Layer	Monitor and protect the ozone layer in partner with other nations included in the Protocol	Requires an assessment every 4 years of the state of the ozone layer •Its recovery •The amounts and origins of ozone depleting substances that drive the ozone layer changes
Great Lakes Water Quality Agreement of 1978	International agreement between Canada and the United States which involves restoring and maintaining the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem	The waters should be: •Free from substances that directly/indirectly enter the water as a result of human activity that will adversely affect aquatic life •Free from floating materials (e.g. debris, oil, scum) •Free from materials and heat directly/indirectly entering the water as a result of human activity that will produce - color, odor, taste or other conditions to interfrewith beneficial uses •Free from materials and heat directly/indirectly entering the water as a result of human activity that will produce toxic/harmful conditions to life •Free from nutrients directly/indirectly entering waters as a result of human activity in amounts that create growths of aquatic life that interfere with beneficial uses

(Continued)

TABLE 1 | Continued

Legislation	Mandated task(s)	Requirements
EXECUTIVE ORDERS		
The National Ocean Policy for the Stewardship of the Ocean, Our Coasts, and the Great Lakes Executive Order 13547	•Establishes a national policy to ensure the protection, maintenance, and restoration of the health of ocean, coastal, and Great Lakes ecosystems and resources	
	•Enhance the sustainability of ocean and coastal economies, preserve our maritime heritage, support sustainable uses and access, provide for adaptive management to enhance our understanding of and capacity to respond to climate change and ocean acidification •Coordinate with our national security and foreign policy interests	•NOAA administrator must serve on National Ocean Commission •Development of coastal and marine spatial plans
Gulf of Mexico Long Term Restoration Executive Order 13554	Creates Gulf Coast Restoration Task Force	Identify linkages and opportunities for the Task Force to complement the restoration progress of the Natural Resource Damage Assessment Trustee Council
Chesapeake Bay Restoration Executive Order 13508	•Established the Federal Leadership Committee for the Chesapeake Bay •Charged the Federal Leadership Committee with developing and implementing a new strategy for protection and restoration of the Chesapeake Bay region	•Remore monitoring and scientific support •Representation on Committee •Ecosystem restoration
Coral Reef Conservation Executive Order 13089	•Creates Coral Reef Task Force •Directs all federal agencies to protect coral reef ecosystems to the extent feasible •Instructs particular agencies to develop coordinated, science-based plans to restore damaged reefs as well as mitigate current and future impacts on reefs, both in the United States and around the globe	•Implement coral reef monitoring and mapping program •NOAA administrator to chair task force
National Invasive Species Executive Order 13112	Calls on all federal agencies to: •Identify those actions that may affect the status of invasive species •Take positive steps within their authorities to prevent the introduction of invasive species •Provide for the control of invasive species •Minimize the economic, ecological, and human health impacts that invasive species cause	•Research invasive species •Conduct ecosystem restorations •Not conduct activities that may introduce invaseive species
Marine Protected Area Executive Order 13158	Strengthen the management, protection and conservation of existing marine protected areas and establish new or expanded MPAs •Develop a scientifically based, comprehensive national system of MPAs representing diverse U.S. marine ecosystems, and the Nation's natural and cultural resources •Avoid causing harm to MPAs through federally conducted, approved, or funded activities	•Develop a national system of MPA •Prepare annual report
Great Lakes Regional Collaboration Executive Order 13340	Creates Great Lakes Interagency Task Force	•Representation on task force •Provide funding •Leverage other federal funding for ecosystem restoration
Responsibilities of Federal Agencies to Protect Migratory Birds Executive Order 13186	Further implement the migratory bird treaty act	Create a Memorandum of Understanding with FWS to promote conservation of migratory birds

(Continued)

TABLE 1 | Continued

Legislation	Mandated task(s)	Requirements
Federal Leadership in Environmental, Energy and Economic Performance—Executive Order 13514	•Establish an integrated strategy toward sustainability in the Federal Government •Make reduction of greenhouse gas emissions (GHG) a priority for Federal agencies	•Meet a number of numeric and qualitative environmental improvement requirements (e.g., reduce water, petroleum use, increase renewables use, make contracts that require use of environmentally friendly materials) •Submit sustainability performance plan •Set agency percentage reduction •Submit GHG inventory
National Arctic Policy (National Security Presidential Directive (NSPD 66)/Homeland Security Presidential Directive (HSPD 25)	•Promote international scientific cooperation •Research into sustainable development of resources in the Artic Region •Monitor and research for environmental protection and conservation of natural resources in the Artic Region	
Executive Order 12234 (Enforcement of the Convention for the Safety of Life at Sea)	Sets forth U.S. marine weather responsibilities in the areas of commerce, transportation, and homeland security	Perform functions prescribed in the International Convention for the Safety of Life at Sea (1974)

TABLE 2 | A listing of ocean ecosystem goods and services (EGS) by type.

PROVISIONING SERVICES	
	Food
	Genetic resources
	Mineral resources
	Energy resources
	Bio-derivative products
SUPPORTING SERVICES	
	Habitat provision
	Primary production
	Nutrient cycling
	Water cycling
REGULATING SERVICES	
	Climate regulation
	Carbon sequestration
	Filtration/detoxification
	Nutrient regulation
	Water supply/hydrology
	Shoreline stabilization/protection
	Waste disposal
CULTURAL SERVICES	
	Tourism and ecotourism
	Recreation
	Historical and heritage value
	Religious and spiritual value
	Aesthetic value
	Knowledge and science value

Shuford, F. Schwing, M. Brady, M. Effron, all pers. comm.) and modified following those discussions.

Linking the NOAA Portfolio of Mandates to Ecosystem Goods and Services

A list of EGS was created based on the Millennial Ecosystem Assessment (MEA) (MEA, 2003, 2005). Many other EGS classification schemes exist (de Groot et al., 2002; Costanza, 2008), and several have been adopted for an ocean ecosystem context (e.g., NRC, 2004; Halpern et al., 2008, 2012; Scarlett and Boyd, 2011; Reed et al., 2013; O'Higgins and Gilbert, 2014). The main categories were modified to align them with the missions of NOAA and NOAA-Fisheries, resulting in the final list of ocean-oriented EGS grouped into four major types of services-provisioning, supporting, regulating, or cultural (**Table 2**).

To explore the "coverage" of the suite of EGS by NOAA and NOAA-Fisheries mandates, we evaluated the relative degree that each mandate addressed each EGS. The term "coverage" implies the extent to which a mandate or mandates addresses a particular EGS or set of EGS. Certainly a mandate could address certain specific, focal features of a given EGS, but as long as it was topically relevant it would be considered as addressing it. The degree to which the tasks and requirements of the mandate specifically direct the agency to monitor, measure, forecast, maintain, conserve, protect, manage or otherwise afford governance attention to a particular EGS were estimated. The

EGS addressed by each mandate were assigned using a modified Delphi method (Okoli and Pawlowski, 2004). Consultation with NOAA personnel (noted above) with expertise in policy, legislation and regulation, science, and resource management relevant to EGS and EBM was used to review and codify the initial assignments. The degree to which a mandate addressed an EGS was recorded as:

- *Non-applicable (0):* The mandate does not address the EGS.
- *Minimal (1):* Complying with the mandate may address a limited facet of the EGS.
- *Low (2):* Complying with the mandate is likely to addresses some features of the EGS.
- *Moderate (3):* Complying with the mandate addresses the EGS.
- *High (4):* Complying with the mandate significantly addresses the EGS.

As an example, the Magnuson-Stevens Fishery Conservation and Management Act (MSA) was identified as covering 7 of the EGSs. In linking the MSA to those 7 EGS for NOAA, the mandate was considered to have a high degree of coverage (4) for food provisioning, moderate coverage (3) for genetic resources, habitat provisioning, tourism and ecotourism, and recreation, low coverage (2) for bio-derivative products and minimal coverage (1) for knowledge and science value.

Evaluating the Coverage of the Suite of EGS by the NOAA Portfolio of Mandates

A 10-point weighting method was also used to estimate the priority of a particular EGS relative to NOAA's or NOAA-Fisheries' missions. These were informed by examining several years of strategic plan documents and discussions with some NOAA planning personnel. All weights were reviewed by NOAA experts (noted above) and modified after those discussions. These weights were used in comparison with the degree that mandates collectively address the EGS to visualize mandate coverage of the suite of EGS. The total number of mandates addressing each EGS was noted and normalized. The total degree of mandate coverage (sum of mandates times the degree to which each is addressed) was also noted and normalized. Both the simple count of relevant mandates and the scaled mandate coverage were displayed as a percentage of the total, plotted against a line showing the normalized EGS weight which represents the relative priority of each EGS to the agency.

Overlap Across Mandates with Respect to EGS

Each mandate was evaluated separately in terms of how it contributes to an understanding of the suite of EGS. However, it is clear that fulfillment of one mandate may support EGS as needed for another mandate. Therefore, the overlap across mandates was calculated for the 10 most prominent NOAA mandates in relations to all other mandates; the most prominent mandates were those with the highest estimated effort that addressed the most EGS. The same overlap calculation was done with the 5 most prominent NOAA-Fisheries mandates in relation to all other applicable mandates. These 15 mandates (10 NOAA, and 5 NOAA-Fisheries) were identified by ranking each mandate using the following approach:

(1) the value of each mandate for a particular EGS was obtained by multiplying the degree to which it addressed an EGS (i.e., 0–4) by the weight representing the organizational priority (i.e., 1–10);
(2) this value for each EGS was summed across all EGS for that mandate and multiplied by the score corresponding to the relative effort in compliance (i.e., 1–10);
(3) each mandate's calculated value [Σ EGS (degree$*$ priority weight) $*$ effort score] was ranked and the top 5 or 10 mandates were selected[1].

For the overlap analysis, all 22 EGS were considered. Overlaps scores reflect the proportion of all 22 EGS in which each mandate of the pair were recorded as relevant (scores 1–4). For example, consider the MSA and Endangered Species Acts. Both were noted as addressing six of the same EGS and not addressing 5 of the same EGS, and they differed in the scoring for the remaining 11 EGS. These two mandates would have an overlap score of 0.5 or 50% (11 identical scores and 11 differing scores).

RESULTS

Applicable Mandates and Linking the NOAA Portfolio of Mandates to Ecosystem Goods and Services

We cataloged 94 mandates (**Table 1**) that apply to NOAA, and a subset of 48 of these that apply to NOAA-Fisheries. URLs for each mandate are included in the Supplementary Information. Many of these, such as the Endangered Species Act or the Coral Reef Conservation Act, center on the conservation or protection of specific resources or species. These require analysis of current and historic information, development of management plans and best practices, periodic review and coordination of enforcement practices and protocols. The major international agreements generally include NOAA in international organizations which require the analysis and sharing of information and practices that inform a specific process or fishery (i.e., ozone depletion, tuna). The established international organizations generally require NOAA's periodic review of information and negotiation of specific recommendations or agreements (i.e., carbon pricing, catch limits). Executive Orders relevant to NOAA and NOAA-Fisheries often require participation of the agency in an additional "task force" and contribution to a plan or a process that positively impacts the problem (i.e., ecosystem restoration). The NOAA-Fisheries mandates, not surprisingly, focus on assessment and projection of the populations of high economic value fish species (i.e., MSA) and critical aspects of ecosystem function (i.e., ocean acidification, estuary monitoring and protection, coral

[1]The RESTORE Act of 2011 was ranked #1 within the NOAA analysis and #2 in the NOAA-Fisheries analysis; however, this mandate was not included in the top 5 or 10 list because the mandate does not have a national focus (instead it is directed toward impacts of the Deepwater Horizon Oil Spill in the Gulf of Mexico).

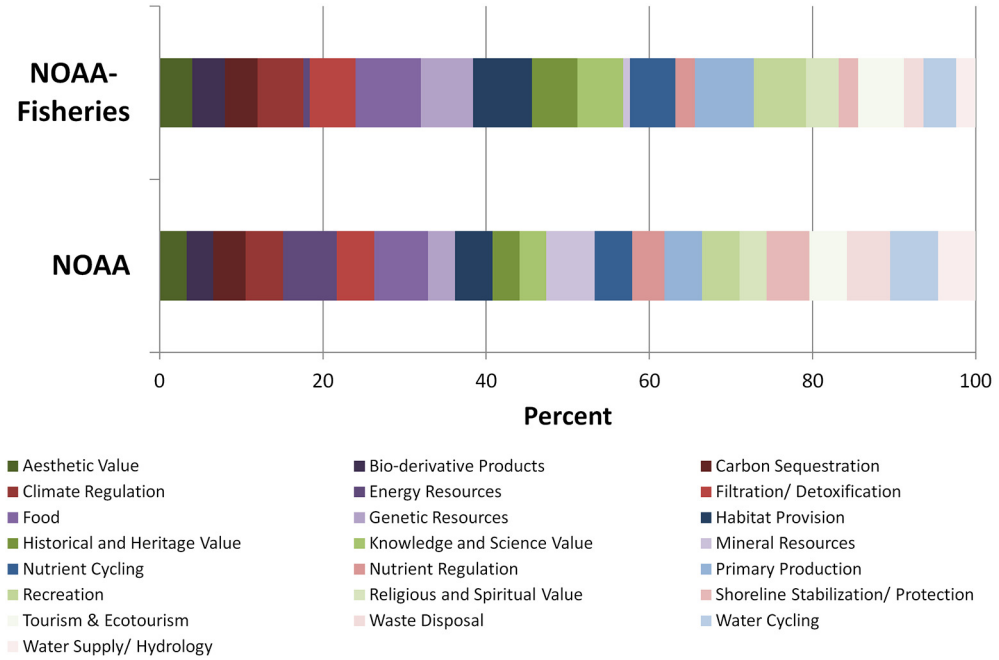

FIGURE 1 | The relative priority of each EGS to NOAA's mission, and to NOAA-Fisheries' mission was estimated. Here we visualize the weight of each EGS as a percentage of the total (100%) for NOAA and NMFS. EGS are graphed in alphabetical order. Provisioning services are indicated with purple hues. Supporting services are indicated with blue hues. Regulating services are indicated with red hues. Cultural services are indicated with green hues. EGS are listed in alphabetical order.

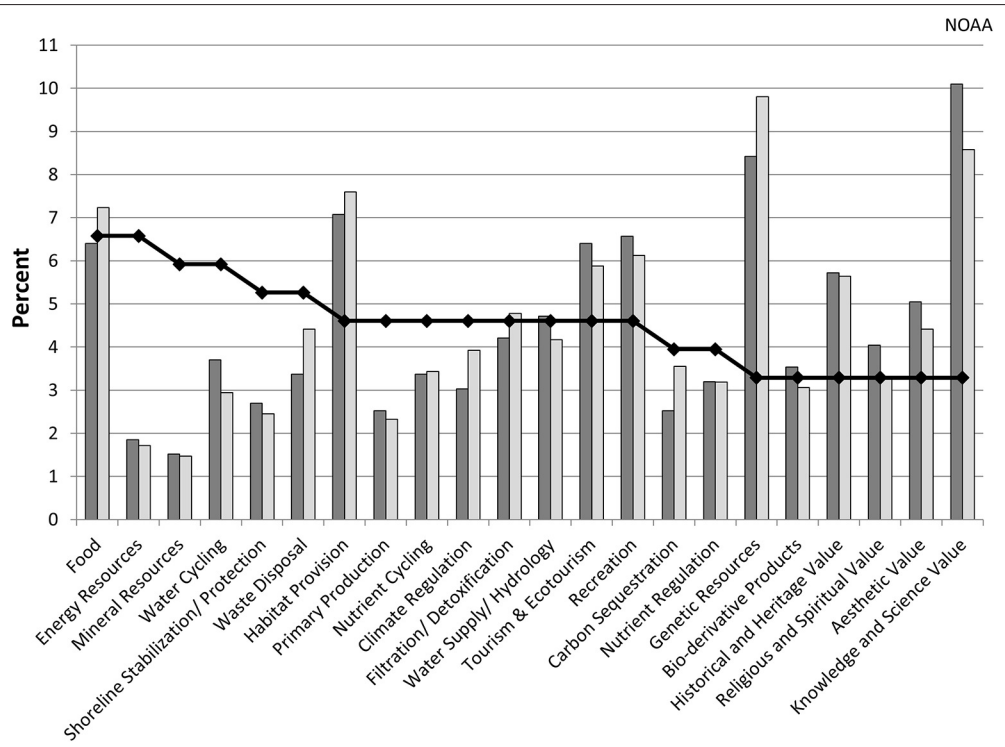

FIGURE 2 | The normalized value of all the mandates collectively is shown for all NOAA mandates. The dark bars reflect of the number of mandates relevant to each of the identified EGS (count). The light bars reflect the collective degree to which the mandates address each EGS, with the degree scored on a high, moderate, low, minimal scale (4, 3, 2, 1 respectively). The line shows the normalized organizational priority of the EGS for NOAA expressed as a percent.

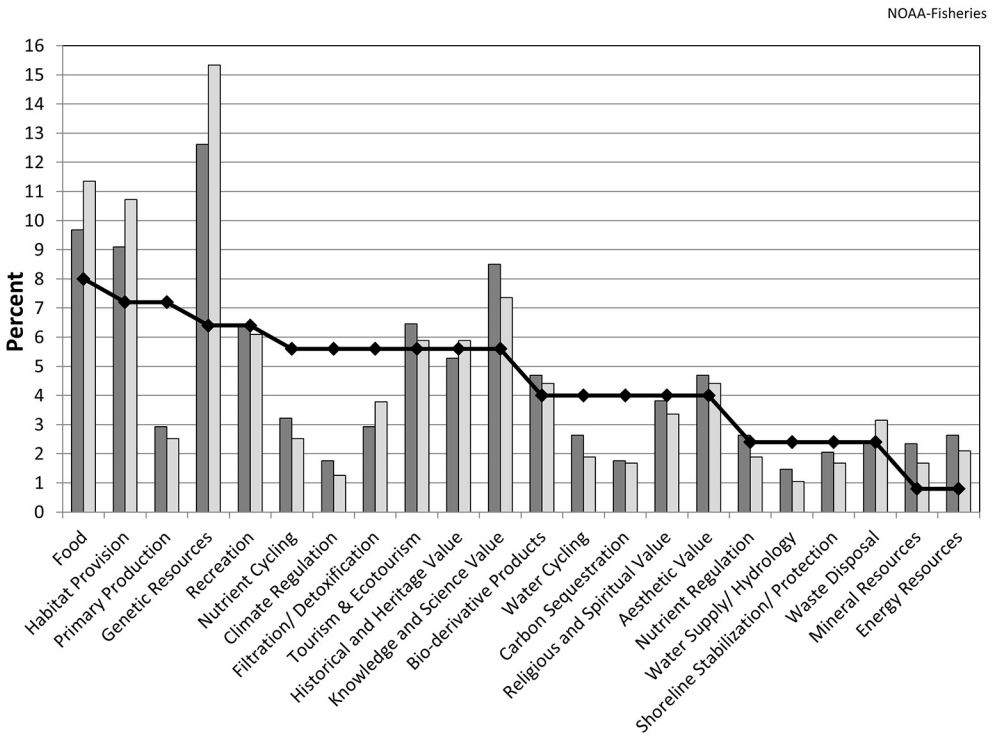

FIGURE 3 | The normalized value of all the mandates collectively is shown for the subset of mandates informing the mission and activities of NOAA-Fisheries. The dark bars reflect of the number of mandates relevant to each of the identified EGS (count). The light colored bars reflect the collective degree to which the mandates address each EGS. The line shows the normalized organizational priority of the EGS for NOAA-Fisheries expressed as a percent.

reefs). Many of these mandates require regular monitoring and analysis, research, and the development and implementation of management plans.

We associated the mandates with 22 different EGS (**Table 2**). These EGS span the range of services and, although tailored for ocean ecosystems, are consistent with other categorizations and listings (MEA, 2003, 2005). These services can generally be considered as provisioning specific resources (food, minerals, and energy), supporting the ecosystem functionally, regulating (nutrients, elements, water levels, temperature) or being the source of cultural services (tourism, heritage value, knowledge value). Worth noting is that provisioning services are associated with economic value and therefore may require assessment and regulation for sustainable utilization. Supporting and regulating services may require protection; however, the roles of these resources and the factors that impact their performance must be understood in order to ensure these EGS are adequately addressed. Mandates associated with cultural services may be plentiful based on the long history of human observation of changing utilization of ocean resources over time, and the desire to preserve access to places of cultural importance.

Evaluating the Coverage of the Suite of EGS by the NOAA Portfolio Of Mandates

Of the 22 EGS, four had the highest relative priority for NOAA (scored as 9 or 10) and two more had a notably high value (scored as 8) (**Figure 1**). These were food provisioning, energy resources, mineral resources, water cycling, shoreline stabilization and waste disposal. These top 6 collectively comprise/account for 35.5% of all the NOAA Fisheries' EGS priorities. For NOAA-Fisheries, 3 out of 22 were weighted at or above 9 and two more were considered higher priority (weight above 7) EGS. These were food provisioning, habitat provision, primary production, genetic resources and recreation. These top 5 collectively comprise/account for 35.2% of all the NOAA Fisheries' EGS priorities. Notably, each of the EGS was addressed to some extent by the NOAA or NOAA-Fisheries mandates. This implies there is wide coverage of EGS.

There are 7 EGS that have at least 5% of mandates that address them for NOAA (**Figure 2**). These are food provisioning, habitat provision, genetic resources, recreation, tourism, historical and heritage value, and knowledge and science value. The mandates most relevant to addressing all of the these EGS (combined degree of relevance greater than 10) are the MSA, the Oil Pollution Act, the Resources and Ecosystems Sustainability, Tourism Opportunities and Revived Economy of the Gulf Coast Act of 2011 (RESTORE Act), the National Marine Sanctuaries Act, and the Chesapeake Bay Restoration Executive Order 13508. Clearly most EGS have multiple mandate coverage. Several EGS have a lower number of mandates that address them, less than 2% of all mandates. Conversely two EGS, genetic resources and knowledge and science value, have a high percentage (∼8%) of NOAA mandates that address them. In comparing the relative number of mandates that address each EGS (dark bars) and

TABLE 3 | A listing of the overlap between the 10 major NOAA mandates and all other mandates.

Mandates	The National Ocean Policy for the Stewardship of the Ocean, Our Coasts, and the Great Lakes Executive Order 13547	Magnuson-Stevens Fishery Conservation and Management Act (MSA)	Coastal Zone Management Act (CZMA)	Oil Pollution Act (OPA)	National Sea Grant College Program Act	Federal Ocean Acidification Research and Monitoring Act (FOARAM Act)	National Environmental Policy Act (NEPA)	Ocean and Coastal Mapping Integration Act	Harmful Algal Bloom and Hypoxia Research and Control Act	U.S. Weather Research Program (USWRP) Authorization Act
The National Ocean Policy for the Stewardship of the Ocean, Our Coasts, and the Great Lakes Executive Order 13547	**1.00**	0.32	0.55	0.55	0.95	0.50	0.64	0.59	0.50	0.36
Magnuson-Stevens Fishery Conservation and Management Act (MSA)	0.32	**1.00**	0.50	0.68	0.36	0.64	0.59	0.45	0.82	0.59
Coastal Zone Management Act (CZMA)	0.55	0.50	**1.00**	0.64	0.50	0.32	0.36	0.77	0.59	0.45
Oil Pollution Act (OPA)	0.55	0.68	0.64	**1.00**	0.50	0.32	0.64	0.68	0.59	0.45
National Sea Grant College Program Act	0.95	0.36	0.50	0.50	**1.00**	0.55	0.59	0.55	0.55	0.41
Federal Ocean Acidification Research and Monitoring Act (FOARAM Act)	0.50	0.64	0.32	0.32	0.55	**1.00**	0.50	0.27	0.73	0.41
National Environmental Policy Act (NEPA)	0.64	0.59	0.36	0.64	0.59	0.50	**1.00**	0.50	0.59	0.36
Ocean and Coastal Mapping Integration Act	0.59	0.45	0.77	0.68	0.55	0.27	0.50	**1.00**	0.45	0.50
Harmful Algal Bloom and Hypoxia Research and Control Act	0.50	0.82	0.59	0.59	0.55	0.73	0.59	0.45	**1.00**	0.41
U.S. Weather Research Program (USWRP) Authorization Act	0.36	0.59	0.45	0.45	0.41	0.41	0.36	0.50	0.41	**1.00**
America Competes Act of 2007	0.09	0.59	0.55	0.55	0.14	0.41	0.36	0.41	0.41	0.55
Aquatic Nuisance Species Program 16 USC 4722	0.18	0.77	0.45	0.55	0.23	0.59	0.45	0.41	0.59	0.55
ATLANTIC STRIPED BASS CONSERVATION ACT	0.27	0.86	0.55	0.73	0.32	0.59	0.55	0.50	0.68	0.55

(Continued)

TABLE 3 | Continued

Mandates	The National Ocean Policy for the Stewardship of the Ocean, Our Coasts, and the Great Lakes Executive Order 13547	Magnuson-Stevens Fishery Conservation and Management Act (MSA)	Coastal Zone Management Act (CZMA)	Oil Pollution Act (OPA)	National Sea Grant College Program Act	Federal Ocean Acidification Research and Monitoring Act (FOARAM Act)	National Environmental Policy Act (NEPA)	Ocean and Coastal Mapping Integration Act	Harmful Algal Bloom and Hypoxia Research and Control Act	U.S. Weather Research Program (USWRP) Authorization Act
Billfish Conservation Act	0.09	0.77	0.36	0.55	0.14	0.59	0.45	0.32	0.59	0.55
CERCLA	0.45	0.68	0.64	0.91	0.41	0.32	0.64	0.59	0.59	0.45
Chesapeake Bay Restoration Executive Order 13508	0.73	0.50	0.45	0.73	0.68	0.41	0.91	0.50	0.59	0.27
Clean Air Act 1990	0.45	0.41	0.45	0.45	0.50	0.59	0.36	0.32	0.50	0.55
Clean Water Act	0.50	0.45	0.77	0.68	0.45	0.27	0.50	0.64	0.55	0.59
Coast and Geodetic Survey Act of 1947	0.09	0.59	0.45	0.36	0.14	0.41	0.36	0.41	0.41	0.73
Coastal Ocean Program (§ 201(c); PL 102-567)	0.09	0.68	0.45	0.45	0.14	0.59	0.27	0.41	0.50	0.73
Coastal Wetlands Planning, Protection, and Restoration Act	0.50	0.55	0.86	0.50	0.45	0.36	0.41	0.73	0.64	0.59
Comprehensive Everglades Restoration Plan (CERP)	0.36	0.77	0.64	0.82	0.32	0.41	0.64	0.68	0.59	0.64
Consolidated Appropriations Act of 2005	0.18	0.68	0.45	0.45	0.23	0.59	0.27	0.41	0.59	0.64
Convention for a North Pacific Marine Science Organization	0.50	0.64	0.32	0.32	0.55	0.91	0.50	0.18	0.73	0.50
Convention for the Conservation of Antarctic Marine Living Resources	0.23	0.82	0.50	0.68	0.27	0.64	0.50	0.45	0.64	0.50
Convention for the Establishment of an Inter-American Tropical Tuna Commission	0.14	0.82	0.41	0.59	0.18	0.64	0.41	0.36	0.64	0.59
Convention for the International Council for the Exploration of the Sea	0.50	0.64	0.32	0.32	0.55	0.91	0.50	0.18	0.73	0.50
Convention on Future Multilateral Cooperation in the Northwest Atlantic Fisheries	0.09	0.77	0.36	0.55	0.14	0.59	0.45	0.32	0.59	0.55

(Continued)

TABLE 3 | Continued

Mandates	The National Ocean Policy for the Stewardship of the Ocean, Our Coasts, and the Great Lakes Executive Order 13547	Magnuson-Stevens Fishery Conservation and Management Act (MSA)	Coastal Zone Management Act (CZMA)	Oil Pollution Act (OPA)	National Sea Grant College Program Act	Federal Ocean Acidification Research and Monitoring Act (FOARAM Act)	National Environmental Policy Act (NEPA)	Ocean and Coastal Mapping Integration Act	Harmful Algal Bloom and Hypoxia Research and Control Act	U.S. Weather Research Program (USWRP) Authorization Act
Convention on International Trade in Endangered Species of Wild Fauna and Flora	0.23	0.73	0.50	0.68	0.27	0.45	0.50	0.55	0.55	0.68
Coral Reef Conservation Act	0.36	0.86	0.64	0.64	0.32	0.50	0.55	0.59	0.68	0.55
Coral Reef Conservation Executive Order 13089	0.50	0.73	0.68	0.68	0.55	0.55	0.59	0.55	0.82	0.41
Data Quality Act of 2001	0.05	0.73	0.50	0.50	0.09	0.55	0.32	0.45	0.55	0.68
Endangered Species Act (ESA)	0.27	0.77	0.55	0.73	0.23	0.50	0.55	0.59	0.59	0.64
Establishment of Papahānaumokuākea Marine National Monument (71 FR 36443/10031; PP 8031/8112)	0.36	0.77	0.64	0.82	0.32	0.41	0.64	0.68	0.59	0.64
Estuary Restoration Act	0.50	0.55	0.86	0.50	0.45	0.36	0.41	0.73	0.64	0.59
Executive Order 12234 (Enforcement of the Convention for the Safety of Life at Sea)	0.14	0.73	0.59	0.59	0.18	0.45	0.41	0.55	0.55	0.68
Federal Insecticide, Fungicide, and Rodenticide Act	0.59	0.55	0.68	0.77	0.55	0.36	0.59	0.55	0.64	0.50
Federal Leadership in Environmental, Energy and Economic Performance - Executive Order 13514	0.23	0.82	0.59	0.68	0.18	0.45	0.59	0.55	0.64	0.59
Federal Records Act of 1950 (as amended)	0.09	0.68	0.55	0.45	0.14	0.50	0.27	0.50	0.50	0.73
Fish and Wildlife Coordination Act (FWCA)	0.86	0.36	0.59	0.59	0.82	0.36	0.77	0.64	0.55	0.23
Global Change Research Act of 1990	0.18	0.59	0.45	0.36	0.23	0.59	0.18	0.41	0.41	0.82

(Continued)

TABLE 3 | Continued

Mandates	The National Ocean Policy for the Stewardship of the Ocean, Our Coasts, and the Great Lakes Executive Order 13547	Magnuson-Stevens Fishery Conservation and Management Act (MSA)	Coastal Zone Management Act (CZMA)	Oil Pollution Act (OPA)	National Sea Grant College Program Act	Federal Ocean Acidification Research and Monitoring Act (FOARAM Act)	National Environmental Policy Act (NEPA)	Ocean and Coastal Mapping Integration Act	Harmful Algal Bloom and Hypoxia Research and Control Act	U.S. Weather Research Program (USWRP) Authorization Act
Global Climate Protection Act of 1990	0.18	0.59	0.45	0.36	0.23	0.59	0.18	0.41	0.41	0.82
Government Performance and Results Act	0.09	0.59	0.55	0.55	0.14	0.41	0.36	0.41	0.41	0.55
Great Lakes Regional Collaboration Executive Order 13340	0.27	0.68	0.36	0.64	0.32	0.59	0.64	0.50	0.50	0.36
Great Lakes Water Quality Agreement of 1978	0.32	0.55	0.68	0.50	0.27	0.45	0.50	0.45	0.64	0.50
Gulf of Mexico Long Term Restoration Executive Order 13554	1.00	0.32	0.55	0.55	0.95	0.50	0.64	0.59	0.50	0.36
High Performance Computing and Communication Act of 1991	0.05	0.73	0.50	0.50	0.09	0.55	0.32	0.45	0.55	0.68
High Seas Driftnet Fishing Moratorium Protection Act	0.09	0.77	0.36	0.55	0.14	0.59	0.45	0.32	0.59	0.55
Hydrographic Services Improvement Act of 1998	0.09	0.59	0.45	0.36	0.14	0.41	0.36	0.41	0.41	0.73
Inland Flood Forecasting and Warning System Act of 2002	0.18	0.59	0.45	0.36	0.23	0.50	0.27	0.41	0.41	0.82
Integrated Coastal and Ocean Observation System Act of 2009	0.41	0.45	0.41	0.23	0.45	0.73	0.32	0.27	0.55	0.68
Inter-American Convention for the Protection and Conservation of Sea Turtles	0.09	0.77	0.45	0.55	0.14	0.50	0.45	0.41	0.59	0.64
International Convention for the Conservation of Atlantic Tunas	0.14	0.82	0.41	0.59	0.18	0.64	0.41	0.36	0.64	0.59
International Pacific Halibut Commission	0.18	0.86	0.45	0.64	0.23	0.68	0.45	0.41	0.68	0.55

(Continued)

TABLE 3 | Continued

Mandates	The National Ocean Policy for the Stewardship of the Ocean, Our Coasts, and the Great Lakes Executive Order 13547	Magnuson-Stevens Fishery Conservation and Management Act (MSA)	Coastal Zone Management Act (CZMA)	Oil Pollution Act (OPA)	National Sea Grant College Program Act	Federal Ocean Acidification Research and Monitoring Act (FOARAM Act)	National Environmental Policy Act (NEPA)	Ocean and Coastal Mapping Integration Act	Harmful Algal Bloom and Hypoxia Research and Control Act	U.S. Weather Research Program (USWRP) Authorization Act
International Plan of Action for the Reducing the Incidental Catch of Seabirds in Longline Fisheries (IPOA-Seabirds)	0.09	0.77	0.45	0.55	0.14	0.50	0.45	0.41	0.59	0.64
International Scientific Commission (ISC) for tuna and tuna-like species in the North Pacific Ocean	0.14	0.82	0.41	0.59	0.18	0.64	0.41	0.36	0.64	0.59
International Whaling Commission	0.32	0.73	0.50	0.77	0.27	0.45	0.59	0.55	0.55	0.59
Lacey Act Amendments of 1981	0.09	0.77	0.36	0.55	0.14	0.59	0.45	0.32	0.59	0.55
Marine Debris Research Prevention and Reduction Act	0.09	0.59	0.55	0.55	0.14	0.41	0.27	0.41	0.50	0.55
Marine Mammal Protection Act (MMPA)	0.27	0.77	0.55	0.73	0.23	0.50	0.55	0.59	0.59	0.64
Marine Protected Area Executive Order 13158	0.18	0.86	0.36	0.55	0.23	0.68	0.55	0.32	0.68	0.45
Marine Protection, Research, and Sanctuaries Act (16 U.S.C. § 1431; PL 106-513)	0.36	0.77	0.64	0.82	0.32	0.41	0.64	0.68	0.59	0.64
Migratory Bird Treaty Act	0.27	0.86	0.64	0.73	0.23	0.50	0.55	0.59	0.68	0.64
Montreal Protocol on Substances that Deplete the Ozone Layer	0.09	0.59	0.36	0.36	0.14	0.59	0.27	0.32	0.41	0.73
National Aquaculture Act of 1980	0.23	0.82	0.50	0.50	0.27	0.73	0.41	0.45	0.73	0.50

(Continued)

TABLE 3 | Continued

Mandates	The National Ocean Policy for the Stewardship of the Ocean, Our Coasts, and the Great Lakes Executive Order 13547	Magnuson-Stevens Fishery Conservation and Management Act (MSA)	Coastal Zone Management Act (CZMA)	Oil Pollution Act (OPA)	National Sea Grant College Program Act	Federal Ocean Acidification Research and Monitoring Act (FOARAM Act)	National Environmental Policy Act (NEPA)	Ocean and Coastal Mapping Integration Act	Harmful Algal Bloom and Hypoxia Research and Control Act	U.S. Weather Research Program (USWRP) Authorization Act
National Arctic Policy (National Security Presidential Directive (NSPD 66)/Homeland Security Presidential Directive (HSPD 25)	0.64	0.50	0.45	0.73	0.59	0.50	0.55	0.59	0.41	0.36
National Climate Program Act of 1978	0.14	0.55	0.41	0.32	0.18	0.55	0.23	0.36	0.36	0.77
National Coastal Monitoring Act	0.50	0.45	0.86	0.68	0.45	0.18	0.41	0.82	0.45	0.50
National Integrated Drought Information System Act of 2006	0.14	0.55	0.41	0.32	0.18	0.45	0.32	0.36	0.36	0.77
National Invasive Species Act	0.18	0.77	0.45	0.55	0.23	0.59	0.45	0.41	0.59	0.55
National Invasive Species Executive Order 13112	0.27	0.86	0.55	0.64	0.23	0.50	0.64	0.50	0.68	0.55
National Marine Sanctuaries Act	0.36	0.77	0.64	0.82	0.32	0.41	0.64	0.68	0.59	0.64
National Ocean Pollution and Planning Act 1978	0.45	0.41	0.73	0.64	0.41	0.14	0.45	0.68	0.41	0.64
National Weather Service Organic Act of 1890 (as amended)	0.36	0.59	0.45	0.45	0.41	0.41	0.36	0.50	0.41	1.00
Navigation and Navigable Water-Water Resource Development-Great Lakes Water Quality Agreement of 1978 amended 1987 33 USC 2326B	0.14	0.55	0.59	0.41	0.09	0.36	0.32	0.55	0.36	0.59

(Continued)

TABLE 3 | Continued

Mandates	The National Ocean Policy for the Stewardship of the Ocean, Our Coasts, and the Great Lakes Executive Order 13547	Magnuson-Stevens Fishery Conservation and Management Act (MSA)	Coastal Zone Management Act (CZMA)	Oil Pollution Act (OPA)	National Sea Grant College Program Act	Federal Ocean Acidification Research and Monitoring Act (FOARAM Act)	National Environmental Policy Act (NEPA)	Ocean and Coastal Mapping Integration Act	Harmful Algal Bloom and Hypoxia Research and Control Act	U.S. Weather Research Program (USWRP) Authorization Act
NOAA Chesapeake Bay Watershed Monitoring, Education, Training, and Restoration Act - amendments to Section 307 of the National Oceanic and Atmospheric Administration Authorization Act of 1992 (15 U.S.C. 1511d)	0.50	0.73	0.68	0.68	0.55	0.55	0.59	0.55	0.82	0.41
NOAA Undersea Research Program Act of 2009	0.05	0.73	0.50	0.50	0.09	0.55	0.32	0.45	0.55	0.68
Ocean Dumping Act	0.09	0.59	0.55	0.55	0.14	0.41	0.27	0.41	0.50	0.55
Ocean Exploration Act *PL111-11	0.05	0.73	0.50	0.50	0.09	0.55	0.32	0.45	0.55	0.68
Ocean Exploration Authority	0.05	0.73	0.50	0.50	0.09	0.55	0.32	0.45	0.55	0.68
Oceans Act of 2000	0.27	0.68	0.55	0.55	0.23	0.50	0.45	0.50	0.50	0.45
Oceans and Human Health Act	0.36	0.68	0.64	0.73	0.41	0.32	0.45	0.59	0.59	0.64
Pacific Salmon Treaty	0.27	0.86	0.55	0.73	0.32	0.50	0.64	0.50	0.68	0.55
Port and Tanker Safety Act 1978	0.14	0.55	0.59	0.41	0.09	0.36	0.32	0.55	0.36	0.59
Regional Marine Research Program 16 USC 1447B	0.05	0.73	0.50	0.50	0.09	0.55	0.32	0.45	0.55	0.68
Resources and Ecosystems Sustainability, Tourism Opportunities and Revived Economy of the Gulf Coast Act of 2011 (RESTORE Act).	0.77	0.55	0.68	0.77	0.73	0.45	0.68	0.64	0.73	0.23
Responsibilities of Federal Agencies to Protect Migratory Birds Executive Order 13186	0.32	0.82	0.59	0.68	0.36	0.45	0.50	0.55	0.73	0.59
Rivers and Harbors Act	0.36	0.50	0.73	0.64	0.32	0.14	0.45	0.68	0.32	0.64

(Continued)

TABLE 3 | Continued

Mandates	The National Ocean Policy for the Stewardship of the Ocean, Our Coasts, and the Great Lakes Executive Order 13547	Magnuson-Stevens Fishery Conservation and Management Act (MSA)	Coastal Zone Management Act (CZMA)	Oil Pollution Act (OPA)	National Sea Grant College Program Act	Federal Ocean Acidification Research and Monitoring Act (FOARAM Act)	National Environmental Policy Act (NEPA)	Ocean and Coastal Mapping Integration Act	Harmful Algal Bloom and Hypoxia Research and Control Act	U.S. Weather Research Program (USWRP) Authorization Act
Secure Water Act of 2009	0.18	0.59	0.45	0.36	0.23	0.50	0.27	0.41	0.41	0.82
Submerged Lands and Outer Continental Shelf Act	0.23	0.55	0.68	0.50	0.27	0.36	0.23	0.55	0.36	0.59
The 1995 United Nations Straddling and Highly Migratory Fish Stocks Agreement	0.14	0.82	0.41	0.59	0.18	0.64	0.41	0.36	0.64	0.59
The Atlantic Coastal Fisheries Cooperative Management Act	0.27	0.86	0.55	0.73	0.32	0.59	0.55	0.50	0.68	0.55
Tsunami Warning and Education Act	0.27	0.68	0.73	0.55	0.32	0.32	0.36	0.68	0.50	0.73
U. N. Framework Convention on Climate Change (UNFCCC):	0.09	0.59	0.36	0.36	0.14	0.59	0.27	0.32	0.41	0.73
UN Food and Agriculture Organization Code of Conduct	0.23	0.91	0.41	0.59	0.27	0.73	0.50	0.36	0.73	0.50
US Climate Protection Act	0.18	0.59	0.45	0.36	0.23	0.59	0.18	0.41	0.41	0.82
Water Pollution Prevention and Control Act (33 U.S.C. § 1268)	0.50	0.45	0.77	0.68	0.45	0.27	0.50	0.64	0.55	0.59
Water Resources Development Act of 2000	0.09	0.59	0.45	0.36	0.14	0.41	0.36	0.41	0.41	0.73
Western and Central Pacific Fisheries Convention	0.14	0.82	0.41	0.59	0.18	0.64	0.41	0.36	0.64	0.59

Overlap greater than 0.9 are highlighted in green, greater than 0.7 are highlighted in yellow, and less than 0.2 are highlighted in red. Gray cell are duplicates; the table is symmetric. The bold number is the correlation calculation for a mandate with itself. It should always be 1.00.

the relative degree to which each EGS is addressed (light bar), a similar pattern is observed. Generally the count of relevant mandates is similar to the proportion of total score assessed for coverage or the degree to which each mandate addressed each EGS. The two EGS for which these measures showed the biggest difference were genetic resources, in which a smaller number of mandates were attributed a larger degree of relevance, and knowledge and science value, in which a larger number of mandates were attributed a smaller degree of relevance. The priority we assessed for the agency among all the EGS was not always reflected in the realized number of mandates or proportional degree of relevance (**Figure 2**). For instance, food was a high priority EGS and generally had high mandate coverage, yet genetic resources was a lower priority but had a high degree of mandate coverage.

Similar patterns are observed for NOAA-Fisheries (**Figure 3**). There are 7 different EGS that have at least 5% of mandates that address them for NOAA. These are food production, habitat provision, genetic resources, recreation, tourism, historical and heritage value, and knowledge and science value. The subset of mandates relevant to NOAA-Fisheries that are have the highest combined degree of relevance (greater than 10) for these EGS are the MSA, the Oil Pollution Act, the RESTORE Act, and the National Marine Sanctuaries Act. Clearly most EGS have multiple mandate coverage even within NOAA-Fisheries. This implies there is wide coverage of EGS in the fisheries sector. Three EGS have a lower number of mandates that address them, less than 2% of all mandates; these are climate regulation, carbon sequestration and water supply/hydrology. The EGS of genetic resources is addressed by more than 12% of the NOAA-Fisheries mandates. Generally the count of relevant mandates is similar to the proportion of total score assessed for the degree to which each mandate addressed each EGS for NOAA-Fisheries as well. The three EGS for which these measures showed the biggest difference were food, habitat provisioning and genetic resources; in all three cases, a smaller number of mandates were attributed with a larger degree of relevance. As was the case with NOAA, the number and proportional degree of relevance of the portfolio of mandates did not always match the weighted priority of EGS for NOAA-Fisheries (**Figure 3**). For instance, food and habitat provision were high priority EGS and generally had high mandate coverage. The genetic resources EGS was considered to be of slightly lower performance and yet a higher proportion of mandates were relevant to this EGS. Conversely nutrient cycling and climate regulation were considered higher priority EGS than tourism and knowledge and science value, yet the mandate coverage showed the opposite pattern.

An interesting observation is that the relative number of mandates associated with each EGS may imply the relative priority of that EGS to the agency. An important caveat to note, however, is the degree of coverage by total number of mandates may not necessarily be reflective of the comprehensiveness in addressing a given EGS. Therefore, there may not be a one-to-one match of mandate coverage relative to implied EGS prioritization. Yet it is interesting to note that some high priority EGS have a limited number of mandated coverage and vice versa. Further, many mandates require a high level of coordination from different levels of government (state, local, federal, and international) in order to collect, develop, disseminate, and implement outcomes from the agency's efforts. The profile of mandate coverage may, in part, reflect different agencies taking the lead on the evaluation and management of specific EGS (i.e., energy resources and mineral resources with Bureau of Ocean Energy Management).

Overlap across Mandates with Respect to EGS

Relative to the 10 major NOAA mandates, 69 out of 94 mandates have a calculated overlap >70% with at least one of the major mandates, and 7 have an overlap of >90% (**Table 3**). This means that across EGS, there is some reinforcement among mandates. Certainly the caveats of geographic, taxonomic, or process specificity need to be considered in the portfolio of such mandates. Yet for some of the mandates that address shared EGS, there is some potential for redundancy. Conversely, 48 out of 94 mandates have an overlap of <20% with at least one of the 10 major NOAA mandates (**Table 3**). Note in this table that a single mandate under consideration may have an overlap of more than 70% with one of the major mandates and an overlap of less than 20% with another of the major mandates. This means that some facets of some EGS may have less reinforcement in their mandated coverage. The same caveats of geographic, taxonomic, or process specificity apply here, especially if the mandate is particularly integrative or general. Another caveat worth repeating is that the degree of coverage by total number of mandates may not necessarily be reflective of the comprehensiveness in addressing a given EGS. However, the analysis of overlap does highlight some mandates as being relatively unique in the EGS that they address.

Relative to the five major NOAA-Fisheries mandates, 37 out of 48 that have an overlap calculated to be >70% with at least one of the major mandates, and 5 with >90% overlap with a major mandate (**Table 4**). This means that across EGS in the fisheries sector, there is reinforcement among the major mandates. Again, the caveats of geographic, taxonomic, or process specificity need to be considered in the portfolio of such mandates. However, for some of the mandates that address shared EGS, there is some potential for redundancy. Conversely, 13 out of 48 mandates have an overlap of <20% with at least one of the 5 major NOAA Fisheries mandates (**Table 4**). This means that some facets of some EGS may have less reinforcement in their mandated coverage for the fisheries sector. The same caveats of geographic, taxonomic, or process specificity also apply here, as do caveats pertaining to resources and effort applied to the fulfillment of a mandate. Yet again this implies that some elements of the EGS may be more vulnerable to not being addressed.

We started with an obvious observation, that there are a relatively large number of mandates providing requirements to address ocean EGS. One less obvious, emergent observation from this evaluation is that some mandates may overlap (**Tables 3, 4**), but have competing objectives (see tasks and requirements, **Table 1**). Certainly some EGS are supporting or regulating features that afford provisions for other EGS beyond direct

TABLE 4 | A listing of the overlap between the 5 major NOAA-Fisheries mandates and all other mandates.

Mandates	Magnuson-Stevens Fishery Conservation and Management Act (MSA)	The National Ocean Policy for the Stewardship of the Ocean, Our Coasts, and the Great Lakes Executive Order 13547	Marine Mammal Protection Act (MMPA)	Endangered Species Act (ESA)	National Environmental Policy Act (NEPA)
Magnuson-Stevens Fishery Conservation and Management Act (MSA)	**1.00**	0.32	0.77	0.77	0.59
The National Ocean Policy for the Stewardship of the Ocean, Our Coasts, and the Great Lakes Executive Order 13547	0.32	**1.00**	0.27	0.27	0.64
Marine Mammal Protection Act (MMPA)	0.77	0.27	**1.00**	1.00	0.55
Endangered Species Act (ESA)	0.77	0.27	1.00	**1.00**	0.55
National Environmental Policy Act (NEPA)	0.59	0.64	0.55	0.55	**1.00**
ATLANTIC STRIPED BASS CONSERVATION ACT	0.86	0.27	0.73	0.73	0.55
Billfish Conservation Act (October 9, 2012)	0.77	0.09	0.73	0.73	0.45
CERCLA	0.68	0.45	0.73	0.73	0.64
Chesapeake Bay Restoration Executive Order 13508	0.73	0.50	0.59	0.59	0.59
Convention for a North Pacific Marine Science Organization	0.64	0.50	0.50	0.50	0.50
Convention for the Conservation of Antarctic Marine Living Resources	0.82	0.23	0.77	0.77	0.50
Convention for the Establishment of an Inter-American Tropical Tuna Commission	0.82	0.14	0.77	0.77	0.41
Convention for the International Council for the Exploration of the Sea	0.64	0.50	0.50	0.50	0.50
Convention on Future Multilateral Cooperation in the Northwest Atlantic Fisheries	0.77	0.09	0.73	0.73	0.45
Convention on International Trade in Endangered Species of Wild Fauna and Flora	0.73	0.23	0.86	0.86	0.50
Coral Reef Conservation Act	0.86	0.36	0.82	0.82	0.55
Coral Reef Conservation Executive Order 13089	0.86	0.27	0.82	0.82	0.64
Estuary Restoration Act	0.55	0.50	0.59	0.59	0.41
Federal Leadership in Environmental, Energy and Economic Performance—Executive Order 13514	0.41	0.27	0.45	0.45	0.36
Federal Ocean Acidification Research and Monitoring Act (FOARAM Act)	0.64	0.50	0.50	0.50	0.50
Fish and Wildlife Coordination Act (FWCA)	0.36	0.86	0.32	0.32	0.77
Great Lakes Regional Collaboration Executive Order 13340	0.82	0.32	0.68	0.68	0.50
Gulf of Mexico Long Term Restoration Executive Order 13554	0.50	0.73	0.45	0.45	0.91
High Seas Driftnet Fishing Moratorium Protection Act	0.77	0.09	0.73	0.73	0.45
Inter-American Convention for the Protection and Conservation of Sea Turtles	0.77	0.09	0.73	0.73	0.45
International Convention for the Conservation of Atlantic Tunas	0.82	0.14	0.77	0.77	0.41
International Pacific Halibut Commission	0.86	0.18	0.82	0.82	0.45
International Plan of Action for the Reducing the Incidental Catch of Seabirds in Longline Fisheries (IPOA-Seabirds)	0.77	0.09	0.73	0.73	0.45
International Scientific Commission (ISC) for tuna and tuna-like species in the North Pacific Ocean	0.82	0.14	0.77	0.77	0.41
International Whaling Commission	0.73	0.32	0.86	0.86	0.59
Lacey Act Amendments of 1981 (16 USC 3371-3378)	0.77	0.09	0.73	0.73	0.45
Marine Protected Area Executive Order 13158	0.68	0.27	0.64	0.64	0.64
Migratory Bird Treaty Act	0.86	0.27	0.91	0.91	0.55
National Aquaculture Act of 1980	0.82	0.23	0.68	0.68	0.41
National Invasive Species Act	0.77	0.18	0.73	0.73	0.45

(Continued)

TABLE 4 | Continued

Mandates	Magnuson-Stevens Fishery Conservation and Management Act (MSA)	The National Ocean Policy for the Stewardship of the Ocean, Our Coasts, and the Great Lakes Executive Order 13547	Marine Mammal Protection Act (MMPA)	Endangered Species Act (ESA)	National Environmental Policy Act (NEPA)
National Invasive Species Executive Order 13112	0.86	0.18	0.73	0.73	0.55
National Marine Sanctuaries Act (16 USC 1431-1439)	0.77	0.36	0.91	0.91	0.64
National Sea Grant College Program Act	0.36	0.95	0.23	0.23	0.59
Oil Pollution Act (OPA)	0.68	0.55	0.73	0.73	0.64
Pacific Salmon Treaty	0.86	0.27	0.73	0.73	0.64
Resources and Ecosystems Sustainability, Tourism Opportunities and Revived Economy of the Gulf Coast Act of 2011 (RESTORE Act)	0.55	0.77	0.50	0.50	0.68
Responsibilities of Federal Agencies to Protect Migratory Birds Executive Order 13186	0.82	0.23	0.86	0.86	0.59
The 1995 United Nations Straddling and Highly Migratory Fish Stocks Agreement	0.82	0.14	0.77	0.77	0.41
The Atlantic Coastal Fisheries Cooperative Management Act	0.86	0.27	0.73	0.73	0.55
UN Food and Agriculture Organization Code of Conduct	0.91	0.23	0.77	0.77	0.50
Western and Central Pacific Fisheries Convention	0.82	0.14	0.77	0.77	0.41

Overlap greater than 0.9 are highlighted in green, greater than 0.7 are highlighted in yellow, and less than 0.2 are highlighted in red. Gray cell are duplicates; the table is symmetric. The bold number is the correlation calculation for a mandate with itself. It should always be 1.00.

human benefit. Yet some facets of even overlapping mandates highlight the need to balance the full range of mandated objectives and how they address EGS.

DISCUSSION

Many EGS are provided by the ocean (Costanza et al., 1997; MEA, 2003, 2005; Halpern et al., 2008). A number of mandates address the monitoring, management, measurement, forecasting, maintenance, conservation, or protection of these goods and services. The interplay between mandate coverage of EGS remains worth examining. To our knowledge, this is the first attempt to comprehensively link mandates to the EGS they are addressing. Some EGS have a limited number of mandates addressing them. This may be acceptable; EGS may require different levels of resources in order to be assessed or protected. The interpretation of this low coverage must be understood with the caveats of the full amount of resources, effort, and prioritization that is actually afforded to the EGS by each mandate. Some mandates may have a narrow focus, touch on only a limited set of facets of any given EGS, but are well resourced and well emphasized. Other mandates may relate to these EGS but lay outside the purview of NOAA or NOAA-Fisheries. That would not necessarily emerge from this evaluation. However, we do note that EGS with a limited amount of mandate coverage should be monitored so that no significant deficiencies arise. Some EGS have copious numbers of mandates addressing them. This is excellent in terms of reinforcement of coverage to ensure that the EGS are being addressed adequately. It is wise to have some modicum of redundancy. Yet caveats associated with the geographic, taxonomic or topical focus of particular mandates may lessen the perceived coverage for a given EGS.

All EGS had some coverage by the portfolio of mandates. But are there EGS, or even emerging facets of some EGS, that we did not emphasize? The use of our categorization scheme may miss or deemphasize some EGS. For example, it is debatable whether biodiversity is in itself an EGS, or is an important facet of one, or is not one at all but rather an emergent feature of an ecosystem (Haines-Young and Potschin, 2010). The salient point is that any categorization and evaluation system of EGS needs to be flexible enough to handle these considerations. Yet despite this concern, it does appear that the majority of ocean-oriented EGS have some degree of mandated coverage.

This method has some utility. The prioritization weightings, effort scoring and establishment of linkages are undoubtedly reflective of our biases and limitations, even though they are generally reflective of documented priorities for the agency. Yet the method noted here represents a useful approach to examine and explore how a portfolio of mandates covers a suite of EGS. Certainly more nuanced inputs could be employed and future work could explore this topic more thoroughly, but any such advances would be able to build on the elements developed here.

Although technically feasible, we resisted the temptation to conduct a full multi-criteria portfolio analysis (e.g., Salo et al., 2011; Linkov and Moberg, 2012). We did not conduct this analysis for four main reasons. The first is the previously mentioned biases and limitations of our priority weightings and effort scoring. Second, the difficulty of establishing more detailed criteria for the effectiveness of efforts relative to addressing EGS from an understanding of the specific requirements of mandates limited our ability to characterize the extent to which an EGS was addressed. Third, these agencies are required to fulfill these mandates regardless of the level of priority, effort or resources. Finally, Congressional and Executive priorities change regularly, directly impacting the number and coverage of a portfolio of mandates. Rather this approach highlights a few areas of excellent EGS coverage and a few areas that may warrant closer attention as the oceans, and the human uses thereof, change in the future. Certainly the method could be amplified for further evaluation of realized and implied prioritization, and alignments or adjustments made accordingly. More so, it provides a transparent framework within which this could be done (Linkov and Moberg, 2012).

Most work on ocean-oriented EGS focuses on either descriptions thereof (Daily et al., 1997), limits thereto (MEA, 2003, 2005; Halpern et al., 2012), or valuation thereof (Costanza et al., 1997; de Groot et al., 2002). This work emphasized links between EGS and the mandates required to fully address them. An earlier study (Scarlett and Boyd, 2011) did qualitatively link a limited number of mandates to some EGS, even to the point of treating EGS as "natural capital" in a policy context (Schaefer et al., 2015). Other works describing mandates and associated policies (McFadden and Barnes, 2009) qualitatively hint at addressing some EGS. Yet to attempt to establish direct linkages between a portfolio of mandates and a suite of EGS, and then quantify them, is not only novel, it is illustrative as an approach of how future evaluations of ocean governance relative to ocean uses could be done. One conclusion from this work is that coordination across mandates is necessary to fully address all EGS. Certainly numerous mandates touch on all categories of EGS and there may be perceived redundancies. However, specific facets of any given EGS may still be missed. Conversely, some mandates may have competing objectives that affect the same EGS. Hence, the analysis highlights the need to adopt an EBM approach. Less obvious is that these nearly 100 mandates collectively provide a basis for doing EBM. Within the extant mandate portfolio, there is enough precedent collectively to authorize EBM. To implement these mandates in more fully coordinated, cross-linked and systematic manner is not only allowable, it is imperative if we are to wisely manage the important EGS of the ocean.

AUTHOR CONTRIBUTIONS

All authors participated in the conceptualization and design of the analysis. Mandate collection and analysis performed by CF, JL, and WP, who drafted the original manuscript. All authors participated in refinement of the analysis, as well as in the editing of the manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: http://journal.frontiersin.org/article/10.3389/fmars.2016.00005

REFERENCES

Christensen, N. L., Bartuska, A. M., Brown, J. H., Carpenter, S., D'Antonio, C., Francis, R., et al. (1996). The report of the ecological society of America committee on the scientific basis for ecosystem management. *Ecol. Appl.* 6, 665–691.

Costanza, R. (2008). Ecosystem services: multiple classification systems are needed. *Biol. Conserv.* 141, 350–352. doi: 10.1016/j.biocon.2007.12.020

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., et al. (1997). The value of the world's ecosystem services and natural capital. *Nature* 387, 253–260.

Crowder, L. B., Osherenko, G., Young, O. R., Airamé, S., Norse, E. A., Baron, N., et al. (2006). Resolving mismatches in U.S. ocean governance. *Science* 313, 617–618. doi: 10.1126/science.1129706

Daily, G. C., Alexander, S., Ehrlich, P. R., Goulder, L., Lubchenco, J., Matson, P. A., et al. (1997). Ecosystem services: benefits supplied to human societies by natural ecosystems. *Issues Ecol.* 2, 1–18.

de Groot, R. S., Wilson, M. A., and Boumans, R. M. J. (2002). A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecol. Econ.* 41, 393–408. doi: 10.1016/S0921-8009(02)00089-7

FAO (Food and Agriculture Organization) (2003). *The Ecosystem Approach to Fisheries*. Rome: FAO Technical Guidelines for Responsible Fisheries 4, Supplement 2, 112.

Fluharty, D. (2014). *Exploration of Ecosystem Based Fishery Management in the United States: A Report from the NOAA Science Advisory Board*. Maryland: NOAA Fisheries, Office of Science and Technology, Silver Spring, 111. Available online at: http://www.sab.noaa.gov/Reports/SAB%20EBFM%20Report%20to%20NOAA_July%202014_Final.pdf

Haines-Young, R., and Potschin, M. (2010). "The links between biodiversity, ecosystem services and human well-being," in *Ecosystem Ecology: A New Synthesis*, eds D. Raffaelli and C. Frid (Cambridge: Cambridge University Press), 110–139.

Halpern, B. S., Longo, C., Hardy, D., McLeod, K. L., Samhouri, J. F., Katona, S. K., et al. (2012). An index to assess the health and benefits of the global ocean. *Nature* 488, 615–620. doi: 10.1038/nature11397

Halpern, B. S., Walbridge, S., Selkoe, K. A., Kappel, C. V., Micheli, F., D'Agrosa, C., et al. (2008). A global map of human impact on marine ecosystems. *Nature* 319, 948–952. doi: 10.1126/science.1149345

Leslie, H. M., and McLeod, K. L. (2007). Confronting the challenges of implementing marine ecosystem-based management. *Front. Ecol. Environ.* 5, 540–548. doi: 10.1890/060093

Link, J. S. (2010). *Ecosystem-Based Fisheries Management: Confronting Tradeoffs*. Cambridge: Cambridge University Press.

Linkov, I., and Moberg, E. (2012). *Multi-Criteria Decision Analysis. Environmental Applications and Case Studies*. Boca Raton, FL: CRC Press.

MEA (Millennium Ecosystem Assessment) (2003). *Ecosystems and Human Well-being: A Framework for Assessment*. Washington, DC: Island Press.

MEA (2005). *Ecosystems and Human Well-Being: Synthesis*. Washington, DC: Island Press.

McFadden, K. W., and Barnes, C. (2009). The implementation of an ecosystem approach to management within a federal government agency. *Mar. Policy* 33, 156–163. doi: 10.1016/j.marpol.2008.05.007

McLeod, K., and Leslie, H. (2009). *Ecosystem-Based Management for the Oceans*. Washington, DC: Cambridge University Press.

NRC (Natural Research Council) (2004). *Valuing Ecosystem Services: Toward Better Environmental Decision-Making*. Washington, DC: National Academies Press.

O'Higgins, T. G., and Gilbert, A. J. (2014). Embedding ecosystem services into the Marine Strategy Framework Directive: illustrated by eutrophication in the North Sea. *Estuarine Coastal Shelf Sci.* 140, 146–152. doi: 10.1016/j.ecss.2013.10.005

Okoli, C., and Pawlowski, S. D. (2004). The Delphi method as a research tool: an example, design considerations and applications. *Inf. Manage.* 42, 15–29. doi: 10.1016/j.im.2003.11.002

Pitcher, T. J., Kalikoski, D., Short, K., Varkey, D., and Pramod, G. (2009). An evaluation of progress in implementing ecosystem-based management of fisheries in 33 countries. *Mar. Policy* 33, 223–232. doi: 10.1016/j.marpol.2008.06.002

Reed, M. S., Hubacek, K., Bonn, A., Burt, T. P., Holden, J., Stringer, L. C., et al. (2013). Anticipating and managing future trade-offs and complementarities between ecosystem services. *Ecol. Soc.* 18:5. doi: 10.5751/ES-04924-180105

Salo, A., Keisler, J., and Morton, A. (2011). *Portfolio Decision Analysis: Improved Methods for Resource Allocation*. New York, NY: Springer Verlag.

Scarlett, L., and Boyd, J. (2011). "Ecosystem services: quantification, policy applications, and current federal capabilities," in *Resources for the Future Discussion Paper No. 11-13*. Available online at: http://ssrn.com/abstract=1794242. doi: 10.2139/ssrn.1794242

Schaefer, M., Goldman, E., Bartuska, A. M., Sutton-Grier, A., and Lubchenco, J. (2015). Nature as capital: advancing and incorporating ecosystem services in United States federal policies and programs. *Proc. Natl. Acad. Sci. U.S.A.* 112, 7383–7389. doi: 10.1073/pnas.1420500112

Slocombe, D. S. (1993). Implementing ecosystem-based management: development of theory, practice, and research for planning and managing a region. *BioScience* 43, 612–622. doi: 10.2307/1312148

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