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The status of marine and coastal ecosystem-based management among the network of U.S. federal programs

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ABSTRACT

In the United States, management of marine and coastal resources has moved towards ecosystem-based management (EBM), which is a more systematic and integrated approach than conventional (e.g., single sector or single species) approaches. This paper summarizes the status of EBM for federal programs under the agencies of the National Ocean Council that implement or support marine and coastal EBM activities. Using social network analysis techniques, including network visualization, cohesion measures, programs degree and betweenness centrality, similarities among programs in different topic areas (e.g., type of audience, partners, training, EBM best management practices and principles) were explored. Results highlight substantial differences in perceived and effective performances across programs, with Management programs showing a higher level of integration of EBM approaches than Non-Management programs. The use of EBM best management practices and principles among programs is unbalanced, with some key elements of EBM strategies less commonly employed in the management planning. This analysis identified gaps in the implementation of EBM strategies that can inform natural resource managers and other interested parties. This paper presents the results of the analysis and discusses the implications for the implementation of EBM approaches and strategies at the federal level.

1. Introduction

Marine ecosystems provide a broad range of crucial economic, societal, and environmental services to humans [1]. The condition of these ecosystems and the services they provide have been influenced by a variety of natural and human-based processes and activities for centuries [2,3]. These activities (e.g., fisheries, energy exploration, shipping, tourism and recreation, and coastal development) and their impacts (e.g., resource overexploitation, reduced water quality, habitat loss and degradation) have resulted in increased use of and pressure on natural marine resources, which has altered the natural state of marine ecosystems [2,4,5]. The cumulative impacts of multiple human "drivers" and "pressures" on ocean, coastal, estuarine, and Great Lakes ecosystems are compounded by natural drivers (e.g., climate change, natural fluctuations) and associated habitat and biodiversity losses, and shifting species distribution [6–8].

Conventional approaches (e.g., single user sector or single species) to the management of ocean and coastal uses and natural resources have limitations in successfully predicting and addressing variability in resource condition and the outcomes of management actions [3,6]. In this regard, many scientists, managers, and policy experts, as well as marine users and interests, have argued in support of ecosystem-based management (EBM) as a valid, comprehensive strategy to address multiple pressures exerted by human activities on the state of natural resources and ecosystems [9].

EBM is a management approach that integrates across multiple user sectors and that considers the entire ecosystem, including humans.[1] The goal of EBM is to collectively manage natural resources, habitat, and species in a sustainable manner, while

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[1] For the purpose of this study the definition of EBM adopted by the NOP, which was included in the ORAP [19] guidelines, was employed:
"Ecosystem-based management (EBM) is an integrated approach to resource management that considers the entire ecosystem, including humans. It requires managing ecosystems as a whole instead of separately managing their individual components or uses. EBM considers all the elements that are integral to ecosystem functions and accounts for economic and social benefits as well as environmental stewardship concerns. It also recognizes that ecosystems are not defined or constrained by political boundaries. The concept of EBM is underpinned by sound science and adaptive management as information or changing conditions present new challenges and opportunities".

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maintaining ecosystem productivity and resiliency so that it can provide the services humans need and want on a long-time horizon [9]. This strategy differs from traditional approaches that focus on single species, sectors, and activities, in that it considers different aspects of ecosystem management through an integrated and comprehensive approach [9]. To support decision-making, EBM is informed by science and includes as key elements: connections and linkages between and within ecosystems as well as with social and economic systems; cumulative impacts of multiple activities both within and among activities; adaptive management strategies; multiple objectives among services or sectors; and trade-off evaluations [7,10]. As such, EBM is a dynamic, adaptive, and iterative management approach that changes based on the spatial scale (i.e., local, regional, ecosystem) of the natural resource managed [11].

Despite the great potential for better coordinated and integrated management through EBM, and a broad interest in applying this approach in the marine environment [12], there has been limited systematic implementation of EBM in ocean and coastal ecosystems [13]. One reason for this is a lack of knowledge and understanding by managers of the principles and best practices of marine EBM and its implementation [13]. Documenting and sharing the lessons of other efforts to implement EBM would help to address this gap. Specifically, knowing the current state of practice among federal EBM programs in the U.S. will provide natural resource managers from these and other programs a better understanding of how to implement EBM efficiently, effectively, and consistently across the federal government, and in compliance with federal legislative and regulatory authorities. Similarly, this information may guide appropriate or suitable EBM approaches and strategies outside of the federal government.

The primary aim of this paper is to provide a general picture of the current state of practice among the many and varied U.S. federal programs employing EBM approaches in the ocean, coastal zone, and the Great Lakes. The results of this study allow managers to compare their use of marine and coastal EBM with other programs and to identify gaps in knowledge or implementation strategies to enhance their EBM framework. They inform natural resource managers and other stakeholders about EBM implementation within U.S. federal agencies, and will advance the discussion on the best strategies for enhancing marine and coastal EBM implementation. Therefore, this information is not only relevant for individual programs but for federal management as a whole.

After a brief review of the history of EBM adoption and implementation in the U.S. and a description of some examples of marine and coastal EBM programs in the U.S. and worldwide, the research methods are presented, followed by results of the analysis. This paper concludes with a discussion on the implications for implementing EBM strategies within U.S. federal agencies followed by a conclusion describing what considerations this study raises for marine and coastal resource managers.

2. A brief background of marine and coastal EBM history and policy in the U.S.

The absence of an integrated holistic strategy for the management of marine natural resources and their environments was one of the main shortcomings reported by two separate national commissions studying U.S. ocean policy: the Pew Ocean Commission (POC) in 2003 [14]; and the U.S. Commission on Ocean Policy (USCOP) in 2004 [15]. Results from both Commissions called for comprehensive EBM strategies to manage marine resources, and led to a Joint Ocean Commission to monitor implementation of their recommendations [16,17].

Echoing these recommendations, the George W. Bush administration issued Executive Order 13366 (Fed. Reg. 76591, December 21, 2004) to establish a Committee on Ocean Policy. This group established working committees for science and technology and for coordination, although it lacked a legislative mandate and funding to advance ocean policies and programs [17]. In recognition of these efforts and the necessity for a long-term vision, the Interagency Ocean Policy Task Force (OPTF) was established in June 2009 by President Obama. This task force was charged with organizing a comprehensive policy approach to enhance national stewardship of the Nation's ocean, coasts, and Great Lakes, by developing and implementing EBM strategies and recommendations for the long-term conservation and use of national natural resources [17].

Following on the recommendations provided by the OPTF, Executive Order 13547 (Fed. Reg. 43023, July 22, 2010) was signed by President Obama on July 19, 2010, to establish a comprehensive National Ocean Policy to ensure the protection, maintenance, and restoration of the health of ocean, coastal, and Great Lakes ecosystems and resources. This Order establishes EBM as the foundational approach to address conservation, economic activity, users' conflict, and sustainable use of ecosystem services across sectors. To translate this long-term vision into action, the National Ocean Council (NOC) developed a National Ocean Policy Implementation Plan (NOP-IP) [18]. The NOP-IP describes specific actions that federal agencies will take to address key challenges for ocean, coasts, and Great Lakes by adopting EBM strategies. The NOP-IP established a federal interagency subgroup (NOP EBM-Subgroup) to provide policy advice on EBM strategies and technical representation from the federal agencies that are part of the NOC. As a result of this national effort, and in support to the NOC long-term strategy, a guideline to identify strategies and recommendations to advance national implementation of EBM for oceans was released by the Ocean Research Advisory Panel (ORAP) in December 2013 [19]. A key finding of the ORAP is the need for clarity and understanding of EBM's concepts, practices, and principles across participatory groups. This requires federal agencies and their partners to develop and implement a coordinated and integrated set of decision-support tools, training materials and products to enhance EBM strategies, to address inconsistencies in EBM approaches, and to identify effective EBM best practices in support of cross-sectoral federal priorities.

3. Marine and coastal EBM implementation in the U.S. and elsewhere

Many examples of successful marine and coastal EBM implementation exist across the U.S. and internationally, which vary in their spatial scale and the level of cross-sectoral integration. Nevertheless, they offer important lessons for the current efforts to apply regional scale and fully integrated EBM approaches [19].

Chesapeake Bay restoration efforts offer one of the largest and longest running examples of EBM in the U.S. This initiative began in the 1980s and over the years has expanded integrating many state and federal efforts across terrestrial and marine sectors to improve ecosystem health and habitat restoration. In 2009, President Obama signed an executive order establishing the Federal Leadership Committee for the Chesapeake Bay to further coordination and ecosystem-based protection for the bay [19].

The Elkhorn Slough National Estuarine Research Reserve on the central coast of California offers a smaller scale EBM effort; it is a collaboration of the California Department of Fish and Game, NOAA, and a local non-profit organization, the Elkhorn Slough Foundation. The restoration and conservation efforts at Elkhorn Slough are science-based multi-stakeholder efforts, expanding beyond the slough to consider the watershed and the impacts of land use, water-based activities, and the near-shore ocean on the slough's habitats, wildlife populations and economic values (http://www.elkhornslough.org/restoration.htm).

At the international level, the Benguela Current Large Marine Ecosystem Program (BCLMEP) was one of the first attempts for a large scale marine and coastal EBM effort. The objective of the BCLMEP, which ran from 2002 to 2008, was for the three south west Atlantic countries (i.e., Namibia, Angola, and South Africa) signatory members of the Benguela Current Commission to work together in promoting the long-term management of marine and coastal resources of the Benguela Current Large Marine Ecosystem (BCLME). Multiple trans-boundary projects were designed and implemented through an EBM approach to contribute to the integrated and sustainable management of the BCLME (http://www.benguelacc.org/index.php/en/). The knowledge generated by the BCLMEP helped to facilitate the analysis of the interactions between human use and impacts on the marine coastal environment and the ecosystem in the Benguela Current region [20].

The Coral Triangle Initiative on Coral Reefs, Fisheries, and Food Security represents a multilateral partnership of six west-Pacific countries (i.e., Malaysia, Philippines, Indonesia, Timor-Leste, Papua New Guinea, and Solomon Islands) joining their efforts to sustain marine and coastal resources related to the local large coral reef ecosystem. The approach agreed upon in 2009 for their 10-year regional plan of action falls under a marine EBM strategy, with five goals: strengthening the management of seascapes, promoting an ecosystem approach to fisheries management, establishing and improving effective management of marine protected areas, improving coastal community resilience to climate change, and protecting threatened species (http://www.coraltriangleinitiative.org).

4. Material and methods

4.1. Data collection

Data on marine-based EBM programs were collected by means of a questionnaire (available upon request to the authors) developed to identify cases where federal agencies are implementing EBM and/or providing data, information, and training support. The questionnaire was delivered to various federal agencies of the NOC that conduct programs employing EBM components. It consisted of 21 questions on key topic areas of EBM. The first set of questions collected general information on programs' characteristics, including the name of the program, the federal agency in which the program is conducted, and the geographic location and spatial scope of the program (e.g., national vs. regional). Respondents were also asked to provide a short description of the program. Based on this description, programs were categorized into four types: science/research (SR; programs focusing on science and research to support EBM); resource management/extractive uses (RMEU; programs focusing on management of natural resources with primary emphasis on extractive uses); resource management/non-extractive uses (RMNEU; programs focusing on management of natural resources with primary emphasis on protecting species and areas for non-extractive uses); and mission driven (MD; programs focusing on aspects of natural resources and guided by specific challenges and project demands) (see Fig. 1 for further details on the categorization).

For different topic areas in the questionnaire, a breakdown in further categories was used (Table 1).

Additionally, respondents were asked to self-score their program based on how well it aligns with the working definition of EBM used by the NOP[1] (on a 0–5 scale, where 0 = program does not encompass the definition at all, 5 = program perfectly encompasses the definition).

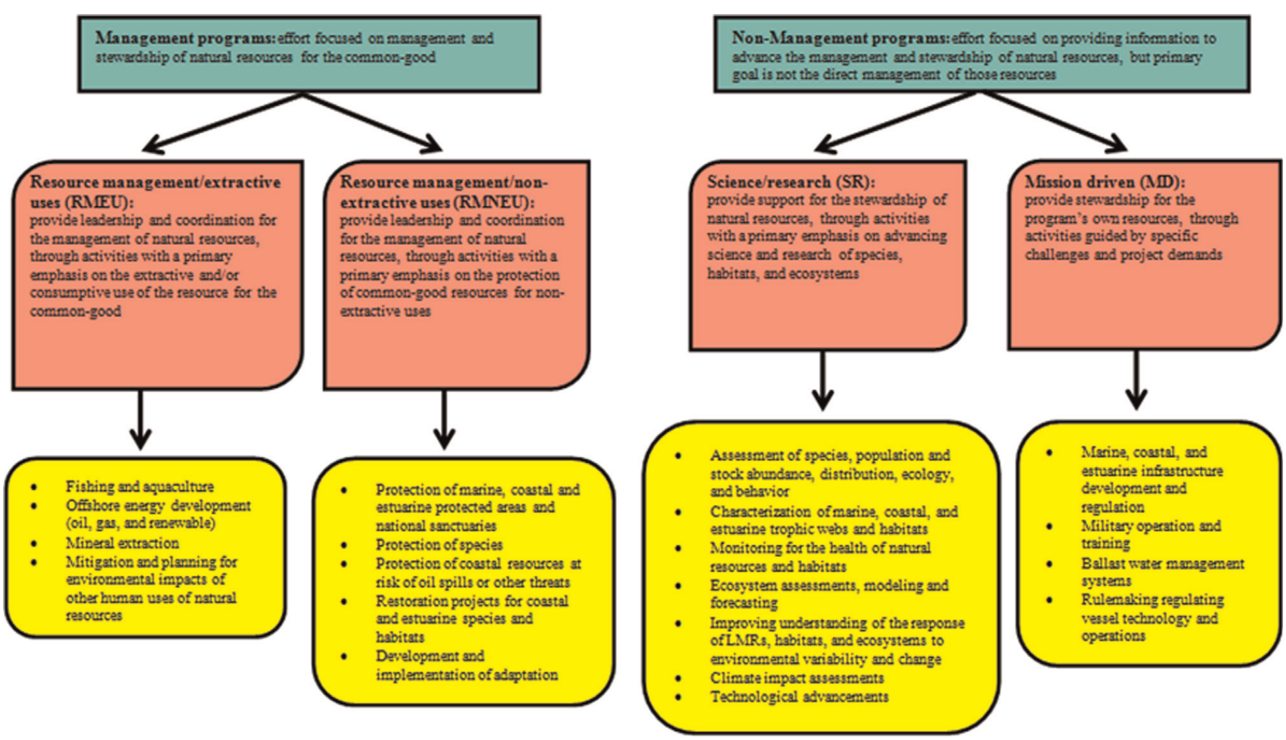

Fig. 1. Programs were partitioned initially into two main categories (green boxes on top of figure): Management and Non-Management; based on the primary goals and objectives of the program (text within the box). Programs were further partitioned into four sub-categories (red boxes at the middle of figure) based on the program primary goals and objectives (text within the boxes): Resource management/extractive uses (RMEU); Resource management/non-extractive uses (RMNEU); Science/research (SR); and Mission driven (MD). Examples of activities managed by programs in each sub-category are included in the yellow boxes at the bottom of the figure.

Table 1
List of categories included in the analysis for each topic area of the questionnaire.

Subject category	Breakdown within categories
Program	Science/Research; Resource Management/Extractive Uses; Resource Management/Non-extractive Uses; Mission Driven
Region	Nationwide; Alaska; Northeast; Pacific Islands; Southeast; West; Great Lakes; Gulf of Mexico and Caribbean; International
Audience	Internal to Agency; Federal Managers; Academia; Public; Private; Tribes; Non-Governmental Organizations; State Agencies; Foreign Governments; Inter-Governmental Organizations; Industries
Partners	Federal; State; Local; Non-Governmental Organizations; Academia; Community; Private; Tribes; Foreign Governments; Inter-Governmental Organizations; Industries
MoU	Federal; State; Local; Non-Governmental Organizations; Academia; Private; Tribes; International
Training	On-line tools; Handbooks; Workshop; Classes; Other Materials
Products	Peer-reviewed Publications; Other Publications; Guidance Documents; Forecasts; Websites; Workshops; Newsletters; Decision/Management Tools; Handbooks; Data; Other Products

4.2. Data analysis

Differences among program self-scoring, which represents how agencies and bureaus perceive their program performance in terms of EBM strategies, were tested for by type of programs with a Kruskal–Wallis single-factor ANOVA and a pairwise Wilcoxon non-parametric test with Bonferroni correction. The analysis used the 0.05 level of significance. The use of non-parametric tests is due to the unbalanced number of programs for each type, which does not guarantee homogeneity of variance and normal distribution. Based on the resulting differences of self-scoring among program type, a permutation ($n=10{,}000$) t-test in Ucinet 6.5 [21] was conducted to test the hypothesis of significant ($P<0.05$), non-random differences between broader categories for program type (see Section 5 for the categories used) and between National and Regional programs.

Social network analysis (SNA) methods were used to analyze and visualize relations and similarities among programs for specific topic areas associated to EBM processes. The use of SNA techniques has proved successful in analyzing common aspects of collaborative processes in marine EBM planning [22,23]. Data to develop EBM networks were analyzed using Ucinet and visualized using Netdraw [24]. Questions on types of: (1) Audience; (2) Partners; (3) MoU; (4) Training; (5) Products; (6) EBM-BMP; and (7) EBM principles were analyzed and visualized separately. The analysis focused on similarities among programs for each aspect of EBM reported by respondents in each of the questions. Initially, for each of these topic areas, a 2-way 2-mode matrix (i.e., affiliation matrix) was developed with programs in the rows and specific subjects in the columns (e.g., types of audience, EBM principles employed, etc.). By employing a binary coding, a value of one was assigned if a specific tie (i.e., relationship) was reported, while a value of zero was assigned otherwise (e.g., if a program reported having Academia as one of its partners, a value of one was assigned for the tie within the matrix). This matrix was used to provide a preliminary visualization of the 2-mode network showing relationships between and among programs for each specific topic area of EBM.

The 2-mode matrix was then converted to a 2-way 1-mode matrix (i.e., adjacency matrix) with the rows and columns indexing the same actors, which in this case were represented by programs. This matrix indicates the level of affiliation, or similarity, between a pair of programs for each specific topic area. The Jaccard similarity index [25] was employed to define the percentage of similarity in ties between programs. The size of nodes in the 1-mode network of program similarities was set arbitrarily to the respective value of betweenness centrality for each node, and the size of ties was set arbitrarily to the magnitude of similarity between programs. Betweenness centrality [26] measures a node's centrality in the network, and is equal to the number of shortest paths from all nodes to all others that pass through the focal node. Betweenness centrality is a measure of the importance of a node in the network, and it is typically interpreted in terms of the potential for a node to control flow of information through the network; that is, playing a gatekeeping role [27].

The 1-mode matrix of Jaccard similarities for each topic area analyzed was used to measure cohesion metrics in the network of similarities among programs. Densely connected nodes are an indication of more cohesive networks, from which it is hypothesized that better information flow between nodes and more productive working relationships can be generated [22,28,29]. Useful cohesion measures in SNA include density and fragmentation. The network's density is the ratio (i.e., proportion) of the number of existing ties over the total number of possible ties between all pairs of nodes [27]. Density is a useful measure of cohesion to compare against networks of similar size [30], which is the case for this study. Fragmentation is defined as the proportion of pairs of nodes that cannot reach each other, and it increases with the number of isolates within the network [27,31].

Finally, a series of permutation tests were performed to measure the association between the different 1-mode networks of program similarities using the Quadratic Assignment Procedure (QAP)-correlation non-parametric procedure in Ucinet, with 10,000 permutations to increase independency. This type of test is useful for hypothesizing that if a pair of actors (in this study, programs) holds a certain type of relationship (e.g., partners), it is more likely they will also have another kind of relationship (e.g., MoU) [27]. The permutation test consists of two steps. In the first step, it computes Pearson's correlation coefficient (r) between corresponding cells (e.g., same program within the two different data matrices). In the second step, it randomly permutes rows and columns (synchronously) of one matrix and recalculates the correlation. The second step is carried out several times ($n=10{,}000$ in this case) to compute the proportion of times that a random measure is larger than or equal to the observed measure calculated in the first step. A low proportion, or significance of the test ($P<0.05$) suggests a strong relationship between the matrices that is unlikely to have occurred by chance [21,27]. The underlying logic of the QAP-correlation is that one can compare the observed correlation between matrices against the distribution of correlations that could be obtained if the two variables were in fact independent of each other [27].

5. Results

5.1. Descriptive results and program self-scoring

The responses to the questionnaire provided data from a total of 62 programs from 13 different federal agencies and bureaus of the NOC (Table 2).

It should be noted that this was not a complete census of all

Table 2
List of all federal agencies and bureaus that participated in the study.

Federal agencies and bureaus
Bureau of Ocean Energy Management
Bureau of Land Management
National Aeronautics and Space Administration
National Oceanic and Atmospheric Administration
National Science Foundation
US-Army Corps of Engineers
US-Coast Guard
US-Department of Transportation
US-Environmental Protection Agency
US-Fish and Wildlife Service
US-Geological Survey
US-National Park Services
US-Navy

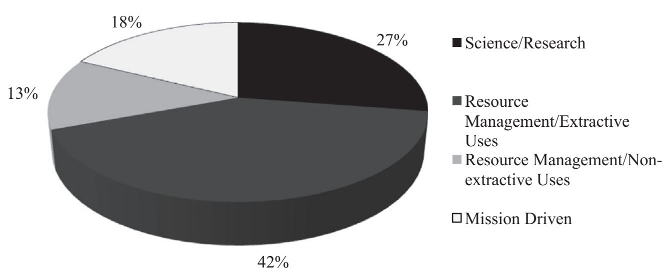

Fig. 2. Questionnaire responses (percentage) by type of EBM-program.

federal marine EBM programs, as the program respondents were determined by each participating agency. The majority of programs reporting (42%) were from the RMEU category, while fewer programs were included in the SR (27%), MD (18%), and RMNEU (13%) categories (Fig. 2).

The geographic distribution included 29 nationwide programs, 11 on the west coast (from Washington to California), 7 in the northeast region (from Maine to North Carolina), 4 in the Great Lakes region, 3 at international level, and 2 each in Alaska, the Pacific Islands, the southeast region (from South Carolina to the Atlantic side of Florida), and the Gulf of Mexico (from Texas to the Gulf side of Florida) and Caribbean region (Fig. 3).

The program self-scoring was significantly different among type of programs ($F_{0,05}=17.9$, df=3, $P<0.01$). The median value for the self-score of MD programs (3) was significantly ($P<0.01$) lower than for RMEU programs (5) and lower ($P<0.05$) than for RMNEU programs (5) (Fig. 4).

This result suggests that MD programs perceived their activities as aligning less with the definition of EBM employed by the NOP compared to other program types. Also, both RMEU and RMNEU programs reported the highest median value (5) for program self-

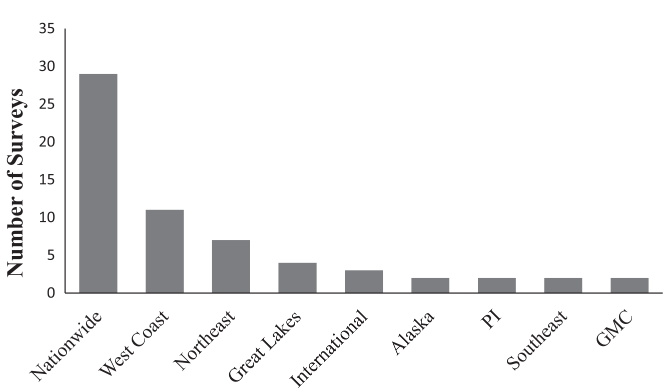

Fig. 3. Questionnaire responses (numbers) by geographic region/area of EBM-programs (PI=Pacific Islands; GMC=Gulf of Mexico and the Caribbean).

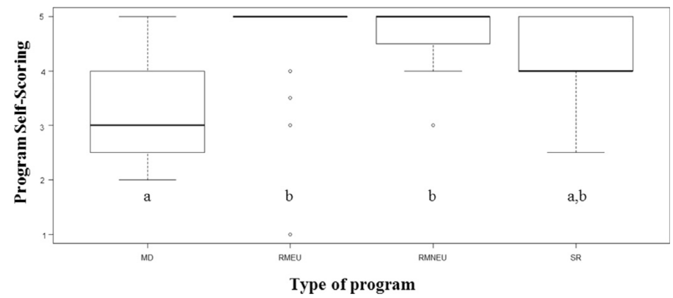

Fig. 4. Box-plot of program self-scoring by type of program (MD=mission driven – $n=11$; RMEU=resource management/extractive uses – $n=26$; RMNEU=resource management/non-extractive uses – $n=8$; SR=science/research – $n=17$). The dark bars within the boxes represent the median, the box dimensions span the range of values from the 25th to the 75th percentiles, the whiskers span the range of values from the 10th to the 90th percentiles, and the dots represent the outliers. Letters at the bottom of the box represent significant differences among groups (ANOVA $F_{0,05}=17.9$, df=3, $P<0.01$).

scoring (Fig. 4).

In light of that, a series of permutation ($n=10{,}000$) t-tests were conducted using the 2-mode matrices to test the hypothesis that "Management" (RMEU and RMNEU) programs have a higher degree centrality than "Non-Management" (MD and SR) programs for each EBM topic area (Fig. 1), and that this result was not significantly random. Degree centrality is measured as the number of ties that a node has within the network [27]. In this study, degree centrality represents the number of relationships that each node has for each topic area (e.g., the number of different EBM-BMP employed by a program, etc.). A higher degree centrality can be interpreted as one program being more central in the network and thus performing better in terms of EBM approaches compared to other programs for the specific topic area tested. Since it was hypothesized that Management programs have a higher degree centrality than Non-Management programs (Fig. 4), the significance level of the test ($0<0.05$) was considered for a one-tail t-test. Results indicate that Management and Non-Management programs significantly differ in their degree centrality for EBM–BMP ($P<0.001$) and EBM principles ($P<0.001$), with programs in the Management category having a significantly higher degree centrality than Non-Management programs, and that this result is not random. Results for permutation t-tests (one-tail) for other topic areas were not significant.

Additionally, a series of permutation ($n=10{,}000$) t-tests were conducted to test for significant (non-random) differences in degree centrality between National and Regional programs. In this case, as specific differences in one direction were not expected, the significance level ($P<0.05$) for a two-tail t-test was considered. Results indicate that Training was the only topic area for which significant ($P=0.017$), non-random differences were found between National and Regional programs, with National programs having a higher degree centrality than Regional programs.

5.2. EBM best management practices and EBM principles

Fig. 5 is a summary of the percentage of use of each EBM-BMP by type of program.

Overall, with the exception for "Other" practices, at least half of the programs within each category reported using each EBM-BMP (smallest response was 45.5% for MD programs employing "Place Based" BMP). By averaging the use over all EBM-BMPs, RMEU programs employed a mean of 87.4% of EBM-BMP, versus 82.5% of RMNEU programs, 72.2% of SR programs, and 63.6% of MD programs. "Ecosystem Science", "Promote Understanding", and "Integrate Scientific and Socio-Economic Data" were the most widely used EBM-BMP among all types of programs (mean=92.3%;

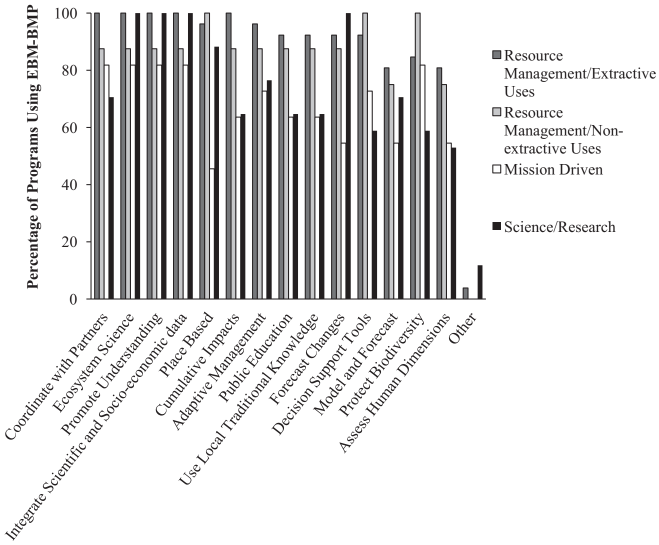

Fig. 5. Summary of use (percentage) of EBM best management practices (EBM-BMP) by type of program. (See Annex 1 for a description of each EBM-BMP.)

range = 100% for SR and RMEU programs to 81.8% for MD programs), followed by "Coordinate with Partners" (mean = 85%; range = 100% for RMEU to 70.6% for SR programs). With the exclusion of "Other", "Assessing Human Dimension" is the EBM-BMP that was least used by all programs (mean = 65.8% over all four types of programs; range = 75% for RMNEU programs to 52.9% for SR programs), followed by "Model and Forecast" (mean = 70.2% over all four types of programs; range = 80.8% for RMEU programs to 52.9% for SR programs).

Fig. 6 is a summary of the percentage of programs using each EBM principle, by program type.

With the exclusion of "Other" principles, each EBM principle was employed by all program types, with at least 63.6% of all types of programs using all eight principles. On average, RMEU programs used 87.6% of all EBM principles, while 84.7% of RMNEU programs, 70.6% of SR programs, and 67.7% of MD programs on average applied all principles. The EBM principle most used among program types was "Ecosystem Resilience" (mean = 92.7% among all four types of programs; range = 100% for RMEU, RMNEU, and MD programs to 70.6% for SR programs), followed by "Place Based" (mean = 90.3% among all four types of programs; range = 100% for RMNEU and SR programs to 72.7% for MD programs). Conversely,

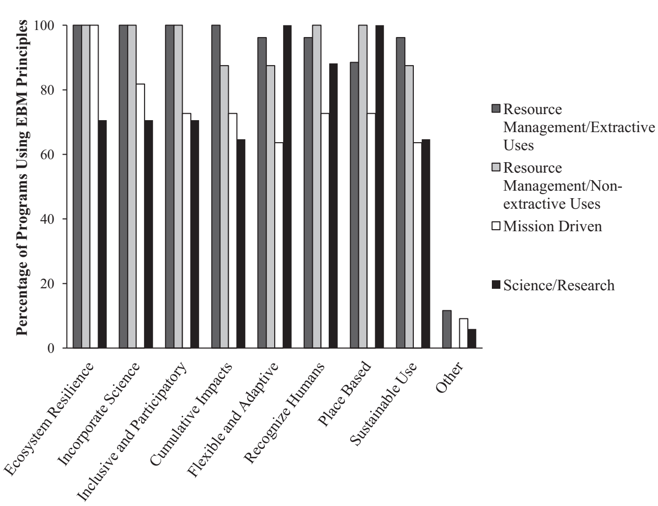

Fig. 6. Summary of use (percentage) of EBM principles by type of program. (See Annex 2 for a description of each EBM principle.)

Table 3
Cohesion measures of network for each topic area in the questionnaire (MoU = Memorandum of Understanding; EBM-BMP = EBM best management practices).

Topical Areas	Network Size (# of nodes)	# of isolates	Density	Fragmentation
Audience	62	1	0.718	0.032
Partners	62	0	0.885	0
MoU	62	32	0.154	0.785
Training	62	19	0.323	0.522
Products	62	1	0.738	0.032
EBM-BMP	62	0	0.999	0
EBM principles	62	0	0.994	0

the least employed EBM principle, with the exclusion of "Other", was "Sustainable Use" (mean = 78% among all four program types; range = 96.2% for RMEU programs to 64.7% for SR programs), followed by "Cumulative Impacts" (mean = 83.1% among all four types of programs; range = 95.7% for RMEU programs to 63.6% for MD programs).

5.3. Cohesion measures and networks

Table 3 presents cohesion metrics for network similarities in each topical area.

The network for MoU (Fig. S6 in supplemental material) had the highest score for fragmentation (0.785), indicating that it is the network with the most disconnected nodes (i.e., less similarity among programs). The Training network (Fig. S7 in supplemental material) also has a fairly high score for fragmentation (0.522) compared to other networks, suggesting a certain level of disconnection among programs and, thus, less similarity in the type of training employed. Also, the MoU and Training networks have the highest number of isolates (32 and 19, respectively), which contributes to increase fragmentation. Conversely, networks for Partners, EBM-BMP, and EBM principles have a score of zero for fragmentation, indicating that these networks are highly dense in terms of all the possible connections between nodes (i.e., high similarity among programs). This result is supported by the high scores for density for these networks, with the networks for EBM-BMP and EBM principles having a score of approximately one (i.e., complete saturation of ties). On the other hand, the networks for MoU and Training have the lowest score for density (0.154 and 0.323, respectively). For further visualization of all 2-mode and 1-mode network similarities for each topic area we refer to figures provided in supplemental material.

5.4. Permutation test (QAP correlation on matrixes of Jaccard similarities)

Table 4 presents results for QAP-correlation between matrix similarities for the seven topical area networks considered in the analysis. (See figures in supplemental material.)

The highest significant correlation (0.83; $P < 0.01$) is between EBM-BMP and EBM principles networks, which indicates that programs' similarities in these two topics are the highest compared to other networks. A positive correlation indicates that the two matrices are related, which in this case supports the hypothesis that programs that employ similar BMPs use also similar principles. Significant ($P < 0.05$), although weak, positive correlations also were found for the programs' similarity between the networks for Audience with MoU (0.12), Products (0.07), EBM-BMP (0.14), and EBM principles (0.14); for the network of Partners with MoU (0.18; $P < 0.01$), Training (0.09), and Products (0.19; $P < 0.01$); for the network of MoU with Training (0.09) and Products (0.11);

Table 4
Pearson's QAP-correlations (r) between programs' similarities (Jaccard index of similarity) with $n = 10{,}000$ permutations (EBM-BMP = EBM best management practices; MoU = Memorandum of Understanding).

Pearson's correlations	Audience	Partners	MoU	Training	Products	EBM–BMP	EBM principles
Audience	–	0.07	0.12*	0.006	0.07*	0.14*	0.14*
Partners		–	0.18**	0.09*	0.19**	−0.06	−0.04
MoU			–	0.09*	0.11*	−0.08	−0.007
Training				–	0.15**	−0.007	0.02
Products					–	0.05	0.05
EBM-BMP						–	0.83**
EBM principles							–

* Significance at $P < 0.05$.
** Significance at $P < 0.01$.

and for the network of Training with Products (0.15; $P < 0.01$).

6. Discussion

This study is not comprehensive of all federal programs using EBM in ocean, coastal and Great Lakes ecosystems in the U.S. The questionnaire was sent primarily to those federal programs thought most likely to be using EBM in each agency. Therefore, the selective nature of programs responding to the questionnaire may result in some bias or artificially high level of agreement. However, we are confident that the analysis resulting from this large subsample of federal EBM programs provides valuable information about general trends in programs similarities for EBM strategies that can be useful for enhancing marine and coastal management planning. Also, there are many paths to EBM, with no specific approach being necessarily better than others. This is because EBM is a dynamic, adaptive, and iterative process that changes based on the spatial scale of the project and according to agency/program goals and objectives [11]. Therefore, differences among programs found in this study are likely dependent on the specific goals and objectives of each program, its regional scope, and agency authorities and mandates. Nevertheless, all EBM strategies are characterized by a common approach, which is framed broadly within a common set of EBM-BMP and EBM principles (Annexes 1 and 2), that consider increased partnership and cross-sectoral collaboration, and acknowledge the simultaneous need to conserve, protect, and use ocean and coastal environments in a manner that maintains the ecosystem health and human well-being for a long-term [11].

Overall, it appears that more federal programs that implement an EBM approach operate at the national level, and regional programs are conducted mainly along the Pacific and Northeast coasts. A more thorough census of NOC agencies conducting marine EBM programs would provide a more comprehensive geographical characterization of federal EBM activities in ocean, coastal and Great Lakes ecosystems.

The differences found between program types indicate that Non-Management programs (mainly MD and, to a lesser extent, SR programs) perceive their EBM activities as aligning less to the definition of EBM used to implement the NOP compared to Management programs. This conclusion is also supported by Management programs employing a larger set of EBM-BMP and EBM principles, and by the significantly higher degree centrality within the networks of EBM-BMP and EBM principles employed by Management programs compared to Non-Management programs.

In general, all federal EBM programs responding to the questionnaire employ a relatively high number of EBM-BMP and EBM principles. In this regard, the high correlation for programs' similarities between EBM-BMP and EBM principles for the QAP-correlation might be interpreted as an indication of the selective nature of programs responding to the questionnaire; requests were primarily sent to the programs thought most likely to be using EBM in each agency.

It appears that "Assess Human Dimensions" and "Model and Forecast" are less commonly employed compared to other EBM-BMP. However, modeling and forecasting are not necessarily common goals for each program, but contingent upon a program specific mission and objectives. In contrast, the employment and integration of human dimension practices in the planning process is a common aspect of EBM programs to facilitate understanding of ecosystem services and management decisions and strategies adopted. This result is in line with previous studies reporting the poor integration of human dimensions aspects in agencies management and planning [6], the weak level of collaboration between natural and social scientists [22], and also with a general asymmetry in the consideration of human systems over natural systems when scientists deal with marine EBM [32]. This finding suggests that federal programs should increase their efforts to employ and integrate human dimension components in their management planning process and activities, which will increase understanding of EBM and result in more effective EBM strategies. In turn, this will increase interdisciplinary and cross-sectoral engagement, which is a key aspect for EBM success. To address this current limitation, social scientists should be engaged from the outset of research and management activities, as they can offer better information on human motivations, needs, cultural heritage, socioeconomic situations, and local expert and indigenous knowledge that can contribute to understanding how people may be affected by management actions [33]. In turn, this information can help in identifying and evaluating trade-offs and reducing conflict [34,35].

Similarly, "Sustainable Use" and "Cumulative Impacts" are the least employed EBM principles among the program respondents. Long et al. [13] found similar results in their recent study analyzing the theoretical literature concerning EBM (both terrestrial and marine-based and not exclusive to the U.S.) to provide a comprehensive list of key EBM principles. In particular, the authors noted that "Consider Cumulative Impacts" was newer to the field of EBM, as it appeared in only three articles (all published after 2007), two of which had a marine focus [13]. These results suggest that federal agencies should increase their training on these important aspects of EBM, which in turn can lead to an increase in the use and integration of these principles in the planning process.

The audience receiving program information or guidance appears to be the most important aspect associated with EBM-BMP and EBM principles when looking at associations between program similarities. This suggests the type of Audience is the main driver for which EBM-BMP and EBM principles a program employs. Also, it appears that programs are less similar in the type of MoU and Training used, with several programs not having any inter-agency and/or partner agreements (Fig. S5 in supplemental material) and not having developed and used Training on EBM strategies (Fig. S7 in supplemental material). However, results from permutation tests suggest that having similar types of Partners and Audience can potentially lead to more MoUs, which can generate more similar Products by programs. In turn, similarities in the types of Partners and Products by programs can potentially lead to similar Training approaches.

A key aspect of planning, implementation, and evaluation strategies to improve EBM [36] is the integration across sectors, which can be improved by partnerships and increased stakeholder engagement in the management process [37]. Increased partnerships allow each sector of human activity to acknowledge how it affects ecosystem structure and function, and ultimately can promote all sectors working jointly toward a common set of regional or ecosystem goals, for example maintaining healthy ecosystems for human well-being in the long-term [11]. In this regard, a crucial aspect for the success of EBM strategies is to effectively integrate multiple perspectives when framing a common goal. In order to do that, more effective communication and exchange of transdisciplinary knowledge is key to a better understanding of the connections between ecological, social, economic, and political components of ocean and coastal ecosystems [11].

At the federal level, training on EBM strategies and approaches can be a valid tool to improve program effectiveness. Programs that currently employ EBM training are mainly nationwide; which suggests that regional programs may benefit from assistance in adapting national trainings to fit the needs of their region. Programs also differ in the format of training, with three distinct categories observed: “In-person” (classes and workshop); “On-line” (on-line tools and handbooks); and “Other” training tools (Fig. S7 in supplemental material). This result suggests that numerous training instruments already exist that may be adaptable to be used by other federal programs, notably the almost two-thirds of federal program respondents that do not have specific training on EBM (Fig. S7 in supplemental material). For instance, on-line tools may be shared to increase collaboration and understanding of EBM activities in other federal agencies. Also, more diversified training can potentially lead to more diversified products. These results indicate the need for greater use of MoUs and more diversified training, which will generate more collaborative partnerships and products to advance marine EBM activities in federal agencies.

Finally, this study illustrates how SNA techniques can be useful to understand commonalities and gaps in the process for marine EBM planning, and how network visualizations can be used as an intervention tool to improve the efficiency of EBM strategies to enhance collaborative processes among stakeholders [22]. The use of 2-mode networks and the analysis of degree centrality and betweenness centrality measures are useful to provide insight into those programs and agencies that are more actively employing and implementing EBM strategies. These active programs can be engaged into strategic partnerships by interested stakeholders. For example, one representative program (number 57, a RMNEU program with a nationwide scope) has a relatively high betweenness centrality in each of the 1-mode networks analyzed (Figs. S2, S4, S6, S8, S10 in supplemental material), which suggests this program may be a key gatekeeper for interdisciplinary and cross-sectoral collaboration and for the exchange of information between other programs in the network. Other programs may take advantage of the lessons learned by this program in the planning and implementation of its EBM activities, and adopt similar strategies as they implement their EBM activities. This exchange of knowledge, expertise, and experience can facilitate the cross-sectoral, integrated, adaptive thinking that is required for applying and advancing EBM strategies and approaches [23].

7. Conclusions

In general, the status of marine and coastal EBM in the U.S. federal agencies is looking promising as indicated by the strong integration of EBM-BMP and EBM principles among all program respondents, although there are aspects that can be improved, including collaboration and cross-sectoral partnerships. However, as Samhouri et al. [35] recognized, the transition to EBM is not fast or simple, but rather gradual and iterative and based on trial-and-error learning.

The cases analyzed indicate that Non-Management programs are fitting less with the working definition of EBM used by the NOP[1] compared to Management programs. Thus, it would be fruitful to ensure that there are more opportunities available for Non-Management programs to engage in the EBM dialogue and communication through increased partnerships and collaboration. Good communication is a key aspect for successful applications of science to management and policy [38,39], while cross-boundary and interdisciplinary collaborations are important to enhance management strategies [40,41].

Therefore, federal programs that implement marine and coastal EBM approaches, mainly MD programs, should increase their level of education, partnerships, training and involvement (e.g., number of MoU) in order to expand their EBM strategies. This objective can be achieved through enhanced cross-sectoral collaboration and training, including increased interagency communication and outreach to stakeholders, possibly drawing from other programs' experience and approaches. This new source of knowledge and information would be essential for programs to widen their use of EBM-BMPs and principles, which will contribute to implement EBM strategies. This increased level of training and partnerships will also promote understanding of less employed practices and principles, such as those dealing with the effects of cumulative impacts of human activities on marine and coastal ecosystems and the importance of integrating human dimensions components into EBM planning. In this regard, more diversified approaches to EBM training, including making online and in-person trainings and training materials available to all relevant federal managers, within and among federal programs can foster the employment of more marine EBM practices and principles.

The advancement of effective EBM strategies relies on scientists, managers, conservationists, and policy-makers bringing together their knowledge and expertise, as we are managing people rather than systems. To confront the challenges of implementing EBM we should keep in mind that management of human activities in marine and coastal ecosystems is about interactions among different spatial and temporal scales, within ecological and social systems, and across stakeholders and interested groups affecting the present and future health of resources [42]. Future research should concentrate on compiling and sharing case studies of regional examples where EBM strategies have been successfully applied and implemented, and focus on the motivations and behaviors of actors within the network that drive specific programs output and performance. Additional research is also needed to define metrics and performance measures to help clarify what successful EBM looks like and how to measure it.

Disclamier

The views expressed in this article are the authors' own and do not necessarily represent the view of NOAA/NMFS or the U.S. Department of Commerce.

A 1
List of EBM best management practices included in the questionnaire. From the following list, respondents were asked to identify all the EBM best management practices that their program employs.[a]

Topical areas	Statement
Coordinate with partners	Build on, engage and coordinate with regional governmental and non-governmental interests to develop explicit, transparent ecosystem management and science plans, goals, and actions that foster the sustainable use of marine, coastal, and Great Lakes resources
Use local traditional knowledge	Incorporate local and traditional knowledge and other sources of qualitative and quantitative data to provide a comprehensive description of ecosystems, and how they are used and valued
Promote understanding	Promote understanding of ecosystem structures, functions, and processes and their importance to ecosystem services and benefits
Assess human dimensions	Assess human decisions and activities to understand why certain decisions are made, what influences those decisions, and how those decisions influence ecosystems and the services and benefits they provide
Place based	Implement place-based, regional ecosystem research to fill information gaps and address uncertainty in a manner consistent with national guidelines
Ecosystem science	Promote comprehensive ecosystem science that comprises and integrates observations, monitoring, research, and modeling
Forecast changes	Assess, characterize, and forecast natural and human-caused changes, including those attributed to a changing climate, in ecosystems at appropriate temporal and spatial scales
Protect biodiversity	Protect biological diversity and species (including human) interactions within and among ocean, coastal, and Great Lakes ecosystems
Model and forecast	Model and forecast ecosystem changes to guide ecosystem management decision-making
Cumulative impacts	Characterize and manage cumulative impacts, whether independent or synergistic, to ensure sustainability of ecosystem services, structure function, and biodiversity
Integrate scientific and socio-economic data	Support decision-making by integrating, synthesizing, using, and disseminating the best available scientific and socio-economic data and local and traditional knowledge
Decision support Ttools	Use decision-support tools to promote objective, transparent management aimed at satisfying ecological, social, economic, and national and homeland security objectives
Adaptive management	Provide the means for adaptive management as deemed necessary based on new information and/or circumstances
Public education	Foster public education, policy, and governance to promote an EBM approach and the stewardship of the oceans, coasts, and Great Lakes
Other	Other

[a] The lists of EBM best management practices (EBM-BMPs) and principles were drafted by consensus after discussion among a federal interagency writing team designated by the National Ocean Council to develop a strategic action plan for the National Ocean Policy (NOP) EBM priority objective. The writing team also developed by consensus the definition of EBM used by the NOP (see footnote 1 in this paper). In drafting an initial list of EBM-BMPs and EBM principles, the writing team drew upon the following list of references: (1) K. McLeod, H. Leslie, Ecosystem-based Management for the Oceans, Island Press, Washington, DC, 2009; and (2) Center for Ocean Solutions (2012). Incorporating ecological principles into California ocean and coastal management: examples from practice. Stanford Woods Institute for the Environment, Stanford University, California.

A 2
List of EBM principles included in the questionnaire. From the following list, respondents were asked to identify all the EBM principles that their program employs.[a]

Topical Areas	Statement
Ecosystem resilience	Supports ecosystem resilience to maintain ecological functions and services
Recognize humans	Recognizes that humans and their activities are an integral part of the ecological system as a whole, and that sustainable use and values are central to establishing management objectives
Place based	Place-based, with geographic areas defined by ecological criteria, and may require efforts at a range of spatial and temporal scales (short-, medium- and long-term)
Sustainable use	Balances and integrates the conservation and sustainable use of ecosystems and their components
Cumulative impacts	Aims to understand, assess, and address the combined, incremental effects (known as "cumulative impacts") that multiple human activities impose upon ecosystems, resources, and communities
Incorporate science	Seeks to incorporate and reflect scientific knowledge regarding natural resources, impacts, etc., as well as expert, traditional, and local knowledge
Inclusive and participatory	Inclusive and encourages participation at all stages by various levels of government, indigenous peoples, stakeholders (including the private sector)
Flexible and adaptive	Flexible, adaptive, and relies on feedback from monitoring and research because ecosystems and human activities are dynamic, the ocean is undergoing rapid changes, and our understanding of these systems is constantly evolving
Other	Other

[a] The lists of EBM best management practices (EBM-BMPs) and principles were drafted by consensus after discussion among a federal interagency writing team designated by the National Ocean Council to develop a strategic action plan for the National Ocean Policy (NOP) EBM priority objective. The writing team also developed by consensus the definition of EBM used by the NOP (see footnote 1 in the paper). In drafting an initial list of EBM-BMPs and EBM principles, the writing team drew upon the following list of references: (1) K. McLeod, H. Leslie, Ecosystem-based Management for the Oceans, Island Press, Washington, DC, 2009; and 2) Center for Ocean Solutions (2012). Incorporating ecological principles into California ocean and coastal management: examples from practice. Stanford Woods Institute for the Environment, Stanford University, California.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.marpol.2015.07.011.

Annex

See Annex Table A 1.
See Annex Table A 2.

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