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Governance characteristics of large marine ecosystems

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ABSTRACT

The Large Marine Ecosystem (LME) concept is widely established as a large-scale approach to coastal and marine management. LME-oriented activities have focused mainly on natural sciences. Socio-economic and governance aspects have only recently been receiving increased attention. The 64 LMEs that have been defined appeared to exhibit considerable diversity in characteristics that would be expected to affect governability. This paper explores two questions: (1) Do the LMEs vary widely enough in geopolitical complexity that different approaches to governance may be required for different LMEs? (2) Are there groups of LMEs within which one might take similar approaches to governance? The analysis demonstrates that there is considerable heterogeneity among LMEs with regard to characteristics that would be expected to affect governability. It concludes that a diversity of governance approaches will be required to cope with this heterogeneity. It also appears that LMEs can be grouped according to these characteristics. This suggests that different approaches could be considered for clusters rather than for individual LMEs and that there can be sharing of experience and learning within clusters. The types of relationships between features of LMEs and the 'best' approaches to marine governance are discussed in the context of emerging governance ideas.

1. Introduction

Large marine ecosystems (LMEs) have been defined as relatively large regions of coastal oceans on the order of 200,000 km^2 or greater, characterized by distinct bathymetry, hydrography, productivity, and trophically dependent populations [1]. Over the past 25 years the LME concept has been used to investigate the problems affecting the world's coastal marine ecosystems, and has had a global impact on how initiatives to address these problems are defined, developed, and funded. The concept has focused attention worldwide on the need to address marine ecosystem issues at a geographical scale that is appropriate to major marine biophysical processes. Attention to LME processes has generated numerous books and articles [e.g., [2,3]]. The LME concept has provided a rallying point for countries to cooperate in dealing with problems relating to the utilization of transboundary resources. This is supported financially by international funding mechanisms such as the Global Environment Fund (GEF). The 64 LMEs have been proposed as ecologically rational units of ocean space in which ecosystem-based management can be applied (Fig. 1).

This attention to LMEs has been underlain by the LME approach, which is based on 5 modules: productivity, fish and fisheries, pollution and ecosystem health, socioeconomics, and governance [4–7]. As usually presented, these modules provide a framework for an indicator-based approach to assessing and monitoring LMEs. As pointed out by Sherman et al. [7], some modules have received more attention in both their conceptualization and practical implementation than others, with the socioeconomics and governance module being the least well developed [8].

In pursuing development of the socioeconomic and governance aspects of the LME approach [9–11] a variety of issues have emerged regarding the way that governance is treated. In particular, there has been the question of how scale issues will be treated. In most LMEs, there is the need for governance arrangements to function across multiple scales (e.g. spatial and jurisdictional) and levels within from local through national to subregional and regional, with links to the global level [12]. There is also the question of whether governance should be partitioned out into a separate module or should be overarching and integrated into each sectoral module [13]. Fanning et al. [12] noted that while the modular approach might be useful as an indicator-based evaluation framework, it provides little guidance on designing interventions for improving governance institutions and processes.

In developing a governance-based LME project for the Caribbean, the above shortcomings in the 5-module approach as

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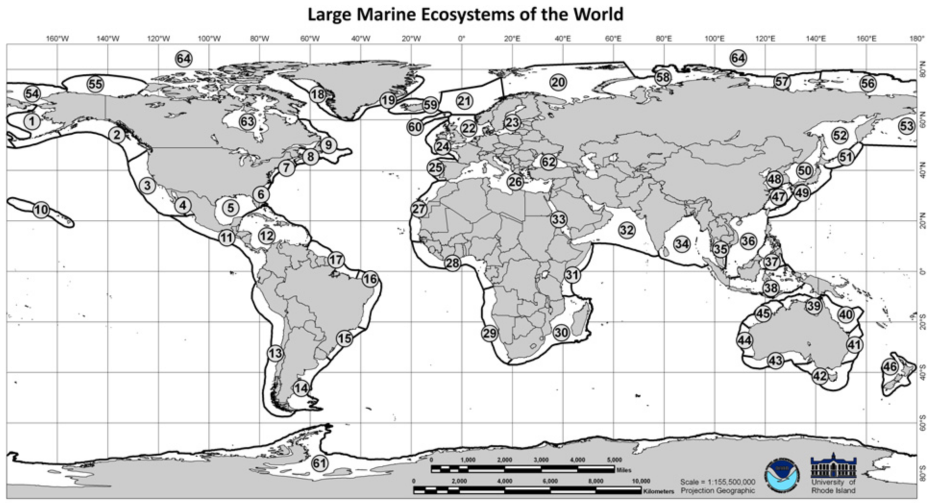

Fig. 1. Large marine ecosystems (LMEs) of the world (http://www.edc.uri.edu/lme/maps.htm).

currently formulated, led to the proposal and adoption of the LME Governance Framework as a basis for effective interventions at the LME level in the Caribbean [12]. Many of the difficulties encountered in attempting to apply the LME modular approach to the Caribbean LME stem from the geopolitical complexity of the Wider Caribbean Region. In developing the Caribbean LME Project and the Large Marine Ecosystem Governance Framework, approaches in other regions of the world were examined and it became apparent that there is a wide variation in the geopolitical complexity of the 64 LMEs. This led us to pose the following questions:

- Do the LMEs vary widely enough in geopolitical complexity that different approaches to governance may be required for different LMEs?
- Are there groups of LMEs within which one might take similar approaches to governance?

This study explores the extent to which the 64 LMEs of the world differ in terms of variables that would be expected to reflect geopolitical diversity and complexity and ultimately, governability. It explores the possibility that there are groupings of LMEs among which different governance approaches or models may be required but within which similar governance approaches may be taken. It is within these groupings of LMEs that exchanges of information on experiences (networking) would be most valuable. Conversely, one would expect that transferability of governance experiences might be least likely between highly different clusters.

2. Methods

All 64 LMEs were included in the analysis (Fig. 1). An LME database was assembled containing the information shown in Table 1, where explanations are provided for the way in which the variables selected might be expected to reflect geopolitical complexity. These variables include geophysical, biological, socioeconomic, and governance descriptor variables of the LMEs. It should be noted that LME boundaries do not correspond to country boundaries. Consequently, assembling information at the LME level is challenging. Spatial analysis using GIS was carried out to derive several of the variables by determining the intersection between the areas of the LMEs and the other features using georeferenced LME boundaries (NOAA. http://www.lme.noaa.gov). Georeferenced bathymetric data were used to determine shelf area, defined as the area of the LME that is shallower than 200 m. Similarly georeferenced data on ecoregions [14] were used to determine the coincidence of these features with LMEs.

For several variables, the mean of the value for the countries in the LME was used as an indicator for the average state for the LME, while the range of the value among countries in the LME was used an indicator of the variability within the LME. Variability among countries is seen as a significant component of complexity. For example, when the countries in an LME range widely in level of development, cooperation among them can be difficult due to issues of capacity, trust, and dominance.

The interrelationships among the variables were explored using principal component analysis (PCA). The aim of this analysis was to reduce the relatively large number of variables into a few composite variables that could be used to define groupings of LMEs and the characteristics of the groupings. The composite variables derived from the factor analysis were used to cluster the LMEs. The K-means clustering method using Euclidean distance was used to produce four levels of clustering with 12, 7, 5, and 3 clusters. This was done in two ways: (1) with variable means being used to replace missing data, and (2) with cases that had missing data removed. The only instances of missing data were for fishery variables in 6 LMEs (Chukchi Sea, Beaufort Sea, East Siberian Sea, Laptev Sea, Kara Sea, Hudson Bay, Arctic Ocean) and governance indicators in 1 LME (Antarctica). The clusters produced at these four levels were compared to determine which level might be most interpretable and useful.

Table 1
The variables used in the analysis of LME governability.

Variable	Description and purpose
LME number	The name and identification number assigned to the LME as shown in Fig. 1
LME name	
LME area	The area of the LME (km^2). A larger LME is assumed to be more difficult to govern.
High seas area	High seas areas (km^2) in an LME adds to the complexity of issues that countries must address (total and proportion)
Shelf area	Shelf areas (km^2) are most productive and generally support the most diverse human uses. Thus it is assumed that the greater the shelf area, the more difficult the LME will be to govern[a].
Coastal countries	The greater the number of countries that have to collaborate in governing of the LME the more complex governance will be.
State entities	State entities include countries (above) as well as territories of countries the main part of which may be outside the LME. State entities may be semiautonomous and have their own EEZs.
Official languages	The greater the number of official languages, the more difficult collaboration is likely to be. (https://www.cia.gov/library/publications/the-world-factbook/).
Country–country maritime boundaries	The more maritime boundaries there are, the greater the difficulty in defining governance space and collaboration (based on EEZ maps at http://w2.vliz.be/vmdcdata/marbound/geointerface.ph).
Country to high seas maritime boundaries	
SIDS	The number of Small Island Developing States in the LME. As SIDS generally have lower capacity for governance and are more vulnerable to a variety of impacts, it is assumed that the higher the number of SIDS in an LME the more difficult and complex governance will be. The UN designation of SIDS was used [36] and http://www.sidsnet.org/.
Mean state area	The mean land area of states within the LME
Mean EEZ area	The mean area of EEZs within the LME
Percentage of population living within 100 km of coast	Indicates the importance of coastal and marine systems to the country and likely human impacts on these systems http://earthtrends.wri.org/country_profiles/index.php?theme=1.
Population	The total population of countries in LME. The higher the population in an LME (1) the more demand there is likely to be for use of marine space and products, and (2) the more impact there is likely to be from land-based sources.
Small-scale fisheries	LMEs were assigned a score of 0–5 based on the authors' assessment of the importance of small-scale fisheries (SSFs) in the LME. Data for a consistent objective assessment of SSF across all LMEs could not be found so the assessment relied on FAO country profiles (http://www.fao.org/fishery/countryprofiles/search) and [37]. SSF are more difficult to manage than commercial fisheries; so a higher score is assumed to indicate governance complexity and difficulty.
Ecoregions	The marine ecoregions [14] are intended to reflect areas of discrete marine biodiversity. The number of these in the LME is assumed to indicate the diversity of marine ecosystems and thus the complexity and difficulty of governance, especially ecosystem-based management[b].
Seamounts	The proportion of the world's seamounts and coral reefs are considered to be indicators of biodiversity and thus the complexity and difficulty of governance, especially ecosystem based management (http://www.seaaroundus.org/lme/lme.aspx).
Coral reefs	
Primary production	Primary productivity in and river discharge into the LME are assumed to be indicators of higher-level productivity the harvesting of which will require governance (http://www.seaaroundus.org/lme/lme.aspx).
River discharge	
Number of fish species	The number of fish species is an indicator of both biodiversity and the likely complexity of fisheries (http://www.seaaroundus.org/lme/lme.aspx).
Small pelagics	The average annual landings of fish in these categories indicate the degree of importance of fisheries and the likely challenges that will be faced in fisheries governance. Four combined categories and a total were created from the initial 11 categories (http://www.seaaroundus.org/lme/lme.aspx)
Medium pelagics	
Large pelagics	
Medium bathypelagics	
Large bathypelagics	
Small demersals	
Medium demersals	
Large bathydemersals	
Shrimps	
Cephalopods	
Lobster and crabs	
Total demersals	
Total pelagics	
Total bathyal	
Total landings	
Fishery diversity	An index of the diversity of fisheries to be dealt with in the LME was created from the 11 categories of landings using Simpson's index of diversity.
Mean GDP	Mean GDP of countries/state entities in LME. GDP is taken as an indicator of the level of development of the countries in the LME. The mean is taken as an overall indicator for the LME and the range as an indicator of the diversity of development levels among states https://www.cia.gov/library/publications/the-world-factbook/.
Voice and accountability	World Bank governance indicator that measures the extent to which a country's citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association, and a free media [38].
Political stability and absence of violence	World Bank governance indicator that measures perceptions of the likelihood that the government will be destabilized or overthrown by unconstitutional or violent means, including domestic violence and terrorism [38].
Government effectiveness (GE)	World Bank governance indicator that measures the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies [38].
Regulatory quality	World Bank governance indicator that measures the ability of the government to formulate and implement sound policies and regulations those permit and promote private sector development [38].
Rule of law	World Bank governance indicator that measures the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, the police, and the courts, as well as the likelihood of crime and violence [38].
Control of corruption	This World Bank governance indicator measures the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests [38].

[a] Two Minute World Bathymetry and Topography, Environmental Data Center, University of Rhode Island, Kingston, RI and NOAA National Marine Fisheries Service http://www.lme.noaa.gov.

[b] http://conserveonline.org/workspaces/ecoregional.shapefile/MEOW/view.html.

3. Results and discussion

3.1. Input variables

Distributions of some of the key variables are shown in Fig. 2. These examples illustrate the level of heterogeneity among the LMEs. Clearly, this is a very preliminary analysis based on available information. Some of the indicators used could be refined, such as population living near the coast or in watersheds draining into the LME. The incidence of urban aggregations would also seem to be relevant as these present both challenges in terms of impacts on oceans, as well as opportunities as governance

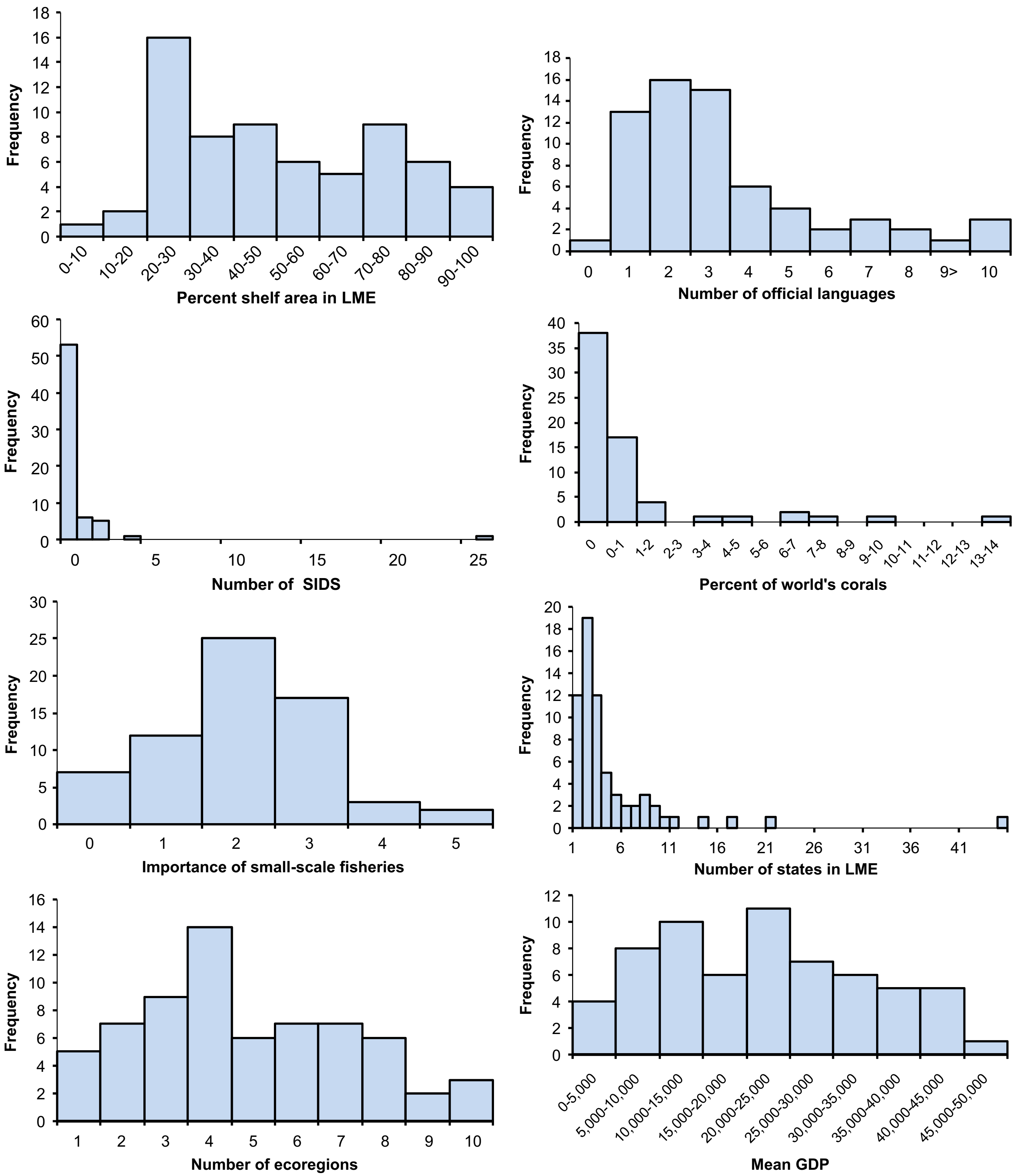

Fig. 2. Frequency distributions of selected variables illustrating the heterogeneity of LMEs.

entities within the LME. No doubt there are other critical types of information that would be useful in exploring governability. These might include:

- physical information such as coastline length;
- economic information such as estimates of the value of productive sectors other than fisheries—namely tourism and oil and gas industries;
- information on the status of resources, habitat degradation, and pollutions, which would relate to the likelihood of system response to governance reforms; and
- political/institutional information at the regional level such as the existence and effectiveness of institutions that could play a role in ocean governance.

It is our hope that as ocean governance increasingly focuses on large marine areas [15] these kinds of information will become increasingly available at spatial scales (either through aggregation or disaggregation) that match proposed management scales to facilitate further analyses of governability.

3.2. Derivation of composite variables

The initial PCA was carried out using varimax rotation (which converged in six iterations) with Kaiser normalization and the scree test was used to select the number of components. The first three principal components (PCs) account for 47% of the total variance and were interpreted as follows. On PC1, LMEs that scored high had countries among which there is a high range of values for World Bank governance indicators as well as GDP, percent of population living in the coast, and area of country in the LME. These will be LMEs that include a mix of developed and developing countries. On PC2, LMEs that scored high had countries with high scores for World Bank governance indicators and high GDP. These are mainly LMEs adjacent to developed countries. On PC3, LMEs that scored high had many state entities, many SIDs, many maritime boundaries, high proportions of the world's coral reefs and sea mounts, and a prevalence of small-scale fisheries. In summary, LMEs that score high on principal components 1 and 3 and low on principal component 2 are likely to be the most difficult to govern and vice versa.

Based on the initial PCA described above, it was decided to analyze groups of variables separately to create more interpretable composite variables that could be used to cluster the LMEs. PCA with varimax rotation using the scree test to select the number of components to be rotated, was used to analyze three groups of variables: (1) the fishery variables, (2) the sociopolitical variables, and (3) LME descriptor variables. The results of these analyses in Tables 2–4 show the variables included and their loadings on each of the PCs. High loadings indicate a strong positive correlation with the PC and vice versa. In interpreting these variables, the loadings of 0.5 and above are viewed as meaningful, and these are shown in bold type. Seven composite variables were derived from these three analyses using the PCs in each case that contributed to a significant proportion of the total variance in the data. These seven variables were used in subsequent analyses and are named and described in Table 5.

For the analysis of the nine fishery variables, the two PCs accounted for 90% of the total variability (Table 2), The first PC

Table 2
The PCA used to derive two composite fishery variables for LMEs.

Fishery variables	PC1	PC2
Total demersals	**0.951**	0.238
Lobster and crabs	**0.950**	0.154
Total bathyal	**0.925**	0.253
Cephalopods	**0.921**	0.273
Shrimps	**0.898**	0.287
Large pelagics	**0.867**	0.143
Small pelagics	0.586	**0.645**
Total landings	0.504	**0.860**
Medium pelagics	−0.012	**0.980**
Percent of variance explained	62.9%	27.1%

Table 3
The PCA used to derive three composite socio-political variables for LMEs.

Socio–political variables	PC1	PC2	PC3
Range control of corruption	**0.915**	−0.206	0.196
Range rule of law	**0.901**	−0.311	0.193
Range government effectiveness	**0.885**	−0.320	0.244
Range regulatory quality	**0.820**	−0.385	0.286
Range GDP	**0.787**	0.063	0.258
Range area of country in LME	**0.695**	0.069	−0.114
Range political stability	**0.682**	−0.336	0.376
Mean rule of law	−0.146	**0.973**	−0.047
Mean government effectiveness	−0.187	**0.967**	−0.099
Mean control of corruption	−0.183	**0.962**	−0.033
Mean regulatory quality	−0.204	**0.957**	−0.067
Mean political stability	−0.093	**0.934**	0.017
Mean GDP	−0.106	**0.854**	−0.147
Small-scale fisheries	0.169	**−0.583**	**0.517**
State entities	0.243	−0.103	**0.944**
Maritime boundaries	0.247	−0.033	**0.942**
Number of SIDS	0.096	0.010	**0.884**
Number of official languages	0.389	−0.165	0.390
Percent of variance explained	28.5%	34.5%	19.2%

Table 4
The PCA used to derive two composite LME descriptor variables.

LME descriptors	PC1	PC2
LME area	**0.850**	0.266
Ecoregions in LME	**0.844**	0.055
Shelf area	**0.816**	0.006
Proportion of worlds seamounts	**0.667**	0.001
Proportion of worlds coral reefs	**0.648**	−0.264
Number of fish species	**0.625**	−0.445
Mean area of country in LME	−0.129	**0.800**
Mean area of EEZs in the LME	0.345	**0.769**
Primary production	−0.371	−0.454
River discharge	0.230	−0.388
Area of High Seas	0.301	0.009
Percent of variance explained	34.2%	17.5%

Table 5
Names and descriptions of seven composite variables derived from PCAs of three sets of variables.

Composite variable	Variable name	Variable description
Fishery 1	Demersal/deep fisheries	Catches of demersal and bathyal species
Fishery 2	Small/medium pelagic fisheries	Catches of medium to large pelagics and overall
Sociopolitical 1	Sociopolitical diversity	Range in World Bank governance indicators and GDP among countries
Sociopolitical 2	Strength of governance	Mean of World Bank governance indicators and GDP among countries
Sociopolitical 3	States and SIDS	Many states, SIDS and boundaries
LME descriptor 1	Size and biodiversity	LME size and biodiversity indicators
LME descriptor 2	Country/EEZ size	Size of countries and their EEZs making up LMEs

included all the demersal and bathyal resources as well as large pelagics. The second PC included small and medium pelagics and total landings.

For the analysis of the 18 sociopolitical variables, three PCs accounted for 82% of the variability in the data (Table 3). The variables with high loading on the first PC were the ranges in the governance indicators, the range in GDP, and the range in country size. LMEs scoring high on this PC would have high variability in all these variables and were viewed as sociopolitically diverse (Table 5). The second PC consisted of the means of the governance indicators and GDP. LMEs scoring high on this PC would have strong governance systems (Table 5). The third PC consisted of variables relating to numbers of states, maritime boundaries, and SIDs. LMEs with a high score on this PC would be high in these variables (Table 5). In this analysis of sociopolitical variables, the indicator for importance of small-scale fisheries had a high negative loading on PC2 and a slightly lower positive loading on PC3. This indicates that they tend to be more important in low governance, low GDP LMEs as well as in LMEs with many states and SIDS.

The third analysis, using 11 variables considered to be LME descriptors resulted in two PCs that accounted for 52% of the variability. The first PC consisted of LME area and shelf area as well as four variables that could be considered as indicators of high biological diversity (Table 5). The second PC consisted of only two variables—the mean country size and the mean EEZ size. Three of the variables used – primary production, river discharge, and area of high seas – did not associate with any PC (Table 4).

3.3. *Clustering LMEs*

The results for clustering with missing data replaced by means and with cases having missing data removed from the analysis produced very similar groupings of LMEs in the clusters. Therefore it was decided to use the results from the analysis with missing data replaced by means. This allowed for the inclusion of the 6 LMEs with missing fishery data and Antarctica. Comparison of the four cluster analyses indicated that the analysis producing seven clusters would be most useful in demonstrating the major differences among groups of LMEs with regard to the selected variables (Table 5). The 3 and 5 Cluster analyses did not provide sufficient discrimination among groups of LMEs, while the 12 Cluster analysis broke the smaller clusters in the 7 Cluster analysis up into clusters with only 1 or 2 LMEs, rather than breaking up the larger clusters, indicating that the majority of the heterogeneity in the data set remained in the smaller clusters.

For the 7 Cluster analysis, the differences among the clusters with regard to the composite variables (principal component scores) demonstrate how the variables appear in different combinations in the clusters (Fig. 3). In Fig. 3, the seven vertical bars for each cluster indicate the average strength (for LMEs in the cluster) of the seven composite variables in Table 6. These variables are principal component scores and therefore have an average of zero. This figure illustrates the diversity in combinations or suites of characteristics that may affect governability in LMEs. Closer examination of these suites of characteristics in the clusters of LMEs provides a perspective on the types of differences among the LMEs that might have a bearing on their governability and on the types of governance approaches that may be appropriate (Fig. 3).

In the cluster analysis, the characteristics of the clusters can be summarised as follows, with the LME composition of each cluster being shown in Table 5 and the geographical distribution of the LMEs in Fig. 4:

- the most prominent characteristics of the 36 LMEs in Cluster 1 are high GDP and governance indicators and low sociopolitical diversity. They consist of a few large countries with large EEZs and being largely temperate and polar. Biodiversity is lowest in this cluster and both the demersal/deep and the small/medium pelagic categories of fisheries resources are also low;

Table 6
The LME composition of the clusters in the cluster analysis.

	7 cluster analysis
1	22 LMEs—Gulf of Alaska, Southeast US Shelf., Northeast US Shelf, Scotian Shelf, Newfoundland-Labrador Shelf, Insular Pacific-Hawaii, West Greenland, East Greenland, Norwegian Sea, North Sea, Celtic-Biscay, Iberian Coast, Southeast Australian Shelf, Southwest Australian Shelf, West-Central Australian Shelf, New Zealand, Beaufort Sea, Iceland Shelf, Faroe Plateau, Hudson Bay, Arctic Archipelago, Baffin Bay/Davis Strait
2	19 LMEs—Gulf of California, Pacific Central, South Brazil, East Brazil, North Brazil, Canary Current, Guinea Current, Benguela Current, Agulhas Current, Somali Coast, Red Sea, Bay of Bengal, Gulf of Thailand, Sulu-Celebes Sea, Indonesian Sea, East Siberia, Laptev Sea, Kara Sea, Black Sea
3	4 LMEs—Arabian Sea, South China Sea, East China Sea, Yellow Sea
4	2 LMEs—Caribbean Sea, Mediterranean Sea
5	16 LMEs—East Bering Sea, California Current, Gulf of Mexico, Patagonian Shelf, Barents Sea, Baltic Sea, North Australian Shelf, Northeast Australian Shelf, East-Central Australian Shelf, Northwest Australian Shelf, Kuroshio Current. Sea of Japan, Oyashio Current, Sea of Okhotsk, Chukchi Sea, Arctic Ocean
6	2 LMEs—West Bering, Antarctic
7	1 LME—Humboldt Current

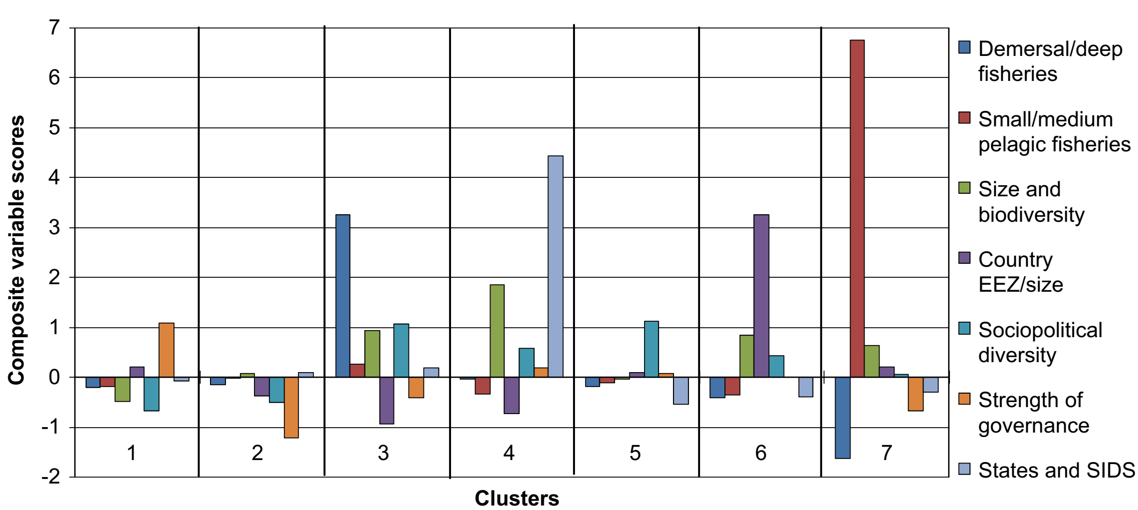

Fig. 3. The relative strengths of the seven composite variables (Table 5) in the seven clusters of LMEs derived by cluster analysis.

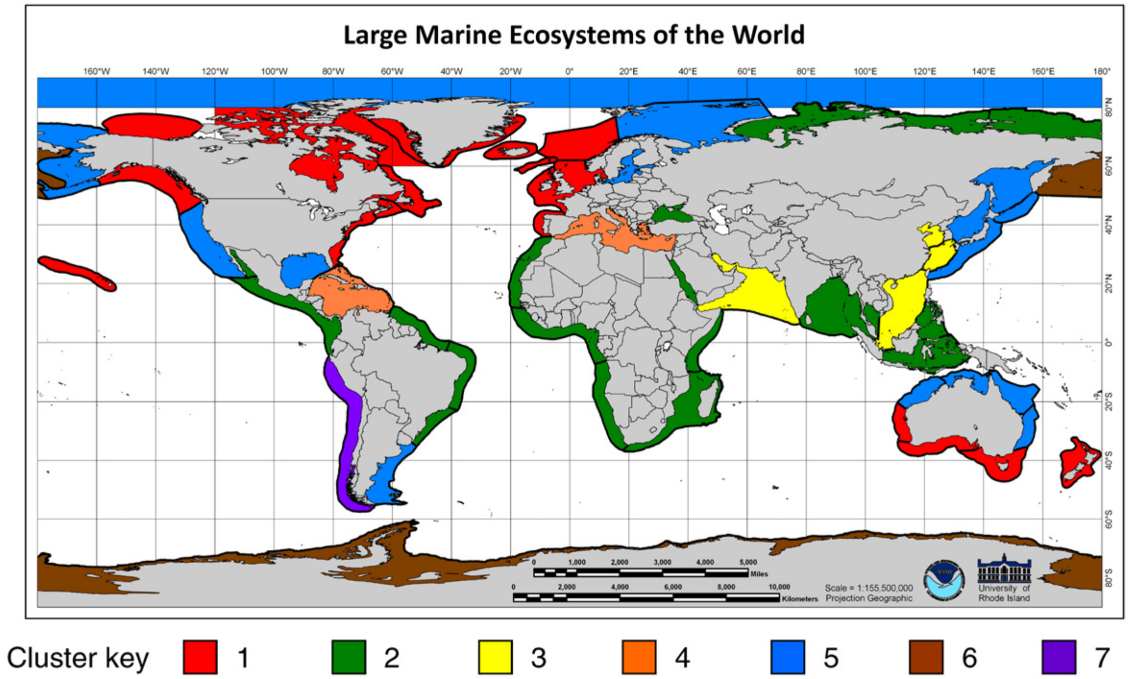

Fig. 4. The geographical distribution of the LMEs in the cluster analysis producing seven clusters (cluster numbers correspond to those in Fig. 3 and Table 6) (see Fig. 1 for a key to the LMEs).

- the strongest characteristic of the 22 LMEs in Cluster 2 is the very low average scores for GDP and governance indicators that are consistently low across all countries in the LME. These LMEs characteristically have a moderate number of small countries. They are also relatively low as regards fishery resources in both categories;
- the strongest characteristic of the 4 LMEs in Cluster 3 is high demersal fishery production. These LMEs also characteristically have relatively few countries with small EEZs, low GDP, and governance indicators. There is high sociopolitical diversity among countries and high biological diversity of ecosystems, as they are largely tropical;
- the most marked characteristics of the 2 LMEs in Cluster 4 are that they have many countries with small EEZs and with a relatively high number of SIDS. There is also the highest biodiversity in these LMEs. In these 2 LMEs, governance indicators and GDP are higher than average and also diverse among countries. However, there is a low fishery resource base;
- Cluster 5 with 16 LMEs is marked by the highest sociopolitical diversity and the lowest numbers of SIDs and states. These are generally LMEs with a few very different countries in them. They have slightly lower than average fish catches and biodiversity and slightly higher than average country/EEZ size and strength of governance;
- Cluster 6 with 2 polar LMEs is characterised by very large country/LME size but few countries. Biodiversity is moderately high but fishery catches are lowest among all clusters;
- Cluster 7 consists of a single LME-Humboldt Current. The strongest characteristics are very high pelagic fish catch and very low demersal fish catch. It is also the second lowest with regard to GDP and governance variables.

3.4. Governability of clusters

The differences among clusters of LMEs regarding the suites of characteristics that they display take us back to the two questions posed in the introduction. These concerned the implications for approaches to governance of both the differences and the similarities in LME complexity. In order to address them, the suites of characteristics are examined from the perspective of various governance models. Among these is the conventional model characterized by a top-down, command and control governance in which governments and intergovernmental organizations take the lead in preference to more people-centered alternatives [16]. At the scale of LMEs, this approach is typically reflected in the diversity of regional fishery management organizations (RFMOs) that have been established with varying capacity and success [17,18]. Recently, fisheries governance thinking has broadened to include a broader range of stakeholders and interactions [19,20]. Others have extended this thinking to all social ecological systems (SESs) [21]. These and other authors have also placed increased emphasis on the principles that underlie fisheries and ocean governance and on the need to pay particular attention to developing them and ensuring that they are shared, or at least understood, among stakeholders [22].

Increased awareness that SESs are typically complex, subject to externalities and unpredictable, has led to new perspectives on the need to make them resilient through adaptive governance arrangements [21,23–25]. There are many dimensions to building adaptive, resilient SESs, including the capacity to both detect imminent change and to respond appropriately and the literature on this topic is expanding rapidly [26,27]. Depending on context, these mechanisms may be highly technical and/or costly or the converse. Such systems require careful analysis of, and attention to, the institutional arrangements for governance, both formal and informal [24,28]. Hence, there has been increased attention to topics such as social capital and social networks and their relationship to governance [29–31]. In highly complex SESs with low capacity and low resources, approaches may lean towards the promotion of self-organisation through enabling support often labeled ‘capacity building’ [13,32].

In the context of the above trends in governance thinking, ideas of governability and the conditions that promote or reduce governability have been developing [33,34]. In this context, the suites of characteristics displayed by the LME clusters are examined to determine whether differences among them would likely lead to different governance approaches for different clusters. The feasibility of pursuing principled ocean governance in each cluster is also considered. For example, in some clusters, there may need to be more of a focus on establishing principles before moving to practice.

The LMEs in Cluster 1 are considered to have high governability in that they are among the least complex LMEs with a highly functional institutional environment and capacity for governance. This, coupled with low heterogeneity among countries, will probably reduce the likelihood of conflict. These LMEs would probably be most amenable to conventional hierarchical governance through interplay of national/international instruments, supported by strong technical inputs. The countries of these LMEs are also those most likely to have the enforcement capacity required for this approach. The authors of this paper are not advocating this governance approach for these LMEs, as it has proven to be flawed in many situations [35]; the indication is simply that these are the LMEs where this approach would have the greatest chance of success.

The LMEs in Cluster 2 are considered to have low governability in the sense that at the national level, governance is not functional. Therefore, governance institutions and political will for ocean governance will face greater challenges than in all other clusters. The chances of implementing principled ocean governance are probably lowest in these LMEs. In this broader context of low capacity for governance, one might focus on building and linking local institutions that are resistant to corruption and political interference. One might take an opportunistic approach to pursuing conservation projects at scales where conditions are favorable, through suites of linked projects rather than at whole system levels. That would be a focus on the development of local policy cycles and lateral linkages in the LME Governance Framework [12].

The LMEs in Cluster 3 are also considered to have low governability, but there is heterogeneity among countries in governance indicators. This suggests that in each LME, there are some countries that can take the lead in promoting good governance and in taking responsibility for regional level institutions. The relatively high importance of marine fisheries also suggests that attention to ocean governance might receive higher priority. There is the opportunity to use their socioeconomic value to promote and support ocean governance reforms. As with Cluster 2, success from an opportunistic approach is likely at scales where conditions are favorable, through suites of linked projects rather than at whole system levels. Here, while there remains a focus on local level policy cycles and lateral linkages, national policy cycles in suitable countries can provide the beginnings for vertical linkages and an incipient LME Governance Framework.

The LMEs in Cluster 4 are also considered to have low governability, but this stems more from diversity and dynamics than from dysfunctional governance at national levels. Many of the small countries do have weak governance but traditions of subregional cooperation provide a means to address these shortcomings. The relatively low value of the fishery resource base does not provide substantial revenue for high-cost technical or enforcement inputs. In these LMEs, full implementation of the LME Governance Framework, leading to multi-level network governance, would probably be the most effective means of achieving LME level ocean governance.

LMEs in Cluster 5 are considered to have moderate governability. It is posited that the high sociopolitical diversity will hamper governance efforts. However, the presence of slightly higher than average strength of governance and generally larger countries suggests that, even more so than is the case in Cluster 3, there are high-capacity countries that can take the lead in promoting and facilitating ocean governance.

This analysis is not extended to Clusters 6 and 7, which are essentially 2 and 1 LMEs, respectively.

4. Conclusions

This analysis has demonstrated that there is considerable heterogeneity among LMEs with regard to characteristics that would be expected to affect governability. It is therefore likely that a diversity of governance approaches will be required in order to cope with this heterogeneity. It also appears that LMEs can be grouped according to these characteristics. This suggests that different approaches could be considered for clusters rather than for individual LMEs and that there can be sharing of experience and learning within clusters. The types of relationships between features of LMEs and the 'best' approaches to marine governance need to be further investigated. Some of the differences in approach that may be required are proposed based on emerging ideas on governance and governability.

This analysis illustrates the type of broad interdisciplinary approach to evaluating governability that will be required if progress is to be made in developing appropriate frameworks for interventions at the level of large-scale marine areas, whether they be LMEs or some other large-scale unit [15]. There is the need for considerably more exploration of the interrelation of these types of governability related variables and even the development of new indicators. These will have to be innovative to capture institutional arrangements for governance that encompass the new and emerging thinking on resilience building in SESs, as well and conventional approaches.

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