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Turning the wheel away from biophysical indicators in coastal zone management: Towards a stakeholder-based systemic framework

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ABSTRACT

Coastal zone management is a pressing matter, especially in developing countries, which are highly vulnerable to the effects of climate change. Human systems are underrepresented in the vast array of indicators aimed at assisting coastal zone management decisions. Clearly, there is room to better capture natural and human system relationships and interactions in coastal area assessments. A case in point is the well-known Coastal Hazard Wheel (CHW). Hence three main objectives guide this paper: (i) Analysing the existing set of indicator themes and categories in coastal areas; (ii) Contrasting this set of indicators with the perceived needs of local coastal stakeholders from a developing country; and (iii) Proposing indicator categories to be included as part of a systemic coastal zone management framework. To this end, we undertook an automated content analysis of 1116 peer-reviewed articles on the subject matter. The analysis and a stringent set of criteria led to 40 articles that were reviewed to identify suitable indicators. In parallel, field research in Ghana allowed for a set of indicators from the quadruple helix stakeholders operating in coastal zones to be elicited. Contrasting the two sets of indicators resulted in three situations. The first involves 14 indicator categories that co-occur in the literature and the detected needs from local coastal stakeholders. In the second situation, the categories mentioned in the literature were those not mentioned at local level. A third situation appeared when the local coastal stakeholders mentioned categories of indicators that were not identified in the reviewed literature. After examining each case, we advocate for the indicators in the first situation to be incorporated into the current coastal indicator monitoring frameworks (for example by upgrading the CHW). The unique contribution of this paper is the combination of literature and stakeholder-based indicator sub-categories that should be added to the current set of coastal monitoring frameworks.

1. Introduction

More than half of the world's population live up to 200 km inland from the coastline, a number that is set to double by 2025 (Inácio et al., 2018; Micallef et al., 2018). This stands to reason as coastal zones contain the most productive habitats around the globe (Eriksen and Silva, 2009) adding to the attraction for human settlement taking advantage of livelihood opportunities in these areas (Barragán and de Andrés, 2015).

However, the latest report from the Intergovernmental Panel on Climate Change (IPCC) suggests that the global mean sea level rise is accelerating (Oppenheimer et al., 2019). Moreover, non-climatic anthropogenic drivers –including rapid urbanisation in coastal areas and growth of megacities are adding to the pressure on coastal communities. Specifically with regards to exposure and vulnerability to the accelerated sea-level rise and extreme weather events (Stronkhorst et al., 2018).

Coastal areas are consequently progressively affected by climate change (Appelquist and Balstrøm, 2015; Appelquist and Halsnæs, 2015; Kronen et al., 2010; Zhu et al., 2010). The disruptive impacts are particularly challenging for developing countries where planning in coastal development is often lacking (Wong et al., 2014). Further compounding this issue, coastal migration has largely taken place in flood and cyclone-prone areas exacerbating the impacts from climate change (de Sherbinin et al., 2011).

Natural and human systems in coastal areas are extensively entwined as paired socio-ecological systems, yet they are often measured separately (Stojanovic et al., 2016). Typically, the natural systems of coastal areas include ecosystems and detailed biophysical attributes (Wong et al., 2014). Meanwhile, the human systems encompass the built

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environment, economic activities (e.g., tourism, aquaculture, fisheries) and the formal and informal institutions that organize human activities (e.g., policies, laws, customs, norms, and culture).

These human systems are critical as they drive many of the impacts (both environmental and social) and the changes that are seen at the local level in coastal areas. The drivers for these human systems involve a combination of social, economic, and institutional factors including taxes and subsidies, aesthetics and recreational attractiveness of the coast, as well as increased mobility (Bagstad et al., 2007).

Identifying both the natural and human-related changes in coastal areas is essential in order to effectively manage them. Developing countries have a greater challenge in this regard, since data, capacity, expertise and economic resources are limited; further, coastal populations in these countries are generally growing more rapidly and haphazardly (Appelquist and Balstrøm, 2014).

In order to make sense of these changes, indicators with the ability to gather and present data in a relatively straightforward manner are required. Only then, can complex systems or phenomena be appreciated in a way that is reasonably simple to understand by coastal zone managers (Choobchian et al., 2015). Indicators are useful for sharing the results of technical analyses or for monitoring the characteristics of these natural and human systems. They also enable comparisons across sustainability criteria or indeed across regions, as it so happens within the fisheries sector for example (Le Gallic, 2002).

Over the years, a plethora of indicators have been developed to give insight, monitor and manage coastal areas. However, the majority of coastal area indicators relate to the biophysical systems, with the human systems (for e.g. socio-economic, economic, governance, culture, norms etc.) requiring a more integrated or holistic focus (Becken et al., 2014; Biedenweg et al., 2017; King et al., 2014). Evaluating indicators in isolation provides a portion of the whole picture. Thus, a systemic framework is required to help guide environmental decision making (Werner et al., 2014). Nguyen et al. (2016) stress the importance of combining social and biophysical systems in an integrated framework, especially in relation to policy-driven assessments towards adaptation measures in coastal areas.

Numerous frameworks, models, and approaches try to make sense of these abundance of indicators to better manage and understand the changes taking place at coastal areas. Table 1 features a non-exhaustive list of approaches divided into four categories according to their focus ((i). social, (ii) interface between social and biophysical, (iii) biophysical, (iv) systemic). This list evidences the lack of an approach that encompasses all aspects of the indicator assessments at coastal areas. Indeed, what is clear from the literature is that there is a general lack of successful implementation of the different approaches (Suinyuy et al., 2016). There also seems to be a poor integration of the human system aspects of economic, political and governance facets within the majority of the indicator approaches.

The Coastal Hazard Wheel (CHW) featured in Table 1 (Appelquist and Balstrøm, 2015) is a recently developed indicator-based framework that has raised significant interest at the practical level for its ease of implementation. As a rapid assessment tool to coastal hazards, it requires low or no primary data collection (Appelquist and Halsnæs, 2015). Examples of its implementation exist for India (Appelquist and Balstrøm, 2015), Timor Lest, and Malta (Micallef, Micallef and Galdies, (2018)). As evidence of its institutional significance, different intergovernmental organisations have adopted the CHW, including the United Nations Industrial Development Organisation (UNIDO), the United Nations Environment Programme (UNEP) (Appelquist Rosendahl et al., 2016) and the Climate Technology Centre and Network (CTCN) (CTCN, 2017).

Developed as a method to address coastal management issues, the CHW has a specific focus on the biophysical elements, with outcomes of the assessments indicating where further interventions are required (Appelquist, 2013). The method therefore assists regional planners and decision-makers in obtaining an overview of the hazard profile of the coastline and in identifying hazard hotspots (Appelquist and Balstrøm, 2015).

Table 1
Indicator frameworks, models and approaches in coastal areas.

Focus	Framework/model/approach	Reference
Social	Community Wellbeing index (CWBi)	Buot and Cardenas (2016)
	Multi-dimensional Poverty Index (MPI)	Alkire and Santos (2010)
	Community Based Management	Baines (1982)
Interface between Social and Biophysical	Drivers-Pressures-Ecosystem Services-Response (DPSER) model	Kelble et al. (2013)
	Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism (MUSIASEM)	Giampietro et al. (2009)
	Socio Ecological Systems at Coastal Areas	Murphy (2015)
Biophysical	Ecosystem health (in relation to coastal areas) (CEH)	Costanza and Greer (1995)
	Coastal Vulnerability Index	Thieler and Hammar-Klose (1999)
	Coastal Hazard Wheel	Appelquist and Halsnæs (2015)
	RISC-KIT Coastal Hazard Assessment module	Van Dongeren et al. (2018)
	Coastal erosion risk assessment	Narra et al. (2017)
	Smartline	Lins-de-Barros and Muehe (2013), Sharples et al. (2009)
Systemic	Integrated approach to community-based coastal resources management	Magpayo (1995)
	Community Capitals Framework	Flora and Flora (2008)
	Integrated Coastal Zone Management	Sorensen (1993)
	Community Based Coastal Resource Management	Maliao et al. (2009)

The lack in the consideration of the human systems within the overall assessment is a major shortcoming of the CHW framework. Indeed, its proponents already detected the need to add the human system to their framework: "supplementing the physical CHW assessment with socioeconomic data may in many cases be relevant for improving the information base for coastal planners and managers. This would provide CHW users with a combined picture of physical hazards and societal activities which could be relevant for supporting long-term planning decisions."(Rosendahl Appelquist and Halsnæs (2015):PP 9). However, to date, the incorporation of this type of data has not been included in any methodological development or practical implementation of the CHW framework.

Wider research also calls for the incorporation of human systems into these types of frameworks and assessments. Howe et al. (2014) identify research needs in the interplay between socio-economic factors, human well-being and ecosystems. Calhoun et al. (2016) suggest that understanding the social-ecological system requires the consideration of the social, cultural, historical, and legal/policy aspects as well. Vugteveen et al. (2015) call for the development of indicators that identify the processes of social, economic and ecological subsystems for integrated management strategies in social-ecological systems.

Clearly, ecosystem analysts need to move away from thinking of ecosystem assessments as decision-making tools and treat them rather as an opportunity to understand and analyse the nature-society (i.e. natural and human system) relationships (Lele et al., 2013). In the same vein, there have been calls for indicator sets at coastal areas to be more consistent, comprehensive and complete and to thus form part of the overall Sustainability Development Goals assessments (Griggs et al., 2014).

Therefore, we can observe that there is a clear call to bring dedicated human system indicators into the current coastal area assessments to enhance management decisions and approaches, as well as to better understand the natural and human system relationships. This article therefore focusses on three main objectives aiming at pursuing this call:

1) To analyse the existing set of indicator themes and categories in coastal areas.
2) To contrast this set of indicators with the perceived needs of local coastal stakeholders from a developing country (Ghana)
3) To propose a set of indicator categories to be included as part of a systemic coastal zone management framework that takes it further than just the natural systems.

This paper thus provides the methods to which this investigation was undertaken followed by a section on the results, the discussion and the final conclusions that were drawn up and the suggestions for further research in this field.

2. Methods

A research framework (Fig. 1) was devised to facilitate the systematic collection of data and its subsequent analysis. The framework was guided by the three main objectives of this paper. The secondary data (scientific literature) and primary data (focus groups) collection was undertaken before their subsequent analysis using supporting software.

2.1. *Eliciting indicators from the scientific literature*

A systematic evaluation of the peer-reviewed literature started with the first set of keywords: coast* AND environ* AND system* AND indicator* in the scientific databases Scopus, Google Scholar and Web of Science (February 2019). The first search strings were followed by a host of others, which eventually totalled a combination of 38 different keyword strings. This resulted in 1116 articles that were identified as relevant to this research. The sheer number of relevant articles is indeed symptomatic of the current challenge facing ecological research in that extensive literature exists on the subject, which is currently referred to as "big literature" (Nunez-Mir et al., 2016).

A further significant challenge in the analysis of the identified and selected literature is that the vast majority of articles involve qualitative outcomes in the form of narrative reviews (Koricheva et al., 2013). To overcome both these challenges we used *Automated Content Analysis* (ACA), i.e., algorithms that enable 'concept mapping', to ascertain the thematic composition of our body of literature. Themes in literature emerge from the frequency at which words and concepts appear and the relationships among them (Nunez-Mir et al., 2016).

The software program chosen to perform the analysis was Leximancer (Leximancer, 2019), which has been abundantly applied to ecological research (Cretchley et al., 2010; Grech et al., 2002; Knott et al., 2019; McCallen et al., 2019; Nunez-Mir et al., 2016; Penn-Edwards, 2010; Sullivan et al., 2018; Wavrek et al., 2017). Apart from the ability to perform ACA, Leximancer also provides a measure of the associations between concepts, which is an important aspect when looking to compare indicators in the literature. This step unveiled key themes, terms associated with those themes, and their connection to the word "indicator(s)". After removing 21 words without substantial relevance (e.g., "different"; "results"; "paper"; etc.), we identified 36 relevant words from the ACA literature analysis.

Next, we selected the articles that included the term "indicators" as the main theme, together with other theme words that emerged from the ACA. The process yielded 296 articles whose abstracts were then reviewed against the following inclusion criteria:

- Based on original research, and not reviews or *meta*-analysis;
- Explicitly identifying indicators, with specific focus on social indicators;
- Based on empirical studies (case studies);
- Focused on coastal regions;
- Local focus (not national, regional or global);
- Case studies undertaken in developing countries
- The articles would need to be 10 years old or younger

The particular focus on the social indicators is due to the perceived gap in the literature in measuring social indicators at coastal areas in

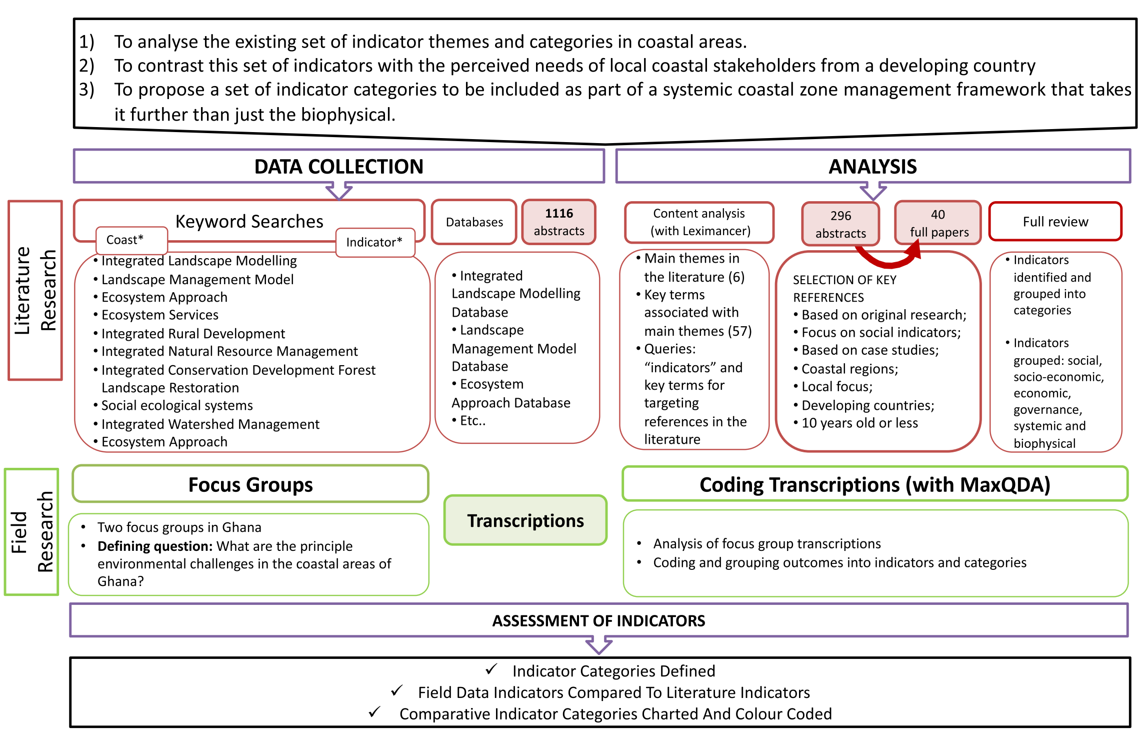

Fig. 1. The Research Framework.

comparison to measuring biophysical indicators. This research is concerned in covering the gap on 'social' indicators, without neglecting its relationship to all the other indicators. However, we realise that with the specific focus on the social indicators in the literature the biophysical issues, for example, may be under-represented, but the concern here is on the systemic indicators for coastal zone management (and the perceived under-representation of social indicators within these systemic indicators) and not with the state of the ecosystem.

This revealed a total of 40 articles that attained these requirements and were thus subjected to a full review. The indicator categories, subcategories and individual indicators were then pulled out of each of these articles and included into a large Excel database.

For practical terms, we grouped the indicators under the following topics: "Biophysical", "Economic", "Socio-economic", "Social", "Built Environment", "Systemic" and "Governance". The grouping in this manner was based on approaches undertaken by other researchers, for example, Abdullaev et al. (2009).

2.2. Eliciting indicators from stakeholders

Two focus groups were held in Accra, Ghana, in March of 2019. Ghana is a suitable location for our enquiry as it fits perfectly within the empirical criteria we used to select the articles, i.e. Ghana is a coastal area in a developing country that is heavily affected by climate change impacts. Additionally, the first author has extensive work experience and a network of contacts in the country that facilitated bringing together local relevant stakeholders into a focus group setting.

The focus group was chosen as a research technique as it employs "a guided, interactional discussion as a means of generating rich details of complex experiences and the reasoning behind [an individual's] actions, beliefs, perceptions and attitudes" (Powell and Single, 1996: PP. 499). The interest for this research was in gathering the perceptions and knowledge from local stakeholders and ensuring that viewpoints could be exchanged between the *quadruple helix* stakeholders that ensures a wide range of opinions (Yun and Liu, 2019). This meant involving industry, academia, government and civil society from the coastal region in Ghana.

We conducted two focus groups ensuring a manageable number of informed stakeholders in each session (8 and 5 participants respectively). To ensure the representativeness of the informed stakeholder groupings the following criteria were used: (i) The stakeholders had to be from Ghana; (ii) The stakeholders had to belong to one of the following stakeholder groups: NGOs; Farmer Organisation; Youth Groups; Women Groups; Government Institution; Traditional Authorities and (iii) The stakeholders had to have a relation to coastal zones. Working together with a local umbrella organization we recruited the informed stakeholders.

The stakeholders were tasked with providing their opinions on indicators related to systemic (natural and human systems) for environmental management in coastal areas in Ghana. The protocol for the Focus Groups outlined the main objectives and a set of guiding questions to help focus the discussions around the following objectives:

1. To define a set of criteria in order to choose practical natural and human system indicator (sub)categories that show the overall health of the environmental system.
2. To determine the needs and perspectives of indicators at local coastal areas in Ghana.

To analyse the data from the focus groups the recorded conversations were transcribed verbatim and then coded using the software program MAXQDA (MAXQDA, 2020). MAXQDA provides functions especially adapted for qualitative data analysis of focus group data (Saillard, 2011). Furthermore MAXQDA provides intuitive access to the focus group transcripts as well as to statements and contributions made by individual participants (Kuckartz and Rädiker, 2019). A code book was developed and imported into MAXQDA, which facilitated the coding of the transcripts grouping them according to the different types of indicators and indicator categories. These codes were further grouped into social, socio-economic, economic, biophysical, systemic, governance and built environment. Grouping in this manner allowed for a comparison to be undertaken with the results from the literature analysis.

2.3. Assessment of indicators

The process described above yielded two sets of indicators for local coastal management, one set from the case studies in the scientific literature and the other from the stakeholders perspective that are currently facing the challenges of holistic coastal zone management in their local area. In order to assess and analyse these two sets, the indicators were grouped into categories, sub-categories and lists of individual indicators using a spreadsheet (Excel). Their comparison unveiled indicator categories absent in the existing literature.

3. Results

3.1. Literature insights of indicator themes and categories

The content analysis, using Leximancer, of 1116 article abstracts from the original dataset (Fig. 2) revealed a number of interesting outcomes. It shows that studies regarding coastal systemic management focusing on the term 'indicator' connects to six main themes. The most frequently mentioned theme was 'ecosystem' (4269 mentions or 'hits'). Clearly, this shows that the literature related to systemic coastal zone management indicators accentuates the notion of ecosystem services, as well as ecosystem-based management approaches, assessments and frameworks with particular emphasis on marine and fisheries aspects.

The following most common theme was 'development' (3699 hits) which has a strong link to the systems theme which in turn links to the management of ecosystems theme. The development theme further relates to human, environmental, natural, ecological, social and economic themes, signaling a clear focus and connection in the literature for both human and natural systems in relation to coastal area development. Interestingly enough, the development sphere relates to the 'changes' sphere (3049 hits) through the terms 'local' and 'impacts', pointing to local coastal areas as a place of environmental and social change. Looking further into the 'changes' sphere, the terms 'climate', 'community' and 'water quality' point to relevant aspects in local coastal areas.

'Changes' also relate to the 'fishing' sphere (1197 hits) through the term 'results'. Therefore, a high number of case studies analyzing change, focus on fishing and show results using indicators. Interestingly, in the 'fishing' sphere the terms 'time' and 'production' are connected to 'indicators' showing us the importance that the literature places on indicators that reflect time spent fishing and the subsequent effects on fish production.

The terms in the 'forest' sphere (262 hits), 'forest' and 'land', are both connected with the terms 'areas' (in the 'change sphere') and 'indicators' (in the ecosystem sphere). This positions forest lands in coastal areas as places of ecosystemic change that the indicators seem to be monitoring. Meanwhile the 'urban' sphere (168 hits) is the least frequent in the literature, connecting with the term 'regional' (in the 'development' sphere).

Fig. 2 offers an insight into the topics that academic research has focused its interest on over the last ten years with regards to coastal systemic management and indicators. With the aim of advancing towards a systemic approach, using indicators for environmental management in coastal areas, we selected the terms (as described in the methodology) according to the well-established indicator categories of: Social; Economic; Governance; Biophysical and Systemic (Li et al., 2018) (Table 2). Admittedly, this categorization forces choices in some overlapping categories. However, this step was fundamental for

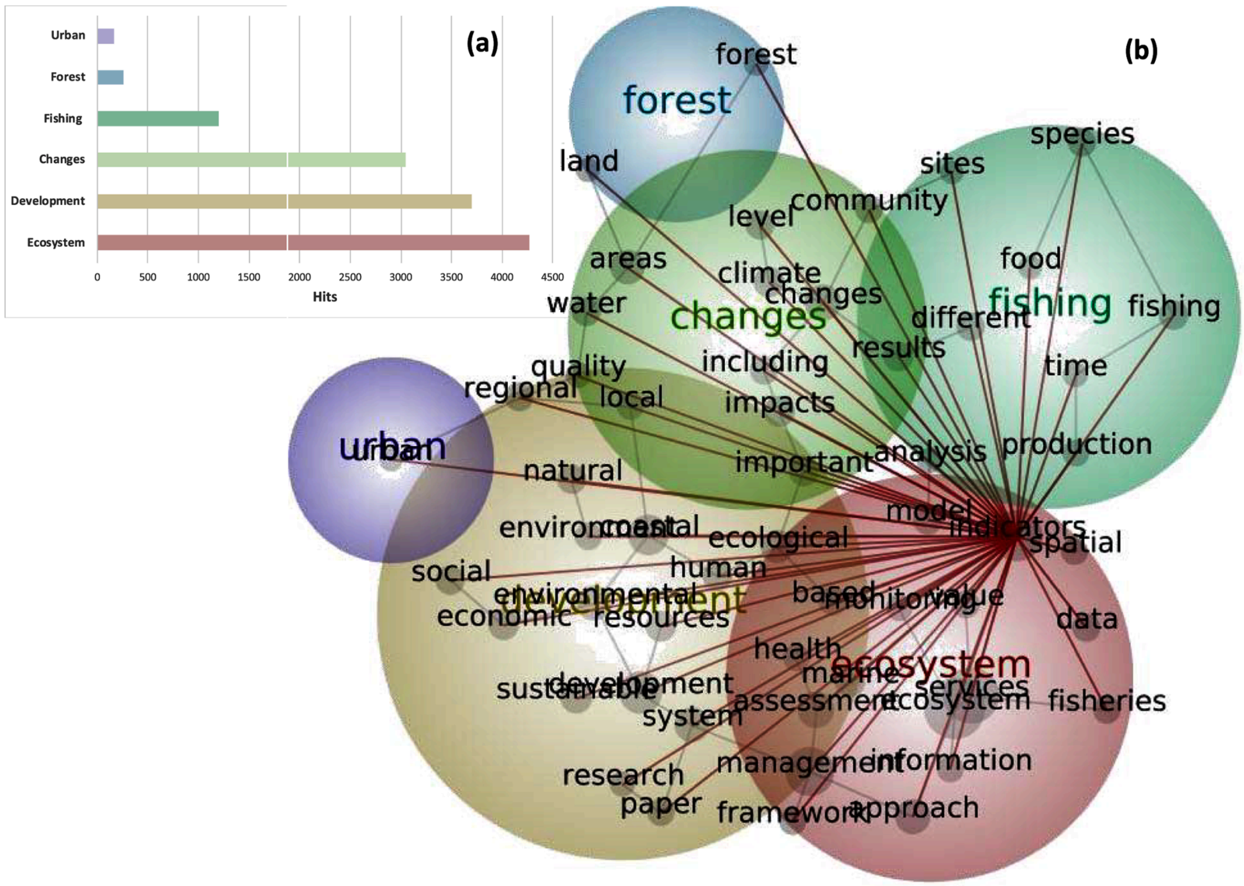

Fig. 2. Graphic representation of main themes in the coastal management literature: (a) number of hits per theme; (b) relationship of the term ‘indicator’ with other terms. Source: Own elaboration using Leximancer.

Table 2
Indicator category and its associated terms as a base for the classification framework.

Indicator category	Associated words from Leximancer analysis
Social	Community; social; human;
Economic	Economic
Governance	–
Biophysical	Ecological; environment/environmental; fishing/fisheries, marine; water; species; land; urban; soil; natural; forest; biophysical
Systemic	Framework; spatial; model; sustainable; system; changes; ecosystem services; management; time; approach; regional; coastal; resources

advancing to the next step: to provide a convergent focus for the full article review on articles that are related to the subject matter.

Table 2 confirms, through the array of topics, that current research screened through content analysis concentrates on the biophysical aspects of coastal area management. Still, many terms fall under the systemic category, where a number of holistic management frameworks and indicators are used to support environmental decision-making processes at local level (Loomis and Paterson, 2014; Werner et al., 2014). The governance category did not reveal any other associated term and the economic category only revealed the associated term of ‘economic’.

Using the selection criteria described in the methodology yielded 40 articles that were subjected to a full review. Indicators were extracted from each of these articles (with the particular focus on social indicators) and classified according to the indicator categories presented in Table 2. Evident from the first full article review was that a further category of ‘built environment’ was required, and thus it was added to the classification framework. The grouping of indicators into the category of “built environment” at coastal areas was based on the approaches from Buot and Dulce (2019), Tefe (2012) and Van Eijck et al. (2014). The category “built environment” considers the human-made environment, however at the coastal zones this indicator set does not take into account the urban context as this would be subject to an entirely different set of indicators.

An extensive list of individual indicators was extracted for each main indicator category. Analogous indicators – the indicators that had similar features to each other and thus comparable – were grouped together. A frequency count of the times that analogous indicators were mentioned in an indicator category is visually represented in Fig. 3A.

This revealed that **Social** was the indicator category with the highest frequency of related indicators (63% of all the listed indicators). Examples of social categories can be found in Choobchian et al. (2015), Dacks et al. (2018), Marín-Monroy and Ojeda-Ruiz de la Peña (2016) and Mollah (2016) that trace aspects such as togetherness; livelihoods; access to basic services; security; health and education levels. They all highlight the importance the analysed literature has placed on community indicators.

The **Biophysical** category (14% of all the listed indicators) delivers a host of indicators from the analysed literature. They range from the specific (e.g., *reduction of emissions of industrial sulphur dioxide* (Meng and Chi, 2018) to the more general, for instance the *Biodiveristy index* (Rakhmanissazly et al., 2018) and the *Coastal Hazard Wheel* (Appelquist and Balstrøm, 2015)) highlighting the vastness of this area of investigation and the need to specify locally relevant indicators.

The **Socio-Economic** category followed in frequency, with 13% of

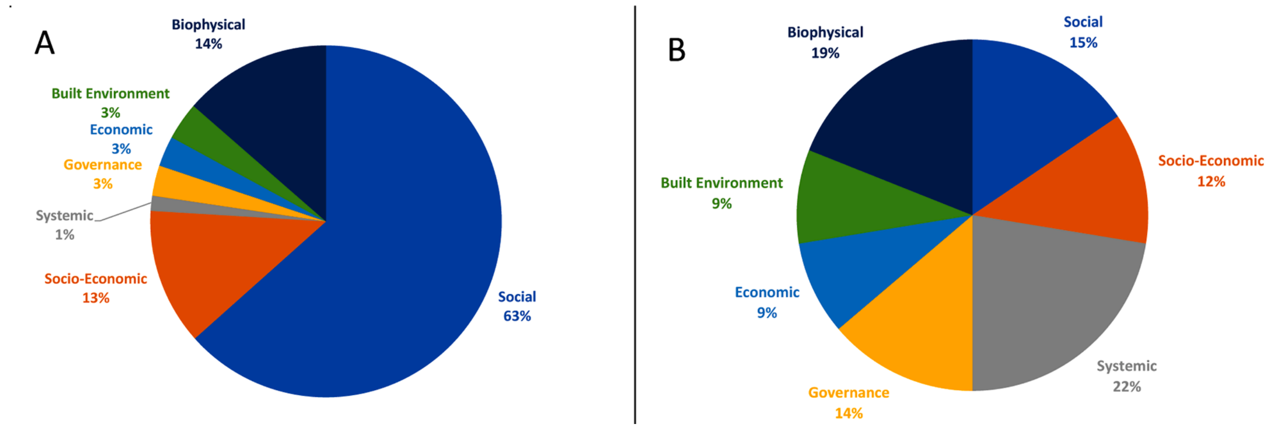

Fig. 3. Frequency of indicators mentioned in the literature (A) and those mentioned in the field data (B).

all the listed indicators. Adger (1999); Tian et al. (2018); Buot and Dulce (2019) are examples of how socio-economic indicators can be used, i.e., in relation to coastal livelihoods and coastal economies; food provision; income stability and housing. Meanwhile, a host of authors (Clements, 2009; Dannevig and Aall, 2015; Dogliotti et al., 2014; King et al., 2014; Thaler and Levin-Keitel, 2016) show the importance of the indicator '*level of food autonomy*', highlighting the relevance of self-subsistence at community level in coastal areas in developing countries.

The **Built Environment** (3% of all the listed indicators) from the analysed literature shows indicators related to aspects such as road infrastructure; water and light infrastructure; state of agricultural infrastructure (Buot and Dulce, 2019; Camill et al., 2012; Ghisellini et al., 2016; McCarter et al., 2018). These indicators highlight the relevance of essential structures to livelihoods at local level.

The **Economic** indicator category (3% of all the listed indicators) focusses on the fishing and tourism sector, as could be expected at coastal regions. This entails indicators of fisheries household income (Miswar et al., 2018); fisheries contribution; market price of fish; income from fishing; share of catches per person (Choobchian et al., 2015; Kronen et al., 2010) and tourism and recreation income (Choobchian et al., 2015; Tian et al., 2018). Indicators in relationship to household economies also appear in the analysed literature: some examples include three or more income sources; savings ratio; ownership asset and household income as some examples from Kronen et al., (2010), Choobchian et al., (2015) and Dacks et al., (2018).

Examples of indicators within the **Governance** category (3% of all the listed indicators) focus on institutional aspects: institutional stability (Mollah, 2016); environmental services of institutional ecosystems (Zaldívar-Jiménez et al., 2010); total sustainability of institutional criteria (Choobchian et al., 2015); fishing tools policy (Choobchian et al., 2015); land management policies (Roy et al., 2018) and protective areas including coastal protection and species protection (Tian et al., 2018). This highlights the relevance the literature has placed on an integrated or holistic look at policies, but also the importance placed on the need for institutions to be stable and sustainable in developing countries.

Finally, the **Systemic** category of indicators (1% of all the listed indicators) from the analysed literature was the least featured. Examples include: cooperative's roles; total sustainability of coastal management criteria, as well as indicators related to frameworks (e.g., Energy Systems Theory (EST) and Emergy Analysis (EA)) (Berrios et al., 2017). Also within the systemic category we found indicators of central tendency and dispersion measurement (Bandoc et al., 2014), ecosystem approach (Engler, 2015) and Community Based Management (Borges et al., 2017; Boyd and Charles, 2006; Courtney and White, 2000; Lawson et al., 2010; Pomeroy et al., 1997; Sherman, 2014). These indicators provide a relation to theories, approaches, analysis or management models which highlight the complexity of implementation in practical terms.

The analysed literature thus reveals a variety of entry points to better portray the processes involved in the management of coastal regions, with a focus away from developed countries according to the OCED definition (United Nations, 2005). We acknowledge the diversity of the so-called "developing countries" that could be divided into several subcategories, from least developed, transition to emergent economies. We have further addressed this point in the discussion.

3.2. Indicators from the bottom up

The perspective from the local level stakeholders provides an insight into the potential indicators that are relevant to monitor and control the natural and human systems at local coastal areas. The coding of the transcripts from the focus groups thus disclosed a greater need for governance, systemic and economic indicators at local level in Ghana than those that have emerged from the literature review. The coded categories are represented in Fig. 3B. Biophysical (26% of all the coded indicators) and Governance (25% of all the coded indicators) were the categories with the most frequently mentioned indicators by the local quadruple helix stakeholders. These were followed by the categories Systemic (16%), Socio-Economic (7%), Built Environment (8%), Economic (9%) and Social (9%).

Diving deeper into the sub-codes mentioned within each category, the analysis disclosed 35 sub-categories of indicators Fig. 4. Within the category 'Built Environment' *Climate Affected Structures* was the most frequently mentioned item by the focus group participants (6,19% of all the listed sub categories). A participant from the Fisheries Commission gave insight into the reason for this: "*along the coast it* [climate change] *affects a lot of infrastructure houses and things in my community. A lot of houses have been destroyed.*"

Within the Biophysical category 'changing rainfall pattern' was most frequently mentioned with 5.15% of the total mentioned items. "*About the rain, we also have periodic drought, for example, in the first rain the farmer thinks 'ok let me start preparing for farming' and then all of a sudden the rain breaks so there are alternating issues of drought and flooding*", comments a local private company participant.

Community Associations (5.15% of the total mentioned items) were most frequently mentioned within the category Governance. A participant from the Fisheries Commission provides insight into the reason for this by talking about equipment for fishing: "*two or three of them* [fishermen] *should come together* [cooperatives] *and have a stronger vessel to work with*".

Within the Economic category the most frequently mentioned subcategory was 'climate affected incomes'. A participant from a farmer association explains why: "*I have 5 acres of land. I'm not getting the same harvest as before as a result of the climate and the weather. Last year there*

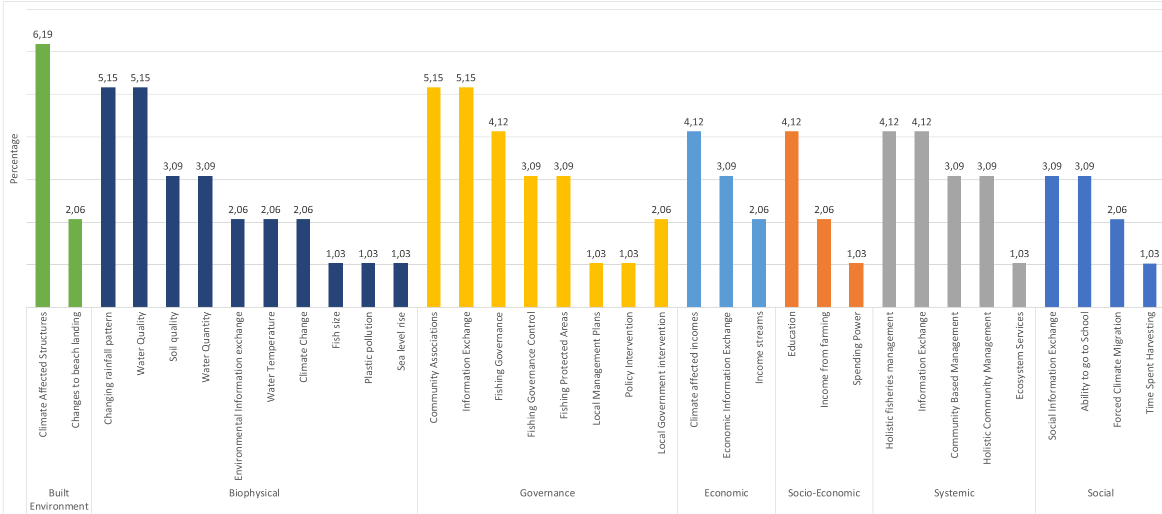

Fig. 4. Categories and their sub categories of indicators from the focus groups, with the percentage of mentions of a sub-category in relation to every other sub-category.

were no crops and the mango it doesn't bear fruit; this has affected my income"

Education (4.12% of the total mentioned items) was the most frequently mentioned sub-category within the Socio-Economic category. The same participant from the farmer association gives insight into this: "*Until the government changes the policy that at a certain age children should be made to go to school and shouldn't be seen loitering around the villages - because school is better, its free - but until that policy is made, we will have trouble with the children in the villages as the elders and leaders cannot force them to go to school*".

Within the Systemic category both with 4.12% of the total mentioned categories are the sub-categories of 'holistic fisheries management' and 'information exchange'. On the topic of holistic fisheries management a participant from a company supporting farmer associations explains: "*… so we asked the oyster fishermen what they wanted to do, and they said that they wanted to have greater income. So, of course, what we did is we put that into a holistic management context with measures to show where it fits. So we don't want to harvest more, we want to add value to the little harvest they have. For example, if I am harvesting three but I am getting the same income level that I was getting* [when I was harvesting two], *there is no motivation to go in to harvest more. We help them to understand this*". The need for a sub-category of Information Exchange becomes apparent in the words of a participant from the Peasant Famers Association of Ghana: "*…for example, if the farmers have issues with chemical fertilizers, this is an issue that they can speak out on at the district level*".

Under the Social category the sub-category of 'Social Information Exchange' had the highest frequency of mentions with 3.09% of the total sub-category mentions. "*It depends on what you want to communicate. In the oyster community, most of the community do not read or write. Then you need to be careful with the kind of information that you share - you should have some positive communication as opposed to negative communication, instead of showing pictures of "don't do this" show pictures of "do, do this"*", stated by a participant from the private company.

Other than the frequency of times a sub-category is mentioned it is important to observe their interaction, as it can signal groupings of indicators of that are of interest for management or monitoring. Fig. 5 shows the sub-categories mentioned together and their the frequency of times mentioned (the number in brackets).

The code map (Fig. 5) is developed through the multidimensional scaling method (Bazeley, 2009) which is used to position the codes on the map given the distances between them. The intersections of the codes are placed in accordance with the number of times two codes have been assigned to a segment together. In this case our interest was to know which codes intersected (co-occurred) in a segment of the transcripts from both focus groups. This allows us to know which indicators could potentially be correlated together allowing for indicators to be handled together, either in terms of joint measure or for selecting one as a signal for a cluster.

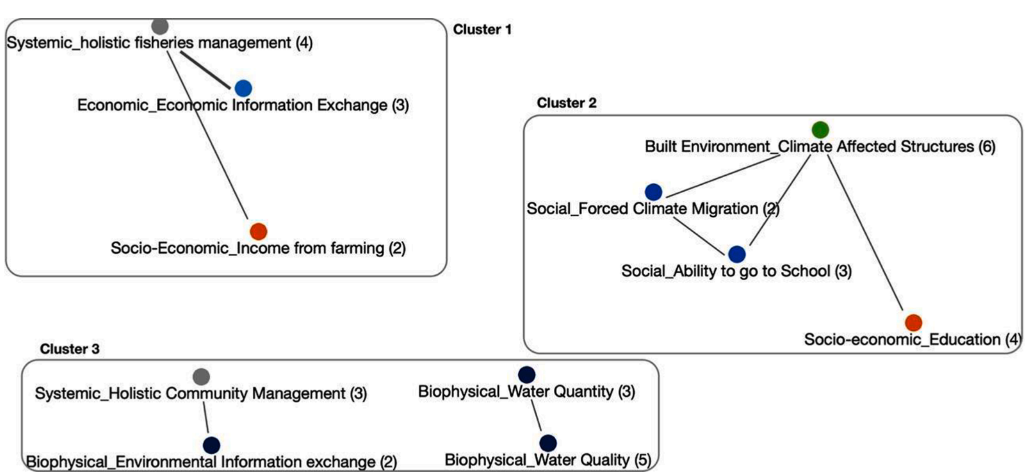

Fig. 5. Clustering of the co-occurrence of codes mentioned from both focus group transcriptions. *The code colours match those of the indicator categories in Fig. 3.

The code map can be clustered into three clusters of codes (i.e. indicators) that have intersected in the transcripts. In intersected codes cluster 1, *Systemic Holistic Fisheries* management was central to *Economic Information Exchange* and *Socio-Economic Income* from farming. This is evident from the reflection from a social advocate participant who mentioned: "*one of the other things that is affecting the local fishermen is the lack of technology or the lack of understanding of the devices to detect the weather patterns. For instance, the fishermen are already set to go out fishing but all of a sudden there is a heavy wind from the sea. So that has disrupted their activities for the day […] What is clear is that they do not have access to this information that can help them to plan ahead and thus they have lost out on their economic activities of that day. I believe that if the fishermen are equipped with these modern technologies, communications and devices they will know the effects the weather will have on their activities and this will also help them to plan better.*"

From cluster 2, participants from the focus groups highlighted the relationship between the following indicators: *Climate Affected Structures* (Built Environment), *Forced Climate Migrations* (Social), *Ability to go to School* (Social) and *Education* (Socio-economic), indicating that the one affects the other. The intersection of these codes is evident from the reflection from an education youth group participant that mentioned: "*I would like to touch on education and coastal communities as climate change has already affected the infrastructure by destroying some local schools. Students have then not been able to go to school in their community and they have to travel quite a distance to another community to go to the school there*".

Within cluster 3, unsurprisingly, water quantity co-occurred with water quality. A representative from a local development consultancy stated "*along the coast there is some fresh patch of water on top of the salt water. But with climate change, now that level of freshwater is being infiltrated by the salt. This creates a combination of things. […] Normally if it rains then the aquifer is recharged, but with the lack of rain, we now have more of the brine water coming up, so it affects the soil quality*. Furthermore, within this cluster, holistic community management co-occurred with Environmental Information Exchange. A social advocate participant, after listing several types of climate and market-related information and services provided to farmers and communities, he reasoned: "…*what I think ESOKO* [Digital Solutions for Agriculture and Data Collection] *needs to do is to add more environmental information about the coastal area as well as economic information and social information and they would need to provide this information in the local dialects in order to solve the high social needs of those places*…"

3.3. Contrasting the literature and field indicator categories

The two components of Fig. 3 described individually in the sections above can be now compared side by side. We note that the social category (Fig. 3A) has the greatest representation meanwhile the systemic category was the least represented from the analysed literature. Meanwhile, the analysis of the data from the focus group participants (field data) reveals an even spread between the indicator categories, with systemic proving to be the category the participants showed slightly more importance towards. Here we note the relevance of bottom-up vs a top-down approaches where a significantly higher importance was placed on the social category from the field data than the top-down literature analysis (a frequency of 63% and 15% respectively).

The difference between the perspectives of academic research and local stakeholders creates a valuable opportunity to assess the state and prospects of indicators for systemic coastal area management. In this respect, Fig. 6 offers a visual representation of the subcategories of coastal zone indicators by combining insights from the literature and from the field data. This visual representation aims at reinforcing the range of indicators included in coastal indicator frameworks, in order for the natural and human systems to be taken into account together.

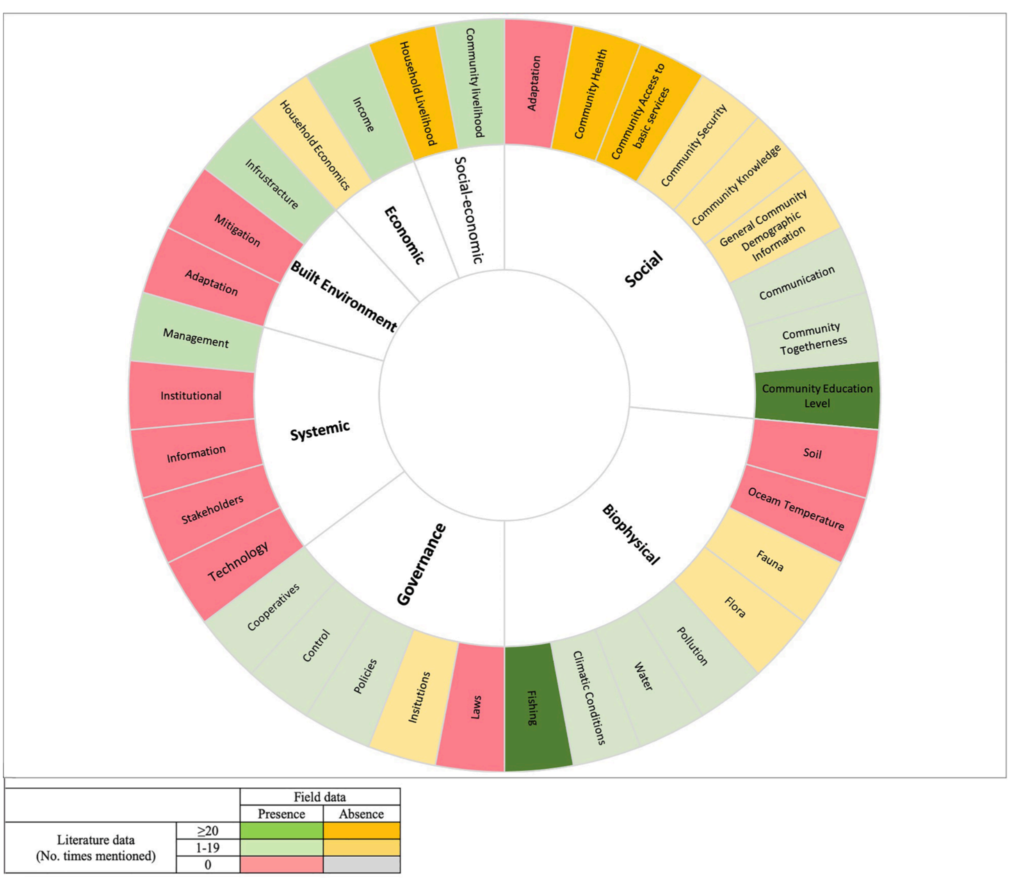

Fig. 6. Homogenised literature and field sub-category coastal zone indicators.

We created a classification system that sorts the indicators into five situations according to their saliency in both the literature and in the field. A colour code qualifies each situation. With 20 or more mentions of a certain sub-category in the literature and if that sub-category was mentioned (presence) in the focus groups, the sub-category was coloured green; if its salience in the literature was less frequent, between 1 and 19 mentions, and was still mentioned (presence) in the focus groups, the subcategory was then coloured light green. If, however it appears in the literature but was absent in the field, it was coloured light yellow (when it is abundantly mentioned in the literature, with at least 20 mentions) or orange (when it is less mentioned in the literature, with 19 mentions or less). If there was no mention of the sub-category from the literature but there was a mention of it (presence) in the field data, it was coloured red.

Therefore, Fig. 6 helps us to distinguish three different scenarios in terms of the indicators for systemic coastal area management. The **first scenario** is a co-occurrence of the literature analysis with the identified needs from local coastal stakeholders. There is a total of 14 analogous indicator subcategories that were mentioned in both the literature and the focus groups, across all the indicator categories (see examples in Table 3). These could be the first candidates towards an expansion of the current existing frameworks vis-à-vis becoming more encompassing of the aspects beyond just the biophysical or social elements currently focussed on in the literature.

The **second** scenario is where we have the sub-categories mentioned in the literature but not mentioned at the local Ghanaian level. In this case, there are 12 sub-categories that have emerged from the literature that at local level, in Ghana, were not considered by the stakeholders. This outcome is crucial as it shows us that a first approximation to the local stakeholders needs to be undertaken to know what is important to be considered in each local coastal community. In other words, armed with a full set of sub-categories, a researcher can approach a local community to discover from the sub-categories which have relevance for them to measure and monitor in terms of their local coastal management of the natural and human system needs. The differences in the types of sub-categories mentioned in the literature also reveals the encompassing nature of the literature case study data. A number of categories from the literature expose the types of indicators that could potentially be more commonly used in least developed, transition and emergent countries than in Ghana. For instance, coastal infrastructures indicators may not emerge from the local stakeholders in Ghana as infrastructure is not seen as an issue that may be a more significant issue in other developing countries. Table 4 provides the sub-categories mentioned from the literature that did not have any mentions from the field data, with some examples.

The **third** scenario is where the local Ghanaian coastal stakeholders have mentioned sub-categories of indicators that were not uncovered in the 40 articles that were subjected to a full literature review. This case shows us that although a researcher may believe to have uncovered all the potential indicator categories from the literature and the current indictor frameworks, there may still be potential indicators that need to be taken into account from a local perspective – at least from the evidence obtained from the case study in Ghana. In this sense, it reiterates the need to have indicators that encompass a wide range of aspects but that ultimately take the local level needs into account. Table 5 provides the sub-categories that were mentioned from the field data but that did not have any mentions from the literature.

4. Discussion

Climate change impacts are currently referred to as a climate crisis (Brugger and Crimmins, 2015; Hoppe et al., 2013; Navarro, 2018). Some countries across the globe are better prepared than others to cope with the impending climate change impacts. For instance, Bangladesh is purported to be one of the most vulnerable countries to climate change in the world (Minar et al., 2013), however it is better prepared than most developed countries in terms of adaptation and mitigation measures. As in Bangladesh, West Africa - specifically Ghana - is going to be one of the more climate vulnerable developing countries affected by coastal zone impacts (Sylla et al., 2016), this determined our choice of empirical reference. Our analysis provides a fined-grained identification of indicators from the literature and from the field that are relevant for the management of coastal areas of developing countries that are highly vulnerable and/or that are currently affected by climate change (and extreme weather) impacts.

While negative impacts will manifest on the biophysical and built environments, it is society that will bear the brunt of these impacts (Adger et al., 2005; Azhoni et al., 2018; Clements, 2009; Odemerho, 2015; Rasul and Sharma, 2016). Our results mirror the idea that the way in which different shorelines and marine environments are managed, and what they are managed for, should be a reflection of what society wants from those environments (Loomis and Paterson (2014). Therefore, the measurement and monitoring of climate change effects and coastal management should include not only the natural systems but the human systems as well.

Thus, it is important that the integration between the natural and human systems relies not only on the scientific advancement in this field but the practical implementation thereof. Therefore, screening the literature to identify the academic advancement, has been an important element of this research, however, the contrast with local stakeholder needs is vital to ensure that the entire process of developing a systemic framework is not only guided by the theoretical approaches that would have difficulty to be implemented.

Unsurprisingly 83% of all the indicators identified in the literature and 70% of the indicators identified in the field refer to domains outside the physical environments and thus emphasizes this human dimension.

Accordingly, we contribute to the idea that a holistic set of indicators at coastal regions with a focus on the local level is well-suited to aid

Table 3
Combined mentions in the literature and field data of the indicator sub-categories with examples of locally (Ghana) defined indicators.

Category	Sub-Category	Indicator example (from the Ghana focus groups)
Social	Community Togetherness	*Number of associations that are present in the community*
	Communication	*Number of information exchange events (meetings, presentations etc) held in the community.*
	Community Education	*Number of children that have the ability to go to school.*
Socio-economic	Community livelihood	*What is the trend in the economic spending power*
Systemic	Management	*Is there a community-based management plan in place?*
Governance	Cooperatives	*Do cooperatives exist at local level (fishing, canoe sharing etc.?)*
	Control	*Are closed fishing seasons implemented?*
	Policies	*Do policies exist against beach sand mining?*
Economic	Income	*Number of community members that are changing their principle income stream*
Built Environment	Infrastructure	*Number of infrastructures destroyed by climatic events over the last 10 years and the number rebuilt since.*
Biophysical	Climatic Conditions	*Rainfall patterns over the last 10 years.*
	Water	*Changes in the lagoon salinity levels.*
	Pollution	*Tons of plastic present in the lagoon in 1 year*
	Fishing	*Change in fish sizes and in fish catch*

Table 4
Sub-categories from the literature not mentioned in the field data.

Category	Sub-Category	Indicator example
Social	General Community Demographic Information	- *percentage of population below 6 years of age* - *percentage of dependent population* Mollah (2016)
	Community Access to basic services	- *percentage of community access to health services* Nemes (2005) - *percentage of community that has access to water* Alamarah Tamimi et al. (2007), Biedenweg et al. (2017), Dondeynaz et al. (2012)
	Community Knowledge	*Utilization of local knowledge on resource management* Biedenweg et al. (2017), Miswar et al. (2018)
	Community Security	*Number of homes and farms located in areas of floods or landslides* Dondeynaz et al. (2012), Hove et al. (2016)
	Community Health	*body mass index/Human Development Index* Biedenweg et al. (2017), Ghisellini et al., 2016; Kwasi et al., 2011)
Socio-Economic	Household Livelihood	*Number of families with credit support and insurance* Buot and Dulce (2019), Matzdorf et al. (2014), Rakhmanissazly et al. (2018)
Systemic	Institutional	*Total sustainability of institutional criteria* Choobchian et al. (2015)

Table 5
Sub-categories from the field data not mentioned in the literature.

Category	Sub-Category	Indicator example (from the Ghana focus groups)
Social	Adaptation	*Number of adaptive measures that have been brought in that affect the community* (i.e. *after a school was destroyed by a storm, the kids stayed at home).*
Systemic	Information	*Full systemic information available to farmers / Farmer access to information regarding the systemic management of the local area / Is information available to be used by farmers? Eg. smartphones, climate data, fishing data etc.*
	Technology	*Do fishermen have access to technologies that can allow them to manage all their fishing aspects in an integrated manner (for* e.g. *weather devices, radios, communication technology etc.)*
Economic	Income	*Number of community members changing economic activities* (i.e. *from fishing to farming) / Changes in rain fed crops to irrigated crops*
Built Environment	Adaptation	*Number of recent changes made to the built environment in response to climate change impacts that improve the community livelihood*
	Mitigation	*Number of well-developed landing beaches in the local fishing community that can support larger vessels*
Biophysical	Ocean Temperature	*Changes in sea water temperature*
	Soil	*Changes in soil salinity*

decision makers. The choice of the right indicators expands their information base on what society wants and how to protect society from climate change impacts.

A recently implemented CHW framework in West Africa as part of a UNIDO funded and CTCN managed project highlighted some of the shortcomings of the CHW framework (CTCN, 2017). The report highlights that even at its first evaluation phase, the CHW would benefit greatly from having a set of rapid social, economic and systemic assessments, with the possibility to expand the list of potential management options of the CHW to include governance or political implications.

A combination of literature and local stakeholder-based sub-category indicators - obtained from Ghana - has allowed us to define three scenarios for uncovering indicator sub-categories that could be included as part of the current set of measuring and monitoring indicators for natural and human systems at local coastal areas. The first scenario (a co-occurrence of the literature analysis with the identified needs from local Ghanaian coastal stakeholders) is the one we promote to be incorporated into the current coastal indicator monitoring frameworks (for example by upgrading the CHW – the framework advocated for use in developing country contexts). This could be by including for instance the sub-category "Community Togetherness" by measuring the number of associations that are present in the community.

The other two scenarios (**scenario 2**: sub-categories mentioned in the literature but not mentioned at the local level and **scenario 3**: local Ghanaian coastal stakeholders mentioned sub-categories of indicators that were not mentioned in the literature) offer insights in terms of implementation, rather than on expanding current indicator frameworks. These last two scenarios imply that coastal management indicator frameworks should be adapted to each local situation. They show us that coastal zone indicator frameworks uncovered in the literature need to be adapted to the natural and human systems at local coastal areas.

5. Conclusion

This paper has detailed the process of discerning, accessing and analysing a complex set of indicator data that has exposed indicator categories and sub-categories. The paper has furthermore contrasted these results with the perceptions and needs of the local quadruple helix stakeholders from the coastal areas in Ghana. Finally, a set of sub-categories has been proposed to be included within the current monitoring/hazard assessment frameworks that combines the natural and human systems.

Literature analysis is no substitute to local assessments and the subsequent understanding of local conditions. Then again, local assessments are no substitute to a literature analysis. This is no more evident than shown in our results where the literature focusses predominantly on social sub-categories of indicators, meanwhile at the local level there is a greater integration of these natural and human systems. The unique contribution of this paper is the combination of literature and stakeholder-based indicator sub-categories that should be added to the current set of coastal monitoring frameworks - such as the Coastal Hazard Wheel - to ensure that the natural and human systems are considered holistically. In other words, our methodological process of combining both a top-down (literature) and bottom-up (local Ghanaian coastal stakeholders) indicator identification has provided the platform for the inclusion of local expert knowledge based on internationally accepted indicators for coastal zone management. This insight provides a salient call to field analysts and the donors or policy makers that commission the work to take into account the value of local experts and local knowledge when devising the natural and human system indicators for coastal zone management.

Researchers at coastal zones should continually drive to be multidisciplinary, focusing on the interconnectedness and the knock-on effects of one system on another. An observation from one of the participants of the focus groups provides the reasoning for this, where she described how an extreme storm destroyed a local school. This resulted in the children no longer able to go to that school meanwhile, those that could, had to travel to the next village to attend school. All participants seemed to have a similar experience to this one as this observation was backed up with anecdotes of how those children that could no longer attend school spent their days loitering around the villages, some turning to crime. From these statements, there is no clearer evidence of how the natural system has impacted the human system and the very reason why both systems need to be measured and monitored and included in the current coastal frameworks that are devoid of these combined indicators.

To build in these sub-categories into the frameworks currently available we propound to focus further research on integrating the human and natural system indicators prioritised from a stakeholder base of data that is easily obtainable. Furthermore, there is a strong need to investigate the concept of weighting or indeed non-weighted indicators and subcategories in function of their importance. Finally, we propose that further work needs to take place in the visualisation of the collected indicator information to provide managers with stronger coastal zone management tools.

CRediT authorship contribution statement

David J. Smith: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Writing - original draft, Visualization, Project administration, Funding acquisition. **Beatriz Rodríguez-Labajos:** Writing - review & editing, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Abdullaev, I., Kazbekov, J., Jumaboev, K., Manthritilake, H., 2009. Adoption of integrated water resources management principles and its impacts: Lessons from Ferghana Valley. Water Int. 34, 230–241. https://doi.org/10.1080/02508060902843710.

Adger, W.N., 1999. Exploring income inequality in rural, coastal Viet Nam. J. Dev. Stud. 35, 96–119. https://doi.org/10.1080/00220389908422593.

Adger, W.N., Brown, K., Hulme, M., 2005. Redefining global environmental change. Glob. Environ. Chang. 15, 1–4. https://doi.org/10.1016/j.gloenvcha.2004.12.002.

Alamarah Tamimi, A.R., Isayed, A.A., Mughli, M.A., 2007. Using socio-economic indicators for integrated water resources management: Case study of Palestine, Water Resources in the Middle East: Israel-Palestinian Water Issues - From Conflict to Cooperation. https://doi.org/10.1007/978-3-540-69509-7_34.

Alkire, S., Santos, M.E., 2010. Acute multidimensional poverty: A new index for developing countries. United Nations Dev. Program. Hum. Dev. Rep. Off. Backgr. Pap.

Appelquist, L.R., Balstrøm, T., 2015. Application of a new methodology for coastal multi-hazard-assessment & management on the state of Karnataka, India. J. Environ. Manage. 152, 1–10. https://doi.org/10.1016/j.jenvman.2014.12.017.

Appelquist, Lars, 2013. Generic framework for meso-scale assessment of climate change hazards in coastal environments. J. Coast. Conserv. 17 (1), 59–74. https://doi.org/10.1007/s11852-012-0218-z.

Appelquist, L.R., Balstrøm, T., 2014. Application of the Coastal Hazard Wheel methodology for coastal multi-hazard assessment and management in the state of Djibouti. Clim. Risk Manag. 3, 79–95. https://doi.org/10.1016/j.crm.2014.06.002.

Appelquist, L.R., Halsnæs, K., 2015. The Coastal Hazard Wheel system for coastal multi-hazard assessment & management in a changing climate. J. Coast. Conserv. 19, 157–179. https://doi.org/10.1007/s11852-015-0379-7.

Appelquist Rosendahl, L., Balstrøm, T., Nicholls, R.J., Linham, M.M., Spensley, J., Bjørnsen, P.K., Lloyd, G.J., Jeppesen, G., Vestergaard, O., 2016. The Coastal Hazard Wheel decision-support system - Quick Start Guide.

Azhoni, A., Jude, S., Holman, I., 2018. Adapting to climate change by water management organisations: Enablers and barriers. J. Hydrol. 559, 736–748. https://doi.org/10.1016/j.jhydrol.2018.02.047.

Bagstad, Kenneth J, Stapleton, Kevin, D'Agostino, John R., 2007. Taxes, subsidies, and insurance as drivers of United States coastal development. Ecol. Econ. 63 (2–3), 285–298. https://doi.org/10.1016/j.ecolecon.2006.09.019.

Baines, C., 1982. Community involvement in creative ecology: some national problems of local significance., An ecological approach to urban landscape design. Workshop.

Bandoc, G., Mateescu, R., Dragomir, E., Golumbeanu, M., Comanescu, L., Nedelea, A., 2014. Systemic approach of the impact induced by climate changes on hydrothermic factors at the Romanian Black Sea Coast. J. Environ. Prot. Ecol. 15, 455–467.

Barragán, J.M., de Andrés, M., 2015. Analysis and trends of the world's coastal cities and agglomerations. Ocean Coast. Manag. 114, 11–20. https://doi.org/10.1016/J.OCECOAMAN.2015.06.004.

Bazeley, P., 2009. Integrating data analyses in mixed methods research.

Becken, S., Mahon, R., Rennie, H.G., Shakeela, A., 2014. The tourism disaster vulnerability framework: An application to tourism in small island destinations. Nat. Hazards 71, 955–972.

Berrios, F., Campbell, D.E., Ortiz, M., 2017. Emergy evaluation of benthic ecosystems influenced by upwelling in northern Chile: contributions of the ecosystems to the regional economy. Ecol. Modell. 359, 146–164.

Biedenweg, K., Harguth, H., Stiles, K., 2017. The science and politics of human well-being: A case study in cocreating indicators for puget sound restoration. Ecol. Soc. 22 https://doi.org/10.5751/ES-09424-220311.

Borges, R., Ferreira, A.C., Lacerda, L.D., 2017. Systematic planning and ecosystem-based management as strategies to reconcile mangrove conservation with resource use. Front. Mar. Sci. 4, 353.

Boyd, H., Charles, A., 2006. Creating community-based indicators to monitor sustainability of local fisheries. Ocean Coast. Manag. 49, 237–258.

Brugger, J., Crimmins, M., 2015. Designing institutions to support local-level climate change adaptation: Insights from a Case Study of the U.S Cooperative Extension System. Weather. Clim. Soc. 7, 18–38. https://doi.org/10.1109/CEC.2011.5949892.

Buot, M., Dulce, M.Z., 2019. An index to determine community wellbeing along coastal community in Leyte. Philippines. Environ. Asia 12, 56–67. https://doi.org/10.14456/ea.2012.23.

M.M. Buot V.R. Cardenas Community wellbeing indices: implications to policy development, in: 13 2016 Change?, College, Laguna (Philippines).

Calhoun, S., Conway, F., Russell, S., 2016. Acknowledging the voice of women: Implications for fisheries management and policy. Mar. Policy 74, 292–299.

Camill, P., Hearn, M., Bahm, K., Johnson, E., 2012. Using a boundary organization approach to develop a sea level rise and storm surge impact analysis framework for coastal communities in Maine. J. Environ. Stud. Sci. 2, 111–130. https://doi.org/10.1007/s13412-011-0056-6.

Choobchian, S.H., Kalantari, K., Asadi, A., Taghavi Motlagh, S.A., 2015. Measurement and comparison of different dimensions of sustainable coastal fishing management in Beach Seine cooperatives in Guilan. J. Agric. Sci. Technol. 17, 1463–1472.

Clements, R., 2009. The economic cost of climate change in Africa. Pan African Clim, Justice Alliance.

Costanza, R., Greer, J., 1995. The Chesapeake Bay and its watershed: a model for sustainable ecosystem management? Barriers Bridg. Renew. Reg. Ecosyst. C. S. Holling S. Light. eds., Chapter 4, pp. 169-213 45.

Courtney, C.A., White, A.T., 2000. Integrated coastal management in the Philippines: Testing new paradigms. Coast. Manag. 28, 39–53.

Cretchley, J., Rooney, D., Gallois, C., 2010. Mapping a 40-year history with Leximancer: Themes and concepts in the journal of cross-cultural psychology. J. Cross. Cult. Psychol. 41, 318–328.

CTCN West African coastal classification, hazard management and standardized communication scheme utilizing the Coastal Hazard Wheel [WWW Document] https://www.ctc-n.org/technical-assistance/projects/west-african-coastal-classification-hazard-management-and 2017 accessed 6.4.20.

Dacks, R., Ticktin, T., Jupiter, S.D., Friedlander, A., 2018. Drivers of fishing at the household scale in Fiji. Ecol. Soc. 23 https://doi.org/10.5751/ES-09989-230137.

Dannevig, H., Aall, C., 2015. The regional level as boundary organization? An analysis of climate change adaptation governance in Norway. Environ. Sci. Policy 54, 168–175. https://doi.org/10.1016/j.envsci.2015.07.001.

de Sherbinin, A., Castro, M., Gemenne, F., Cernea, M.M., Adamo, S., Fearnside, P.M., Krieger, G., Lahmani, S., Oliver-Smith, A., Pankhurst, A., Scudder, T., Singer, B., Tan, Y., Wannier, G., Boncour, P., Ehrhart, C., Hugo, G., Pandey, B., Shi, G., 2011. Preparing for Resettlement Associated with Climate Change. Science (80-.). 334, 456 LP – 457. https://doi.org/10.1126/science.1208821.

Dogliotti, S., García, M.C., Peluffo, S., Dieste, J.P., Pedemonte, A.J., Bacigalupe, G.F., Scarlato, M., Alliaume, F., Alvarez, J., Chiappe, M., Rossing, W.A.H., 2014. Co-innovation of family farm systems: A systems approach to sustainable agriculture. Agric. Syst. 126, 76–86. https://doi.org/10.1016/j.agsy.2013.02.009.

Dondeynaz, C., Carmona Moreno, C., Céspedes Lorente, J.J., 2012. Analysing inter-relationships among water, governance, human development variables in developing countries. Hydrol. Earth Syst. Sci. 16, 3791–3816. https://doi.org/10.5194/hess-16-3791-2012.

Engler, C., 2015. Beyond rhetoric: Navigating the conceptual tangle towards effective implementation of the ecosystem approach to oceans management. Environ. Rev. 23, 288–320.

Eriksen, S., Silva, J.A., 2009. The vulnerability context of a savanna area in Mozambique: household drought coping strategies and responses to economic change. Environ. Sci. Policy 12, 33–52. https://doi.org/10.1016/j.envsci.2008.10.007.

Flora, C.B., Flora, J.L., 2008. Communities: Legacy and Change, 3rd ed. Westview Press.

Ghisellini, P., Cialani, C., Ulgiati, S., 2016. A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems. J. Clean. Prod. 114, 11–32. https://doi.org/10.1016/j.jclepro.2015.09.007.

Giampietro, M., Mayumi, K., Ramos-Martin, J., 2009. Multi-scale integrated analysis of societal and ecosystem metabolism (MUSIASEM): An Outline of Rationale and Theory. Energy 34, 313–322.

Grech, M.R., Horberry, T., Smith, A., 2002. Human error in maritime operations: Analyses of accident reports using the Leximancer tool, in: Proceedings of the Human Factors and Ergonomics Society Annual Meeting. Sage Publications Sage CA: Los Angeles, CA, pp. 1718–1721.

Griggs, D., Smith, M.S., Rockström, J., Öhman, M.C., Gaffney, O., Glaser, G., Kanie, N., Noble, I., Steffen, W., Shyamsundar, P., 2014. An integrated framework for sustainable development goals. Ecol, Soc, p. 19.

Hoppe, R., Wesselink, A., Cairns, R., 2013. Lost in the problem: The role of boundary organisations in the governance of climate change. Wiley Interdiscip. Rev. Clim. Chang. 4, 283–300. https://doi.org/10.1002/wcc.225.

Hove, T., Derman, B., Manzungu, E., 2016. Land, farming and IWRM: A case study of the middle Manyame sub-catchment. Water Altern. 9, 531–548.

Howe, C., Suich, H., Vira, B., Mace, G.M., 2014. Creating win-wins from trade-offs? Ecosystem services for human well-being: A meta-analysis of ecosystem service trade-offs and synergies in the real world. Glob. Environ. Chang. 28, 263–275. https://doi.org/10.1016/j.gloenvcha.2014.07.005.

Inácio, M., Schernewski, G., Nazemtseva, Y., Baltranaitė, E., Friedland, R., Benz, J., 2018. Ecosystem services provision today and in the past: A comparative study in two Baltic lagoons. Ecol. Res. 33, 1255–1274. https://doi.org/10.1007/s11284-018-1643-8.

C. Kelble D. Loomis S. Lovelace W. Nuttle P. Ortner P. Fletcher G. Cook J. Lorenz (Jerry), Boyer, J., The EBM-DPSER conceptual model: integrating ecosystem services into the DPSIR framework PLoS One 8 2013 e70766 10.1371/journal.pone.0070766.

King, M.F., Renó, V.F., Novo, E.M.L.M., 2014. The concept, dimensions and methods of assessment of human well-being within a socioecological context: A Literature Review. Soc. Indic. Res. 116, 681–698. https://doi.org/10.1007/s11205-013-0320-0.

Knott, J., LaRue, E., Ward, S., McCallen, E., Ordonez, K., Wagner, F., Jo, I., Elliott, J., Fei, S., 2019. A roadmap for exploring the thematic content of ecology journals. Ecosphere 10, e02801.

Koricheva, J., Gurevitch, J., Mengersen, K., 2013. Handbook of meta-analysis in ecology and evolution. Princeton University Press.

Kronen, M., Vunisea, A., Magron, F., McArdle, B., 2010. Socio-economic drivers and indicators for artisanal coastal fisheries in Pacific island countries and territories and their use for fisheries management strategies. Mar. Policy 34, 1135–1143. https://doi.org/10.1016/j.marpol.2010.03.013.

Kuckartz, U., Rädiker, S., 2019. Analyzing Focus Group Data, in: Analyzing Qualitative Data with MAXQDA: Text, Audio, and Video. Springer International Publishing, Cham, pp. 201–217. https://doi.org/10.1007/978-3-030-15671-8_15.

A.A. Kwasi L. Larbi P, B.A., atrick Kwabena Ofori-Danson, Impacts of Coastal Inundation Due to Climate Change in a Remote Sens. 3 2011 2029 2050 10.3390/rs3092029.

Lawson, E.T., Schluchter, W., Gordon, C., 2010. Using the paired comparison methodology to assess environmental values in the coastal zone of Ghana. J. Coast. Conserv. 14, 231–238.

B. Le Gallic Fisheries Sustainability Indicators: The OECD experience., in: Joint Workshop EEA-EC DG Fisheries-DG Environment on" Tools for Measuring (Integrated) Fisheries Policy Aiming at Sustainable Ecosystem" 2002 Brussels, Belgium.

Lele, S., Springate-Baginski, O., Lakerveld, R., Deb, D., Dash, P., 2013. Ecosystem services: Origins, contributions, pitfalls, and alternatives. Conserv. Soc. 11, 343–358.

Leximancer, 2019. Leximancer.

Li, Yi, Kappas, M., Li, Y., 2018. Exploring the coastal urban resilience and transformation of coupled human-environment systems. J. Clean. Prod. 195, 1505–1511. https://doi.org/10.1016/j.jclepro.2017.10.227.

Lins-de-Barros, F.M., Muehe, D., 2013. The smartline approach to coastal vulnerability and social risk assessment applied to a segment of the east coast of Rio de Janeiro State. Brazil. J. Coast. Conserv. 17, 211–223.

Loomis, D.K., Paterson, S.K., 2014. Human dimensions indicators of coastal ecosystem services: A hierarchical perspective. Ecol. Indic. 44, 63–68. https://doi.org/10.1016/j.ecolind.2013.12.022.

Magpayo, N., 1995. Integrated approach to community-based coastal resources management. In: Visayas-Wide CB-CRM and Fisheries Co-Management Conference. ECOTECH Center, Lahug, Cebu City, pp. 4–7.

Maliao, R.J., Pomeroy, R.S., Turingan, R.G., 2009. Performance of community-based coastal resource management (CBCRM) programs in the Philippines: A meta-analysis. Mar. Policy 33, 818–825.

Marín-Monroy, E.A., Ojeda-Ruiz de la Peña, M.Á., 2016. The role of socioeconomic disaggregated indicators for fisheries management decisions: The case of Magdalena-Almejas Bay. BCS. Mexico. Fish. Res. 177, 116–123. https://doi.org/10.1016/j.fishres.2016.01.009.

Matzdorf, B., Biedermann, C., Meyer, C., Nicolaus, K., Sattler, C., Schomers, S., 2014. Paying for Green? 207.

MAXQDA, 2020. MAXQDA.

McCallen, E., Knott, J., Nunez-Mir, G., Taylor, B., Jo, I., Fei, S., 2019. Trends in ecology: Shifts in ecological research themes over the past four decades. Front. Ecol. Environ. 17, 109–116.

McCarter, J., Sterling, E.J., Jupiter, S.D., Cullman, G.D., Albert, S., Basi, M., Betley, E., Boseto, D., Bulehite, E.S., Harron, R., Holland, P.S., Horning, N., Hughes, A., Jino, N., Malone, C., Mauli, S., Pae, B., Papae, R., Rence, F., Revo, O., Taqala, E., Taqu, M., Woltz, H., Filardi, C.E., 2018. Biocultural approaches to developing well-being indicators in Solomon Islands. Ecol, Soc, p. 23.

Meng, B., Chi, G., 2018. Evaluation index system of green industry based on maximum information content. Singapore Econ. Rev. 63, 229–248. https://doi.org/10.1142/S0217590817400094.

Micallef, S., Micallef, A., Galdies, C., 2018. Application of the Coastal Hazard Wheel to assess erosion on the Maltese coast. Ocean Coast. Manag. 156, 209–222. https://doi.org/10.1016/j.ocecoaman.2017.06.005.

Minar, M.H., Hossain, M.B., Shamsuddin, M.D., 2013. Climate change and coastal zone of Bangladesh: vulnerability, resilience and adaptability. Middle-East J. Sci. Res. 13, 114–120.

Miswar, E., Natasya, D., Irham, M., Aprilla, R.M., Agustina, S., Affan, J.M., 2018. Analysis of social and economic aspects of management of marine and coastal resources based on EAFM (Ecosystem Approach to Fisheries Management) method in Banda Aceh City. IOP Conf. Ser. Earth Environ. Sci. 216 https://doi.org/10.1088/1755-1315/216/1/012034.

Mollah, S., 2016. Assessment of flood vulnerability at village level for Kandi block of Murshidabad district, West Bengal. Curr. Sci. 110, 81–86. https://doi.org/10.18520/cs/v110/i1/81-98.

Murphy, D.W.A., 2015. Theorizing climate change,(im) mobility and socio-ecological systems resilience in low-elevation coastal zones. Clim. Dev. 7, 380–397.

Narra, P., Coelho, C., Sancho, F., Palalane, J., 2017. CERA: An open-source tool for coastal erosion risk assessment. Ocean Coast. Manag. 142, 1–14.

Navarro, T., 2018. Water reuse and desalination in Spain–challenges and opportunities. J. Water Reuse Desalin. 8, 153–168.

Nemes, G., 2005. Integrated rural development-The concept and its operation. IEHAS Discuss, Pap.

Nguyen, T.T.X., Bonetti, J., Rogers, K., Woodroffe, C.D., 2016. Indicator-based assessment of climate-change impacts on coasts: A review of concepts, methodological approaches and vulnerability indices. Ocean Coast. Manag. 123, 18–43. https://doi.org/10.1016/j.ocecoaman.2015.11.022.

Nunez-Mir, G.C., Iannone, B.V., Pijanowski, B.C., Kong, N., Fei, S., 2016. Automated content analysis: addressing the big literature challenge in ecology and evolution. Methods Ecol. Evol. 7, 1262–1272. https://doi.org/10.1111/2041-210X.12602.

Odemerho, F.O., 2015. Building climate change resilience through bottom-up adaptation to flood risk in Warri. Nigeria. Environ. Urban. 27, 139–160. https://doi.org/10.1177/0956247814558194.

Oppenheimer, M.B.C., Glavovic, J., Hinkel, R., van de Wal, A.K., Magnan, A., Abd-Elgawad, R., Cai, M., Cifuentes-Jara, R.M., DeConto, T., Ghosh, J., Hay, F., Isla, B., Marzeion, B., Meyssignac, Z., Sebesvari, B., 2019. Sea Level Rise and Implications for Low-Lying Islands. Coasts Commun.

Penn-Edwards, S., 2010. Computer Aided Phenomenography: The Role of Leximancer Computer Software in Phenomenographic Investigation. Qual. Rep. 15, 252–267.

Pomeroy, R.S., Pollnac, R.B., Katon, B.M., Predo, C.D., 1997. Evaluating factors contributing to the success of community-based coastal resource management: the Central Visayas Regional Project-1 Philippines. Ocean Coast. Manag. 36, 97–120.

Powell, R.A., Single, H.M., 1996. Focus Groups. Int. J. Qual. Heal. Care 8, 499–504. https://doi.org/10.1093/intqhc/8.5.499.

Rakhmanissazly, A., Permatasari, A.I., Peranginangin, E.C., 2018. Edco-Tourism; A coastal management program to improve social economics. IOP Conf. Ser. Earth Environ. Sci. 116 https://doi.org/10.1088/1755-1315/116/1/012038.

Rasul, G., Sharma, B., 2016. The nexus approach to water–energy–food security: An option for adaptation to climate change. Clim. Policy 16, 682–702. https://doi.org/10.1080/14693062.2015.1029865.

Roy, S., Roy, M.M., Jaiswal, A.K., Baitha, A., 2018. Soil arthropods in maintaining soil health: thrust areas for sugarcane production systems. Sugar Tech 20, 376–391.

Saillard, E.K., 2011. Systematic versus interpretive analysis with two CAQDAS packages: NVivo and MAXQDA. Forum Qualitative Sozialforschung/Forum. Qualitative Social Research.

Sharples, C., Mount, R., Pedersen, T., Lacey, M., Newton, J., Jaskierniak, D., Wallace, L., 2009. The Australian coastal smartline geomorphic and stability map version 1: project report. Prep. Geosci. Aust. Dep. Clim. Chang. by Sch. Geogr. Environ. Stud. Univ. Tasmania, Hobart.

Sherman, K., 2014. Toward ecosystem-based management (EBM) of the world′ s large marine ecosystems during climate change. Environ. Dev. 11, 43–66.

Sorensen, J., 1993. The international proliferation of integrated coastal zone management efforts. Ocean Coast. Manag. 21, 45–80. https://doi.org/10.1016/0964-5691(93)90020-Y.

Stojanovic, T., McNae, H.M., Tett, P., Potts, T.W., Reis, J., Smith, H.D., Dillingham, I., 2016. The "social" aspect of social-ecological systems. Ecol. Soc. 21.

Stronkhorst, J., Levering, A., Hendriksen, G., Rangel-Buitrago, N., Appelquist, L.R., 2018. Regional coastal erosion assessment based on global open access data: A case study for Colombia. J. Coast. Conserv. 22, 787–798. https://doi.org/10.1007/s11852-018-0609-x.

Suinyuy, N., Xue, X., Banyouko Ndah, A., 2016. Exploring the challenges of implementing integrated coastal management and achieving sustainability within the cameroon coastline. Rev. Gestão Costeira Integr./J. Integr. Coast. Zo. Manag. 16 https://doi.org/10.5894/rgci648.

Sullivan, K., Thomas, S., Rosano, M., 2018. Using industrial ecology and strategic management concepts to pursue the Sustainable Development Goals. J. Clean. Prod. 174, 237–246.

Sylla, M.B., Nikiema, P.M., Gibba, P., Kebe, I., Klutse, N.A.B., 2016. Climate Change over West Africa: Recent Trends and Future Projections, in: Yaro, J.A., Hesselberg, J. (Eds.), Adaptation to Climate Change and Variability in Rural West Africa. Springer International Publishing, Cham, pp. 25–40. https://doi.org/10.1007/978-3-319-31499-0_3.

M.K. Tefe Framework for integrating indigenous and scientific knowledge for transportation planning in developing countries 2012 https://doi.org/10.14188/j.2095-6045.2012.06.011.

Thaler, T., Levin-Keitel, M., 2016. Multi-level stakeholder engagement in flood risk management-A question of roles and power: Lessons from England. Environ. Sci. Policy 55, 292–301. https://doi.org/10.1016/j.envsci.2015.04.007.

E.R. Thieler E.S. Hammar-Klose National assessment of coastal vulnerability to sea-level rise 1999 US Atlantic Coast.

Tian, H., Lindenmayer, D.B., Wong, G.T.W., Mao, Z., Huang, Y., Xue, X., Lindenmayer, D. B., Wong, G.T.W., Mao, Z., Huang, Y., Xue, X., 2018. A methodological framework for coastal development assessment: A case study of Fujian Province. China. Sci. Total Environ. 615, 572–580. https://doi.org/10.1016/j.scitotenv.2017.09.309.

United Nations, 2005. Standard country or Area Codes for Statistical Use [https://stats.oecd.org/glossary/detail.asp?ID=6326]. Series M, No. 49, Rev. 4 (United Nations Publ. Sales No. M.98.XVII.9).

Van Dongeren, A., Ciavola, P., Martinez, G., Viavattene, C., Bogaard, T., Ferreira, O., Higgins, R., McCall, R., 2018. Introduction to RISC-KIT: Resilience-increasing strategies for coasts. Coast. Eng. 134, 2–9.

Van Eijck, J., Romijn, H., Smeets, E., Bailis, R., Rooijakkers, M., Hooijkaas, N., Verweij, P., Faaij, A., 2014. Comparative analysis of key socio-economic and environmental impacts of smallholder and plantation based jatropha biofuel production systems in Tanzania. Biomass Bioenergy 61, 25–45. https://doi.org/10.1016/j.biombioe.2013.10.005.

Vugteveen, P., Rouwette, E., Stouten, H., van Katwijk, M.M., Hanssen, L., 2015. Developing social-ecological system indicators using group model building. Ocean Coast. Manag. 109, 29–39.

Wavrek, M., Heberling, J.M., Fei, S., Kalisz, S., 2017. Herbaceous invaders in temperate forests: a systematic review of their ecology and proposed mechanisms of invasion. Biol. Invasions 19, 3079–3097.

Werner, S.R., Spurgeon, J.P.G., Isaksen, G.H., Smith, J.P., Springer, N.K., Gettleson, D.A., N'Guessan, L., Dupont, J.M., 2014. Rapid prioritization of marine ecosystem services and ecosystem indicators. Mar. Policy 50, 178–189. https://doi.org/10.1016/j.marpol.2014.03.020.

P.P. Wong I.J. Losada J.-P. Gattuso J. Hinkel A. Khattabi K.L. McInnes Y. Saito A. Sallenger 2014. Coastal systems and low-lying areas, in: Field, C.B., V.R. Barros, D.J. Dokken, K.J.M., M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.W. (Eds.), Climate Change, Impacts, Adaptation, and Vulnerability 2014 Cambridge University Press Cambridge, United Kingdom and New York, NY, USA 361 409.

Yun, J.J., Liu, Z., 2019. Micro- and macro-dynamics of open innovation with a quadruple-helix model. Sustainability 11, 3301. https://doi.org/10.3390/su11123301.

Zaldívar-Jiménez, M.A., Herrera-Silveira, J.A., Teutli-Hernández, C., Comín, F.A., Andrade, J.L., Molina, C.C., Ceballos, R.P., 2010. Conceptual framework for mangrove restoration in the Yucatán Peninsula. Ecol. Restor. 28, 333–342.

Zhu, D.-S., Zhang, J.-Y., Liao, W.-G., Shi, X.-X., Cheng, H.-G., Li, Y., 2010. A key ecological indicator system for water project planning and design. Shuikexue Jinzhan/Adv. Water Sci. 21, 560–566.