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Sustainable coastal social-ecological systems: how do we define "coastal"?

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The coastal system constitutes only 5% of the earth's surface, but contain 17% of the world's population live in areas that are less than 10 meters above sea level (MEA 2005). In addition, around two-thirds of the world's population lives within 100 km of a coast (Inman and Brush 1973; UN 2017). Coastal system contain some of the most productive and diverse ecosystems in the world, thus providing a wide range of ecosystem services worth an estimated US $12 trillion yr^{-1} (Costanza et al. 1997; Costanza et al. 2014). These ecosystem services include provisioning (e.g., food, fish), supporting (e.g., buffering the coastal population from storm and erosion), regulating (e.g., storing carbon) and cultural (e.g., tourism) services (MEA 2005). Highly enriched coastal ecosystems thus provide human benefits, which may explain why per capita income in coastal countries is higher than landlocked countries (Gallup et al. 1999; He et al. 2014).

Despite growing interest by a wide range of disciplines and policies in the sustainable management of coastal resources (Mee 2012), there is no single definition of how "coastal" is defined. In general, all low-lying areas near the mean sea level are referred to as coasts (IPCC 2014). Because of this generalization in delineating the coast and its wider influence on human society, Hinrichsen (1998), recognizes that "all humankind is coastal". However, in order to resolve conflicts over the ecosystem services provided by coastal systems and to advance the science and theories upon which sustainable coastal management is based, we argue that an explicit definition of "coast" and its ecological (biophysical), social, and social-ecological (SES) components is needed. In curating this special issue on "Sustainable Coastal Socioecological Systems", we recognized that the contributing authors frame coastal SES from multiple perspectives. This reveals the absence of a single unifying definition for what is meant by

coastal. An example of this multiplicity lies in the use of coastal zones and coastal areas. In general, a coastal zone refers to a geographical area that includes both terrestrial and submerged areas of the coast and is delineated administratively for coastal zone management (Finkl 2016). Coastal area, on the other hand, broadly refers to the extent of coastal processes and the ecosystems they support without restriction to a specific geographical entity or spatial boundary. By this definition, the land and water within coastal areas are influenced by interacting biological, physical, and human processes in both their terrestrial and marine extents (FAO 1998; Cullinan 2006). In keeping with this integrated definition of what coastal means, we opt for the more broadly defined "coastal areas" when referencing coastal systems or coastal SES in this introduction to the special issue.

The most common definition of "coastal" is adapted from ecology (biophysical process). In general, the coast has been defined as the area where land and sea meet (FAO 1998; Burke et al. 2001; MEA 2005; Finkl 2016). The coastal area is thus affected both by the sea and its proximity to the land (Hinrichsen 1998). Spatially-limited definitions have been suggested by Small and Nicholls (2003), who delineate coastal areas as 100 horizontal kilometers and 100 vertical kilometers from the intersection of land and sea. Hinrichsen (1998) and OECD (1993) further extend the spatial boundary when defining coastal areas, using a boundary of 200 kilometers inland from the low-tide mark. They emphasize intertidal zones, which include ecosystems such as mangroves, estuaries, and floodplains when describing the coastal area.

Compared to ecological perspectives on defining coastal areas, social and social-ecological approaches have received less attention both in academia and policy. In social science, coastal areas have been defined as regions where a population is highly dependent on the sea and its resources (Fiorini et al. 2017; Bennett 2019). Pomeroy et al. (2006) use a livelihood-based approach when characterizing coastal areas and identify four distinct characteristics that comprise coastal social systems. First, a coastal social system is diversified and heterogenous and is therefore not dependent on a single livelihood or resource. Second, there is a need for adaptation to reduce the risk of dependence on natural resources. Third, coastal populations use short-term survival strategies as an incentive structure, which is mainly due to external factors such as property rights, rule, and resources governance. Finally, high levels of vulnerability in coastal areas relate to exposure to coastal processes, resource dependency, lack of participation in decision-making, and power imbalances. Though these characteristics do not formally delineate coastal areas, they can be used to define coastal areas from social science perspectives.

The SES literature goes beyond defining coastal systems as simply containing discrete ecological and social systems, but also as an interaction between these two systems (IPCC 2007, 2014; Andrés et al. 2018), forming a coupled SES (Hossain et al. 2020a; Amin et al., 2020). The IPCC (2014) argued that a coastal system needs to be conceptualized in terms of both its social and ecological systems, where the coastal ecological system includes sub-sets of ecosystems such as estuaries, deltas, wetlands, coral reefs along with other distinct features such as rocky coasts, beaches, mudflats, and sand dunes. Built environments (e.g., settlements, ports, seawalls), livelihood opportunities (e.g., tourism, fisheries), and coastal-relevant institutions (e.g., policies, laws, customs, culture) are key features of a coastal social system. Lovecraft and Meek (2019) applied SES thinking to coastal systems by describing how humans are dependent on ecosystem services provided by near shore terrestrial and marine ecosystems both for their livelihood and cultural services. However, all these approaches broadly and conceptually define coastal SES without operationalizing by using real world examples. Andrés et al. (2018) proposed a conceptual framework using SES theories (interactions of ecological and socioeconomic) to define coastal SES and then demonstrated application of the theory with examples from the Brazilian coast. According to the framework (Andrés et al. 2018), coastal SES consists of three units: shoreland, coastal uplands and coastal-influence land. Shoreland is the imaginary line between inlands, sea, and the intertidal zone, which places limitations on the area between the sea and human settlements (i.e., mainly urban areas). Coastal uplands refer to the area between shoreland and coastal municipalities. The boundary land between coastal uplands and river basins is referred to as coastal-influence land; it is farther away from the coast, but its economic activity is highly dependent on the coast and sea. In addition, Andrés et al. (2018) argued that economic activities in coastal-influence land effect the environmental quality of the coast. Thus, coastal-influence land is a coastal SES unit despite having no coastal physical characteristics.

Despite their value to human wellbeing, coastal ecosystems are under threat from an increasing population, resource exploitation, and global environmental change (e.g. climate change) (MEA 2005; Lotze et al. 2006). Considering the wide range of drivers and pressures in coastal SES, it has been recognized as overdeveloped, overcrowded, and overexploited (Hinrichsen 1998), as well as over exposed to global environmental changes. In recent years, coastal SES is experiencing severe social and ecological pressures, which have devastating societal impacts in coastal areas. It has been estimated globally that 0.8–1.1 million people per year are flooded (Hinkel et al. 2014) and US$ 1407 billion economic loss due to tropical cyclones since 1942 (WMO 2020). Coastal erosion, tsunamis and sea level rise are also

threatening coastal SES. In addition to these environmental changes, anthropogenic pressures such as habitat loss due to development related pressures, population growth, overexploitation of resources, and land degradation are compromising the ability of coastal SES to sustainably provide ecosystem services (MEA 2005). These challenges will be amplified by climate change (IPCC 2014).

The ecological, social, and economic importance of coastal SES and the increasing human and environmental pressures on them have led to several national and global initiatives towards sustainable coastal SES. The conclusion of the UN Earth Summit at Rio de Janeiro in 1992 resulted in a strong international commitment to coastal management (European Union 2012), which started off as an initiative aimed at emphasizing coastal SES in assessments such as the Millennium Ecosystem Assessment (MEA 2005) and the Intergovernmental Panel on Climate Change (IPCC). Beyond national coastal management policies, there have been transboundary and regional policies adopted such as the integrated coastal zone management policy in Europe in 2002 and the "blue growth" strategy that targets coastal areas of Europe (European Union 2012; European Commission 2012). Recognising the growing threats to coastal SES and the explosion of interest in managing coastal SES, the United Nations' Sustainable Development Goals (SDGs) incorporated coastal areas into one of its 17 goals (Neumann et al. 2017). The SDG 14 incorporates the conservation and sustainable use of the oceans, seas, and marine resources. Within SDG 14, the targets 14.2 and 14.5 specifically focus on the management and protection of coastal areas and ecosystems (UN 2017).

Despite several global, national, and local initiatives, there is a growing consensus that coastal resources are depleting and increasing conflicts in coastal areas (Hinrichsen 1998; European Commission 2012). Besides the population, institutional governance, and management challenges of coastal SES, its highly dynamic nature is one of the prime reasons which makes the sustainability of coastal SES highly challenging (Schlüter et al. 2020). In addition, Earth's climate, which has been adversely affected by anthropogenic activities over the past two centuries, already poses a serious risk to coastal SES (IPCC 2014). There is a growing consensus that climate change will have severe impacts on coastal society in the future (MEA 2005; Woodruff et al. 2013; IPCC 2014). Therefore, there is a pressing need to manage the sustainability of coastal SES by understanding social and ecological systems as a coupled system.

Better understanding coupled social-ecological interactions within coastal areas is vital for implementing development practices that will optimize human well-being and sustain

ecosystems and the resources they generate (Willcock et al. 2016; Hossain et al. 2017a; Gain et al. 2019). Coastal systems comprising both social and ecological elements, with interconnected reliance across multiple scales can be conceptualized as a SES (Hossain and Szabo 2017b; Gain et al., 2020). The objective of this special issue is to advance understanding of the sustainability of social and ecological interactions within coastal areas through theoretical SES approaches and related analytical methods. This special issue emerged as a collaborative idea between two Marie Skłodowska-Curie grants under the European Union's Horizon 2020 research and innovation programme and a project funded through the U.S. National Science Foundation's Dynamics of Coupled Natural and Human Systems program. These projects focus on the advancement of theories and application of the SES concept to understanding feedbacks between coastal processes, built coastal environments, social dynamics, and sustainable development. In general, the scope and potential topics of the special issues are: 1) quantitative and qualitative approaches for assessing the sustainability of coastal systems. 2) operationalization of SES approaches for management and governance of coastal resources in the context of sustainable development of coastal SES; 3) qualitative methods, including case studies, grounded theoretical approaches for examining coastal systems; 4) social, institutional and natural systems in coastal systems analyses; 5) environmental justice/telecoupling/equity for ensuring the sustainability of coastal SES. In total, seven contributions were obtained as a result of various announcements made in 2019. Before inviting the final submission of the papers, 25 abstracts were reviewed by guest editors following the quality and thematic scopes of these papers.

Considering the critical role of qualitative approach and mental models understand the sustainability of coastal SES (Hossain et al., 2020b), Kulsum et al. (2019) describe the conceptual development and operationalization of a participatory approach for understanding how mental models used by farming communities in Southwest Bangladesh may impact the success of Community Livelihood Adaptation currently being used to inform adaptive delta management policies. They propose an integrated technique combining empirical data collection, cognitive mapping, and scenario modelling for understanding the complex cognitive process behind cropping decisions made in the face of uncertainty.

Nguyen et al. (2020) assessed the resilience of mangrove-shrimp farming systems in the coastal province of Ben Tre of the Vietnamese Mekong Delta (VMD) through use of the Motivation and Ability framework in conjunction with a sustainable livelihood framework. They found low levels of resilience and sustainability of the mangrove-shrimp livelihoods

under the impact of extreme salinity intrusion. In order to improve resilience of the coupled SES, they proposed an evidence-based framework.

Through participatory research, Mutahara et al. (2020) analysed the socio-technical transformation of the tidal river management (TRM) approach, a less structural and more natural management intervention to prevent the severe water-logging in the Southwest region of coastal Bangladesh. They identified existing problems of community participation and proposed a method of developing effective multi-stakeholder processes (MSPs) with respect to tidal river management in deltas.

Schéré et al. (2020) highlighted the challenges caused by data availability to the effectiveness of marine protected areas. Their analysis of 111 marine protected areas revealed that few sites incorporate socioeconomic aspects into their management plans. In addition, the existence of a management plan is highly linked to favourable outcomes in terms of management. They contend that previous policies, such as the Birds and Habitat Directive, should remain in force to help achieve successful conservation in the Irish Sea. However, the Brexit issue may make the future uncertain as EU regulations emplaced to protect coastal environments, such as the Natura 2000 network, could be replaced. They conclude that protection of socioeconomic issues is needed in order to achieve biological conservation goals.

Recognizing the role of institutions and adaptability in the governance of coastal SES, Baker et al. (2020) used a mixed method approach to explore hybrid governance, through engaging federal and local government and private actors in Quintana Roo, Mexico. They contended that a strong network of private actors, who self-motivated through engagement and collaborated with the state have played a critical role in environmental governance. They concluded that an understanding of the feedbacks between the conditions and characteristics of system governances is necessary for the sustainability of coastal SES.

Migration decisions are considered adaptive strategies similar to livelihood diversification in response to environmental change (e.g. Renaud et al. 2011). However, Assaduzzaman et al. (2020) find that social status and economic class imprints an individual's perception that they may freely choose to migrate. Applying Sen's capability framework to examine empirical results on push-pull factors behind the decision to migrate in coastal Bangladesh, they add compelling dimension to the emerging environmental migration literature by focusing on the role of freedom of choice in the decision to migrate.

Recently there has been a pressing call to consider social justice when assessing the sustainability of SES (Hossain and Ifejika Speranza 2019), with 'leave no one behind' being pledged in the 2030 UN agenda and other international discourses (Dearing et al. 2014).

Recognizing the global call for the inclusion of social justice to ensure the sustainability of SES, Boillat et al. (2020) examined the potential of agroecology to improve the adaptive capacity of farmers by addressing power and social justice related to SES in the coastal region of Senegal. They suggested that reinforcing feedback influence strongly the resilience of farmers. In addition, this paper also argued that agroecology could be useful in addressing resilience justice.

The sustainability of coastal SES is vigorous and dynamics research field. To support scientific understanding of the sustainability issues of coastal SES, this special issue brings together seven articles on coastal issues. Considering the changing dynamics of coastal SES and growing vulnerability across the globe, there is an urgent need for more research and policy relevant programmes that conceptualize the coastal system as a complex SES in order to understand the complex dynamics (interactions, feedbacks, delay) between SES. In particular, consideration of feedbacks between SES is required when defining coastal systems in order to make the policies effective. Studies such as these have the potential to inform policy action and decision making such that coastal-relevant SDGs may be achieved by 2030. We hope that the special issue will stimulate debate and contribute further thinking to how coastal areas can sustainably respond to both ecological and social changes.

Keywords: Social-ecological systems; Coastal systems; Definition of coastal area, interdisciplinary.

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