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Socializing the coast: Engaging the social science of tropical coastal research

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ABSTRACT

The broad scale and rapid rate of change in the global environment is causing some of the world's most challenging problems, such as habitat degradation, loss of biodiversity, and food insecurity. These problems are especially pressing in coastal environments in the tropics, resulting in significant impacts on human wellbeing and ecological systems across the globe. The underlying causes of marine and coastal environmental change are both anthropogenic and natural; and, while it is difficult to parse out causal linkages as either exclusively human or naturally occurring, feedbacks between drivers only exacerbate the issues. Increasingly, scholars are turning to integrated research efforts, whereby multiple disciplines are used to answer pressing questions about and find solutions for the sustainability of human life and natural ecosystems across the coastal tropics. This article leverages the recent wave of interdisciplinary research to explore the various ways in which the social sciences have successfully contributed to a more complete understanding of coastal systems across the tropics. It also identifies opportunities for research that move beyond single disciplinary approaches to coastal science. The concluding discussion suggests social science knowledge areas that are underutilized in coastal research and provides suggestions for increasing the incorporation of social science in coastal research programs.

1. Introduction

The broad scale and rapid rate of change in the global environment is causing some of the world's most challenging problems, such as climate change, loss of biodiversity, and food insecurity (Ledford, 2015). These problems are especially pressing in marine and coastal environments, where approximately 60% of the global population lives and relies on its natural resources for subsistence and livelihoods (UN, 2011). As a consequence, human wellbeing is being impacted across coastal regions of the globe, particularly in the tropics (Glaser et al., 2012; Moberg and Rönnbäck, 2003). At the same time, a growing coastal population is imparting stress on natural resources and landscapes. Ultimately, the underlying drivers of marine and coastal environmental problems are both anthropogenic and natural (Leenhardt et al., 2015); and, it is the feedback between drivers that exacerbates the issues (Agardy and Alder, 2005). Here, we provide examples of ways in which both human and environmental drivers have been integrated in research, and provide suggestions on how to engage with social science to further understand these complex interactions.

The study of these complex relationships is required to solve challenges at various spatial, temporal, ecological, cultural, societal and political scales. Scientific approaches provide unique tools to do this by tracking baseline data and generating new insights about natural and human coastal systems. It is increasingly recognized, however, that single-discipline approaches are unable to address the problems that threaten our coastal ecosystems (Nature, 2015b). Indeed, unraveling these complexities requires new approaches that span disciplinary boundaries within both natural and social sciences to reduce uncertainty, provide better and more informed solutions, and incorporate a holistic approach to environmental management (Barnard and Elliott, 2015; Liu et al., 2007; Viseu, 2015). In response, scholars are turning to integrated research and graduate training efforts, whereby multiple disciplines are leveraged to answer pressing global questions about the sustainability of human life and natural ecosystems along the coast (Brown et al., 2015; Ciannelli et al., 2014).

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Integrated approaches to science can range from multidisciplinary, interdisciplinary and transdisciplinary efforts. As Rosenfield (1992) suggests, multi- and interdisciplinarity is characterized by the parallel working of more than one discipline on a shared problem, with little to no integration. In contrast, transdisciplinarity calls for a collaborative team of stakeholders, potentially including non-academic actors that work together on a jointly defined issue within a shared conceptual framework and/or approach. At this level, the integration of natural and social sciences requires collaborators to be able to understand each other, at a minimum, and ideally be able to share and synthesize information across all involved disciplines (Ciannelli et al., 2014; Nature, 2015a). Integrative efforts to simultaneously address both human and environmental issues include efforts to link social and natural data using systemic analytical frameworks, and expand these to take into account cultural and political concerns, as well as special attention to modes of engagement and communication. The couplings, and the frameworks used to study and communicate them, can be grouped under the concept of coupled human and natural systems (CHANS), as defined by Liu et al. (2007) by: (a) focusing on processes that link human and natural systems; (b) emphasizing the feedbacks between human actions and environmental outcomes; and (c) paying attending to the scalar dynamics of the interactions. In turn, then, the information generated by these comprehensive research approaches can better inform holistic management and policy efforts.

While calls for interdisciplinary research are on the rise (Van Noorden, 2015), challenges to engaging the social sciences of coastal research remain, and are not easily resolved. These challenges include the difficulties of integrating social and ecological theories into problem formulation, the normalized inclusion of social science as an afterthought to project design, the lack of clarity in the difference between and role of each field of social science, the relative lack of social science data and funding for social science, problems of scale and comparability between social and biophysical data, difference in jargon between social and natural scientists, and existence of complex causalities in social-ecological relationships (Forsyth, 1998; Fox et al., 2006; Gunderson and Holling, 2002; Leenhardt et al., 2015; Strang, 2009; Turner, 2000). A discussion of these challenges, however, is beyond the purview of this paper. Instead, this article leverages the recent wave of interdisciplinary research to explore the various ways in which the social sciences have successfully contributed to a more complete understanding of coastal systems across the tropics. It also identifies opportunities for research and engagement that move beyond single disciplinary approaches to coastal science. We begin with a brief summary of the main threats to tropical coastal social-ecological systems, followed by an overview of the range of social science approaches to coastal research. We then present examples of research that has incorporated social science to address problems along the coast, within three broad tropical coastal issues: fisheries, climate change induced coral bleaching, and habitat degradation. In concluding, we discuss social science knowledge areas that are underutilized in coastal research in the tropics and provide suggestions, in the form of research questions, on ways to engage with social science in coastal research programs. We would like to point out that this is not a primer on how to effectively carry out social science research, nor is it an exhaustive review of interdisciplinary efforts to date. Instead, we highlight research in which natural and social sciences are well integrated, and identify areas with potential to improve on the inclusion and use of social science tools.

2. Summary of social and environmental threats to tropical coastal ecosystems

Coastal environments across the globe are changing at an increasing rate (Valiela, 2006). These changes include rising sea levels, ocean acidification, alterations in freshwater discharges, loss of habitats, increased ocean pollution, introduction of exotic species, and changes in food webs due to high levels of finfish and shellfish extraction. Parallel to these changes we are seeing broad social transformations such as population growth, increased reliance on natural resources from species to landscapes, unequal distribution of income, loss of cultural traditions, as well as rapid rates of urban development, each of which have contributed, to some extent, the degradation of coasts that we currently experience (Glaser et al., 2012; Moberg and Rönnbäck, 2003). The feedback between these environmental and social changes is key to determining outcomes. Below we illustrate these feedbacks in three important aspects of coastal tropics: marine fisheries, coral reefs, and coastal habitats.

Coastal ecosystems are broadly affected by the increase of greenhouse gases in our atmosphere through higher sea surface temperatures and changes in the chemical composition of the ocean. While these impacts are not equally distributed around the globe, they interact with natural environmental variability and ocean cycles resulting in often unexpected and unpredictable outcomes that, in turn, affect the availability and sustainability of tropical marine resources for human use. These same human uses often also represent significant threats to the resilience of marine resources, as unsustainable anthropogenic disturbances reduce their ability to respond to or bounce back from environmental stressors (Hoegh-Guldberg, 2011). Challenges specifically associated with tropical finfish and shellfish harvest include ineffective management schemes, conflicting conservation agendas, shifting global political economies, and technological changes, all of which contribute to the current state of global fisheries (FAO, 2016). Despite efforts to adopt a more comprehensive approach to fisheries governance through the use of strategies such as ecosystem-based fisheries management (Pikitch et al., 2004), there are still inherent limitations to characterizing the social and natural drivers of change in fisheries across the global tropics. For instance, as of 2010, wild marine catch from tropical countries accounted for 45% of the global catch, up from 12% in 1950. Unfortunately, information about these fisheries is very limited, particularly in the small-scale fishing sector (Chuenpagdee et al., 2006). We do know, however, that the combined social and ecological drivers have resulted in decreasing food and livelihood security to resource dependent communities, as well as detrimental effects to non-targeted species, habitats, and species compositions (Valiela, 2006).

Similarly, the extent and health of coral reefs has declined substantially since the 1980s (Goreau and Hayes, 2009). Reefs are critical sources of food, storm protection, medicinal knowledge, and tourism revenue for the over 275 million people who live within 30 km of reef systems (Burke et al., 2011). This important ecosystem is threatened by direct human actions such as destructive fishing habits and increased sedimentation associated with upland modifications as well as from more indirect pathways that include sea level rise and warming, and increased incidences of disease associated with global climate change (Burke et al., 2011; Goreau and Hayes, 2009; Jackson et al., 2014; Valiela, 2006). In particular, large scale coral bleaching has been directly linked to increased seawater temperatures of as little as 1 °C (Goreau and Hayes, 2009). Bleaching, in turn, results in the inability of corals to grow skeletons, reproduce, and defend themselves. The cumulative effect of these drivers of change dramatically affects both social and ecological components of the system (Jackson et al., 2014).

Finally, sediment flows and other disturbances that affect the highly diverse geological composition of terrestrial coastal regions are also driven by region-specific climate and oceanographic conditions. However, these natural processes are rapidly being enhanced by land use changes that result from anthropogenic pressures such as urbanization, deforestation, and infrastructure development (Silva et al., 2014). Climate change and its immediate threats, such as sea level rise and higher frequency of storm events, also play an important role in coastal change, often affecting both the structure of coastal environments, as well as changes in freshwater inputs, sedimentation and runoff (Valiela, 2006). These are relatively well-studied system level processes that necessarily require further consideration in the context of increasing anthropogenic influence. For instance, since 1980, approximately 35% of global mangrove forests have been lost to shrimp and fish aquaculture, forestry, freshwater diversions, and land reclamation (Giri et al., 2011; Valiela et al., 2001). The act of mangrove deforestation is driven primarily by the desires and needs of some human populations. In turn, the loss of mangroves and their associated ecosystem services, such as providing nurseries for smaller fish, coastal protection against storms, and water filtration, often negatively impacts the same or completely different groups of people (Valiela et al., 2001).

Clearly, there are inherent trade-offs in the anthropogenic influences on coastal ecosystems. Over centuries, humans have altered coastal and estuarine landscapes, while these same landscapes have played a pivotal role in shaping human culture (Máñez et al., 2014; Rowland and Ulm, 2012). Indeed, people generally engage in activities to benefit themselves and/or their communities. However, these actions create feedback loops, often at different social, temporal, or geographic scales, that may in turn harm them or others. In light of these feedbacks between human activity and natural outcomes, the need to better understand both human and natural systems, and how they interact, becomes increasingly evident. Indeed, jointly exploring the various components of these social-ecological interactions could substantially improve our understanding of ongoing coastal threats and, thus, provide insights on how to best inform policy and management efforts aimed at mitigating or preventing them (Conchedda et al., 2011; Vilardy et al., 2011).

3. Engaging the social science of coastal research

As we have suggested thus far in this paper, coastal research has often been limited to understanding the biophysical aspects of change, at the exclusion of the social, cultural and political processes leading to or resulting from those ecosystem transformations. Unfortunately, a lack of engagement with or consideration of social science approaches often represents a limitation to truly integrative and comprehensive coastal research that can in turn inform policy and management efforts (Bennett et al., 2016; Fox et al., 2006; Strang, 2009). Admittedly, not all research requires a social component. We argue, however, that problem-based research calls for socially relevant and scientifically informed responses. To this end, in this section we outline the variety of social science disciplines that contribute to a better understanding of the links between social and environmental processes.

The first step to achieve true engagement is to understand the philosophical and epistemological underpinnings of all involved disciplines. A detailed account of these nuances is beyond the scope of this paper. However, we want offer some clarity about our definitions of social science. By “social” we mean the range of human processes, including behaviors, culture, policy and management. Each of these aspects is explored by different academic disciplines through approaches that range from theoretical, to empirical, to applied (Spalding et al., under review). For instance, Psychology studies mental functions and behaviors, Sociology studies human society, Anthropology studies people and culture, Political Science studies government, politics, power, Economics studies the distribution and allocation of goods and services, and Human Geography studies humans across space and place. Understanding and finding ways of incorporating these disciplines into traditionally natural science focused coastal research is especially important for coastal areas in the tropics that are often data poor, have limited institutional resources, and where human communities tend to have a high level of dependency on natural resources. Furthermore, intellectually, the inclusion of social science has the potential to contribute to the reduction of uncertainty around coastal and estuarine system processes. It also provides opportunities to engage with a broad stakeholder base, fostering stewardship, promoting ocean literacy, and generating trust. Take, for example, the use of expert elicitation for collecting and ranking data. Cultural anthropologists focus on eliciting information from key informants, often elders or leaders with substantial power within a local community, while natural scientists often focus on eliciting information from those with an academic degree pertinent to the topic. An understanding of psychology, for instance, would help us recognize that relying exclusively on local community or academic perspectives will inherently contain biases that influence the framing of our results. Integrating both, however, presents a more complete view of the system and facilitates conversations across stakeholders that may not typically interact. The end result is a diverse stakeholder base that can work together to refine research questions and support scientific relevance.

Recent publications highlight scholars' efforts to promote interdisciplinary collaborations by explaining the fundamentals of the human dimension of the environment as they relate to research, conservation and management (Bennett et al., 2016; Biedenweg et al., 2016; Spalding et al., under review). These publications point out that relevant disciplines are often sub-disciplines within the classics, including environmental anthropology (the study of how culture mediates the relationship with the natural environment); environmental, conservation, and social psychology (the study of human cognition and emotion and how those impact human behaviors); environmental and ecological economics (a subfield and interdisciplinary field, respectively, that looks at the relationships between economies and natural resources/ecosystems); sociology (the study of human societies and the factors that influence their processes); and environmental governance (a subfield of political science that focuses on the process of managing natural resources) (Bennett et al., 2016). Within each of these fields are key concepts that have been generally found to be helpful for understanding social-ecological systems (Decker et al., 2012). For example, understanding the foundation of human behaviors, which includes values and attitudes towards the action, is based within psychology as is understanding the perceptions and attitudes that people have towards resources and proposed management strategy. Exploring the way that people value natural resources (also a driver of behaviors) is based in several disciplines, including economics, anthropology, and psychology. And, while not explicitly based in a social science, the evaluation of how public health relates to ecosystem health, such as food-born illnesses associated with harmful algal blooms, is a critical component to understanding the feedbacks between the social ecological systems.

In practice, the incorporation of social science approaches and concerns improves our knowledge base in order to generate better policies (Ban et al., 2009). If we develop potential management strategies in a vacuum of social knowledge, we risk developing

policies that are irrelevant, likely to fail, and don't address the core factors driving change. This also rings true with communication. When we share information about the ecosystem and proposed policies using the language and context of the reader, it is more likely that policies will be understood and followed. Social scientists can enhance this in an obvious way by informing the context and content of targeted communication efforts. Less obviously, the use of many social scientific methods that engage stakeholders in the research process also results in the development of trust and buy-in that are critical for effective communication, policy, and behavior change.

4. Methods: A review of existing interdisciplinary efforts in coastal research and potential opportunities for further engagement

It is our goal to demonstrate effective ways that integrated social and biophysical sciences have been used in tropical coastal research to better understand complex systems, and to identify social science research opportunities that are crucial to strengthening the understanding of the human dimension of coastal research. To achieve this we conducted a literature review on three globally recognized environmental problems within coastal regions: (a) fisheries; (b) coral bleaching as a result of climate change; and (c) habitat degradation. Peer reviewed manuscripts were identified from Web of Science for the period between January 2010–August 2016 using the following keywords: interdisciplinary, social-ecological system, ecosystem-based management, adaptive management, coastal zone management, and social. All searches included marine or coastal and tropical. The results were further refined by whether explicit attention was given to the interaction between the social and biophysical systems in the abstract, and excluded studies that were either entirely social or ecological. This resulted in a total of 182 articles that were coded for their focus on one of the three issues globally recognized as threatening coastal regions in the tropics (fisheries, climate change induced coral bleaching, and habitat degradation).

Within the three issues, these 182 papers were further analyzed in terms of whether authors used an empirical approach to research and whether they looked at how the social system affected the natural system or vice versa. We intentionally excluded literature reviews and/or articles that were limited to calls for interdisciplinarity. This resulted in a total of 50 papers; 30 that looked at fisheries, and 10 each that addressed coral bleaching and habitat degradation. These 50 papers were further coded into seven priority social science research themes enabling us to identify trends in the use of social science information that could contribute to a deeper understanding of coastal environmental problems and potential solutions: 1) perceptions and attitudes about coastal conditions and management practices across diverse social groups, 2) drivers of human behaviors at different levels of society (individual, communal, and commercial) that impact coastal ecosystems, 3) monetary and non-monetary values that people attribute to coastal ecosystems, 4) impacts of management and governance on people's attitudes, perceptions, and behaviors and, consequently, on the status of coastal systems, 5) impacts of changes in human communities, such as cultural modifications or demographic shifts, on coastal resources, 6) links between human and natural coastal ecosystem health, and 7) strategic development of policies as a result of integrated socio-ecological modeling (Table 1). These themes were identified based on our collective experience working in tropical conservation systems and the literature review conducted for this paper.

We recognize that the Web of Science search results did not identify all papers that effectively integrate social and ecological science to respond to tropical coastal problems over the past ten years. Our purpose in this paper, however, is to provide examples of how such work can be done, to generate synthetic categories of social science themes and illustrate the relevant disciplines for each theme in order to facilitate future engagement with social science scholars.

Table 1
Social science themes and relevant disciplines for interdisciplinary coastal systems studies.

Themes	Relevant disciplines
Perceptions and attitudes	Environmental Psychology Cognitive Anthropology
Behaviors	Psychology Economics Sociology
Management and governance	Social and Organizational Psychology Economics Political Science Anthropology
Valuation	Economics Psychology
Changing human communities	Sociology Anthropology Psychology
Physical health	Public health Medicine

5. Findings: Trends in the use of priority social science themes across major coastal issues of concern

5.1. Fisheries

The use of social science in fisheries research appears to be more common than in research on coral bleaching and habitat degradation. The 30 papers that fit our criteria highlighted a variety of social and ecological concerns, ranging from climate change to anthropogenic extractive pressure, and represented the benefit of incorporating social science to the study of tropical coastal fisheries.

Nine of these papers assessed the effectiveness and impacts of management and governance and another nine focused on the development of integrative socio-ecological models to generate findings specifically aimed at informing policy. The former were mostly evaluative of management schemes and covered topics such as improving fish abundance by limiting fishing timing or tools (Cinner et al., 2009), assessments of management efforts (Cohen et al., 2013), how scientific monitoring informs adaptive management and what level of stakeholder engagement is necessary to obtain “positive” management outcomes (Montambault et al., 2015), and what levels of environmental disturbance are acceptable to include in management schemes (Maynard et al., 2015). The latter, in contrast, described integrated socio-ecological models to inform questions of sustainability, resolve conflicting management objectives (e.g. fisheries vs. conservation), and support concerns of economic development and food security (Bell et al., 2013; Cissé et al., 2014; Dichmont et al., 2013).

Eight papers focused on the impacts of human behavior on fisheries and changes in coastal communities. Human behavior studies included, for instance, a coupled analysis of the impact of spearfishing and space-based conservation scheme on reef fish populations (Frisch et al., 2012), and a more traditional look at the impacts of fishing activity on resource availability (Castello et al., 2015). Papers that explored changes in the human communities as a result of resource availability or other variations in the resource included socioeconomic assessments of communities in the

Table 2
Sample research questions for the three fields by overarching themes.

Themes	Fisheries	Coral bleaching	Coastal habitat degradation
Perceptions and attitudes	What are some perceptions and attitudes of coastal resources users towards conflict, as new uses of the marine space emerge and gain traction in the current ideological and administrative shift towards capitalizing on the blue planet as the final frontier?	How do framing and mental models about climate change impacts on corals contribute to a more complete understanding of a coral reef system?	How do resource-dependent coastal communities perceive rapid coastal development and associated increases in economic opportunities, in the context of natural resource degradation?
Behaviors	How do SCUBA fishing behaviors negatively impact reef systems that support important fisheries?	Is there a difference between proximate and distant human impacts on coral bleaching? And what are the implications for management?	What actions do individuals engage in that serve to protect mangrove habitats?
Management and governance	How do current institutions and policies influence individual, communal, and commercial fishing behaviors?	What are best practices for the assessment of implementation and effectiveness of proposed resource management schemes, both at the social and ecological levels? How are decisions related to coastal resource management made and how do current institutions and policies influence individual, communal, and commercial behaviors in the context of rapid climate change?	How are decisions made about coastal development?
Valuation	How can we relate demographic and economic conditions to preferences of different fishing groups, the thresholds under which those preferences remain, now and in the future?	What social, ecological, and future climate scenario information do we need in order to monetize climate change (or any other external stressor)?	What are the economic trade-offs between restrictive fisheries management and tourism growth in climate-change affected tropical coastal regions? What are the differences in perceived value of coastal habitats for recreation, research, ecosystem services, culture, intrinsic or existence values, and bioprospecting?
Changing human communities	What have been the relationships between different types of fisher people over time? And, Why have those relationships changed?	What are the livelihood strategies of current communities near reef ecosystems? How might these change as a result of modified natural regimes?	Who lives on the coast and how has this changed over time?
Physical health	What are the health effects of changes in diet as a result of declines in resource availability? How do alternative sources of employment and income (in response to resource decline) compare to fishing in terms of risk and providing access to health coverage for participants?	How does eutrophication of coastal waters impact the health of those who rely on local foods as compared to those who don't? And, How does recreating in coastal environments affected by rapid climate change contribute to mental health and wellbeing? How do diverse health impacts affect human behaviors (such as migration or shifting resource use) and modify human-induced changes on coral reefs?	How do resource-dependent coastal communities perceive rapid coastal development and associated increases in economic opportunities, in the context of natural resource degradation? And. How does this affect their health and wellbeing?

context of fisheries range shifts (Madin et al., 2012); a study of the changes in consumption and fishing pressure accompanied by increased reliance on alternative occupations, as a result of resource decline (Turner et al., 2007); and an assessment of the implications of ecosystem change for both conservation and food security (Unsworth et al., 2014).

Two of the articles took into account attitudes and perceptions, specifically opinions based on local ecological knowledge as well as scientific expertise, on a range of topics such as food security, sustainability, and conservation. Finally, only one paper used economic valuation approaches to estimate a range of potential economic losses in fisheries-derived income due to projections of coral reef degradation according to varying future climate change scenarios (Speers et al., 2016). A particularly interesting paper by Holdschlag and Ratter (2013), combined three of the social science themes, namely attitudes and perceptions (knowledge), behaviors (stressors, that also included environmental stressors), and change in communities (social responses), in the context of the Bahamas as an island socio-ecological system affected by environmental variability and resource change.

The framework, methods, and findings of these papers improved on existing tropical coastal research by providing innovative modeling tools for the integration of science into the policy-making process by further exploring the proximate and distant role of human behavior in environmental outcomes. They also explored human community responses and adaptation to changing resource availability, illustrating the inextricable link between fisheries and people. Indeed, as the shift from single-species to ecosystem based management of fisheries has improved recognition of the broader ecosystem-level influences on species dynamics and reduces indirect social and economic costs (Pikitch et al., 2004); so does the inclusion of social science. For instance, fisheries management plan design could be streamlined to target species, ecosystem, and human dimensions, effectively reducing uncertainty. As pointed out earlier in the discussion of benefits of socio-ecological integration, these studies would contribute to tropical coastal research by exploring new themes and sources of data, recognizing drivers of change, and supporting non-traditional forms of engagement to expand stakeholder support of policies and governance. Furthermore, fishing and coastal communities' relationship to the sea is filled with mystique and lore. Several authors have produced fascinating literary accounts of the history of fishing and its impacts on people that may, by all accounts, serve in the future as historical references to times past.

Future research could include studies of perceptions and attitudes towards conflict, as new uses of the marine space emerge and gain traction in the current ideological and administrative shift towards capitalizing on the blue planet as the final frontier; and demographic and economic analyses to identify the preferences of a range of diverse fishing groups, the thresholds under which those preferences remain, and whether these will even exist in the future as resources decline. Particularly understudied in fisheries were the linkages between human and natural coastal ecosystem health. In this vein, researchers could attempt to answer questions such as: What are the health effects of changes in diet as a result of declines

in resource availability? And how do alternative sources of employment and income (in response to resource decline) compare to fishing in terms of risk and providing access to health coverage for participants? (Table 2).

5.2. Climate change induced coral bleaching

Based on the extensive academic and political dialogue around the threats of global climate change, we expected to see a growing body of literature addressing the interactions of the social system with both sea level rise and ocean acidification. From our literature review, however, most of the published studies that explored how global climate change modified interactions between human communities and tropical coastal ecosystems focused on coral bleaching. The biological response of corals to warm water events is quite well described and is increasingly being modeled for predictive purposes (Gurney et al., 2013). However, as the papers reviewed for this section demonstrate, the inclusion of social science approaches greatly enhances our ability to mediate the impact of cumulative stressors on reef ecosystems and the human communities that depend on them.

Of the ten papers resulting from our literature search that included social science research related to coral bleaching, four described socio-ecological models aimed at informing policy, where the stressors were primarily human activities and management efforts (Anthony et al., 2015; Gurney et al., 2013; McClanahan et al., 2009; Weijerman et al., 2015). Three reflected on how climate change impacts on coral reefs would affect coastal communities (Cheablam and Shrestha, 2015; Cinner et al., 2013; Hernández-Delgado, 2015); two explored the impacts of specific human behaviors on corals (Bahr et al., 2015; Riegl et al., 2012); and one used expert perceptions of the effectiveness of local management on coral reefs (Ban et al., 2015).

Reports of coral bleaching are often limited to presenting the damage to reefs and serve as a compelling illustration of the effects of climate change on tropical ecosystems. However, as these papers demonstrated, research that includes human concerns goes beyond these messages of devastation, and adds a layer of dynamism where human activities that affect and are affected by coral reefs can exacerbate or mitigate impacts, support coral reef and human community resilience to climate change through effective management, and broadly adopt an active role as either stressor or affected party.

Due to the complex and indirect effects of climate change, it is a challenge to isolate the drivers of ecosystem change to establish causal relationships. In this respect, it was not surprising to note that the social science research incorporated into coral bleaching studies tended to explore combined human and natural stressors, and their cumulative effects on the resource, with implications for management. Furthermore, while the dynamic models described in these papers were aimed at improving governance for environmental outcomes, they rarely focused on the inverse: the impact of coral reef bleaching on human communities. An exception of note is the paper by McClanahan et al. (2009) that explored the links between social adaptive capacity and environmental susceptibility to identify appropriate management options for different sites. Understanding these impacts can play a significant role in describing the feedback loops between the human impacts of coral bleaching and the human actions the perpetuate it, thus informing the development of strategies that attempt to close the loop and more towards a coupled human natural systems approach.

Potential research questions that could further enhance our understanding of the social ecological system around coral bleaching include analyses of the actual implementation and effectiveness of proposed management schemes, both at the social and ecological levels (Table 2). Studies might evaluate strategies for implementing complex management schemes, focusing on how decisions related to coastal resource management are made and how current institutions and policies influence individual, communal, and commercial behaviors in the context of rapid climate change. Another opportunity for research on coral bleaching and human communities is related to issues of human health. Potential areas to explore could include how eutrophication of coastal waters impacts the health of those who rely on local foods as compared to those who do not, and how recreating in coastal environments affected by rapid climate change contributes to mental health and wellbeing. For those interested in coupled human and natural systems research, these studies could be furthered to explore how diverse health impacts then affect human behaviors (such as migration or shifting resource use) and modify human-induced changes on coral reefs.

5.3. Coastal habitat degradation

As in the case of coral bleaching, we identified ten papers from our initial search that explicitly engaged the social sciences to explain tropical coastal habitat change in terms of cause and effect of change. All ten papers addressed the role of human actions and behaviors on the environment as a driver of coastal change and degradation. Specific topics included the combination of human behaviors, governance, and economic effects on the environment, the impact of anthropogenic use variables on coastal water bird habitat, and the role of tourism, urban growth, and ineffective social development policies on coastal erosion. (Camargo et al., 2009; Conchedda et al., 2011; de Araujo Barbosa et al., 2016, Sandberg, 2010; Silva et al., 2014).

Another subset of papers explored linked processes in which human behaviors affected coastal environments that then, in turn, led to changes in the human communities that reside along the coast (Barletta et al., 2010; Vilardy et al., 2011). For instance, Barletta et al. (2010) analyzed the social causes of habitat loss and resulting socioeconomic impacts on three river basins in South America, while Vilardy et al. (2011) provided a historical overview of infrastructure development and its impacts on human wellbeing along the Caribbean coast of Colombia. While potentially useful for future policy-making, their methodology did not explicitly include management concerns. The remaining three papers intellectually included social aspects of habitat degradation, but did so through the use of visualization tools based on satellite imagery of mangroves in South Asia rather (Giri et al., 2011; Gopinath, 2010) and quantitative modeling of tropical coastal lagoons (Tavares et al., 2015) rather than field-based methods that can validate and amplify the understanding of social pressures.

Unique to the studies on habitat degradation was the emphasis on feedbacks between human actions and ecological change. The existence of feedbacks is effectively a key requirement for a complete coupled human and natural system where the human-natural integration is considered as a whole, and provides opportunities for comprehensive management, engagement, and better science overall.

Potential opportunities for improving the integrated science of tropical coastal habitat degradation include developing studies on the attitudes and perceptions towards change, the economic valuation of resources that drive change as compared to resources that are degraded as a result of change, and the possible links between habitat degradation and human health (Table 2). In the context of coastal degradation and associated impacts on human communities, the latter especially represents an opportunity to research the relationship between threats to human health, fisheries decline as a result of habitat change, as well as increased

contamination from sedimentation and runoff from land based sources of pollution. Potential questions to explore could include: how do resource-dependent coastal communities perceive rapid coastal development and associated increases in economic opportunities, in the context of natural resource degradation? What are the economic trade-offs between restrictive fisheries management, tourism growth, in climate-change affected tropical coastal regions? What are the differences in perceived value of coastal habitats for recreation, research, ecosystem services, culture, intrinsic or existence values, and bioprospecting?

6. Discussion

As our literature review shows, there is a range of thematic variety in the research that incorporates social science to the study of tropical coastal change. The existing literature on coastal fisheries drew primarily from management and governance studies, research on coral bleaching was represented mostly by socio-ecological models that included some form of climate predictions, and studies on coastal degradation mostly took into account human actions and behaviors and community change. For all three topics, opportunities to improve interdisciplinary science included the study of attitudes and perceptions, valuation, and the link between environmental and human health. Additionally, we suggest there is a critical need for the use of truly integrated socio-ecological approaches that focus on the three previously listed themes. Indeed, these represent opportunities for future research that could significantly improve our knowledge about coastal ecosystems and efforts to manage these increasingly threatened resources.

Table 2 provides examples of ways to engage with social science that could contribute to our understanding of these complex systems. As we demonstrated, while some themes have been more commonly studied, such as management and governance, human actions, and climate-based socio-ecological models; others have to date been less integrated. For each theme we include examples of social science research questions that could improve tropical coastal research. These questions can span temporal, spatial and analytical scales. For example, stakeholders can refer to individuals, communities, and village or NGO representatives. Similarly, there are often several academic disciplines (see Table 1) that can inform the process of developing social science research questions and appropriate data collection methods. We encourage readers to use Table 2 as a starting point and not assume that it is exhaustive.

In addition to expanding the framework of tropical coastal science to include the social sciences, scientists and resource managers need to address the primary obstacles to this integration that have already been identified at length in other papers (e.g., Bennett et al., 2016; Fox et al., 2006; Strang, 2009; Turner, 2000; Viseu, 2015). This includes committing to developing transdisciplinary research teams prior to defining the research question and methods. Teams should not just include one human dimensions expert, but a sufficient number with appropriate expertise to fully explore the issue. Just as we cannot expect an oceanographer to be able to classify coral species simply because (s)he is a biophysical scientist, we cannot expect an economist to be the best resource for developing a study on culture or governance.

Furthermore, the success of interdisciplinary research teams depends on factors that affect all human relationships: mutual respect, the development and maintenance of trust, the patience and capacity to communicate and clarify misunderstandings, the willingness to compromise and expand framing, and dedication. Too often, social scientists have felt underprivileged, in that they often receive less funding, less respect, and less opportunities for leadership than those from the biophysical sciences. In fact, many social scientists have expressed that their biophysical colleagues are more likely to perceive them as “service” professionals than “equals” (Welch-Devine and Campbell, 2010; Viseu, 2015). In order for interdisciplinary collaboration to be effective, it must be obvious that people's scientific identities will not be denigrated or appropriated, that funding and time will be allocated justly and appropriately, and that sufficient time will be allocated to the substantially complex communication process (Strang, 2009). Lastly, researchers hoping to engage the social sciences need to be clear about the definition and purpose of social science. Incorporating stakeholders in research as is often done with citizen science, for example, is not social science (Strang, 2009). It is a method for collecting biophysical data. As we have shown, the social sciences have their own empirical tools that enable a research team to understand how social processes interplay with biophysical processes to explain our observations. It is our hope that the review conducted for this article served the purpose of illustrating existing efforts at transdisciplinarity as well as new opportunities for social science research that could contribute to future integrated coastal research in the tropics.

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References

Agardy, T., Alder, J., (Coordinating Lead Authors), 2005. “Coastal systems,” chapter 19. In: Hassan, R., Scholes, R., Ash, V. (Eds.), Ecosystems and Human Well-being: Current State and Trends, vol. 1. Island Press, Washington, DC.

Anthony, K., Marshall, P.A., Abdulla, A., Beeden, R., Bergh, C., Black, R., et al., 2015. Operationalizing resilience for adaptive coral reef management under global environmental change. Glob. change Biol. 21 (1), 48–61.

Bahr, K.D., Jokiel, P.L., Toonen, R.J., 2015. The unnatural history of Kāne ‘ohe Bay: coral reef resilience in the face of centuries of anthropogenic impacts. Peer J. 3, e950.

Ban, N.C., Picard, C., Vincent, A.C.J., 2009. Comparing and integrating community-based and science-based approaches in prioritizing marine areas for protection. Conserv. Biol. 23, 899–910.

Ban, S.S., Pressey, R.L., Graham, N.A., 2015. Assessing the effectiveness of local management of coral reefs using expert opinion and spatial Bayesian modeling. PloS One 10 (8), e0135465.

Barletta, M., Jaureguizar, A.J., Baigun, C., Fontoura, N.F., Agostinho, A.A., Almeida-Val, V.M.F.D., et al., 2010. Fish and aquatic habitat conservation in South America: a continental overview with emphasis on neotropical systems. J. Fish Biol. 76 (9), 2118–2176.

Barnard, S., Elliott, M., 2015. The 10-tenets of adaptive management and sustainability: an holistic framework for understanding and managing the socio-ecological system. Environ. Sci. Policy 51, 181–191.

Bell, J.D., Reid, C., Batty, M.J., Lehodey, P., Rodwell, L., Hobday, A.J., et al., 2013. Effects of climate change on oceanic fisheries in the tropical Pacific: implications for economic development and food security. Clim. Change 119 (1), 199–212.

Bennett, N., Roth, R., Klain, S., Chan, K., Clark, D., Cullman, G., Epstein, G., Nelson, P., Stedman, R., Teel, T., Thomas, R., Wyborn, C., Currans, D., Greenberg, A., Sandlos, J., Verissimo, D., 2016. Mainstreaming the social sciences in conservation. Conserv. Biol. http://dx.doi.org/10.1111/cobi.12788. Online, Open Access. http://onlinelibrary.wiley.com/doi/10.1111/cobi.12788/abstract.

Biedenweg, K., Stiles, K., Wellman, K., 2016. A holistic framework for identifying human wellbeing indicators for marine policy. Mar. Policy 64, 31–37.

Brown, R., Deletic, A., Wong, T., 2015. How to catalyse collaboration. Nature 525, 315–317.

Burke, L., Reytar, K., Spalding, M., Perry, A., 2011. Reefs at Risk Revisited. WRI, ISBN 978-1-56973-762-0.

Camargo, C., Maldonado, J.H., Alvarado, E., Moreno-Sánchez, R., Mendoza, S., Manrique, N., et al., 2009. Community involvement in management for maintaining coral reef resilience and biodiversity in southern Caribbean marine protected areas. Biodivers. Conserv. 18 (4), 935–956.

Castello, L., Arantes, C.C., Mcgrath, D.G., Stewart, D.J., Sousa, F.S.D., 2015. Understanding fishing-induced extinctions in the Amazon. Aquat. Conserv. Mar. Freshw. Ecosyst. 25 (5), 587–598.

Cheablam, O., Shrestha, R.P., 2015. Climate change trends and its impact on tourism

resources in Mu Ko Surin marine national park, Thailand. Asia Pac. J. Tour. Res. 20 (4), 435–454.
Chuenpagdee, R., Liguori, L., Palomares, M.L.D., Pauly, D., 2006. Bottom-up, global estimates of Small-scale Marine Fisheries Catches. Fish. Centre Res. Rep. vol. 14 (8). Fisheries Centre, University of British Columbia, Vancouver, Canada, 105 pp.
Ciannelli, L., Hunsicker, M., Beaudreau, A., Bailey, K., Crowder, L.B., Finley, C., et al., 2014. Transdisciplinary graduate education in marine resource science and management. ICES J. Mar. Sci. J. du Conseil fsu067.
Cinner, J.E., McClanahan, T.R., Graham, N.A., Pratchett, M.S., Wilson, S.K., Raina, J.B., 2009. Gear-based fisheries management as a potential adaptive response to climate change and coral mortality. J. Appl. Ecol. 46 (3), 724–732.
Cinner, J.E., Huchery, C., Darling, E.S., Humphries, A.T., Graham, N.A., Hicks, C.C., et al., 2013. Evaluating social and ecological vulnerability of coral reef fisheries to climate change. PloS One 8 (9), e74321.
Cissé, A.A., Blanchard, F., Guyader, O., 2014. Sustainability of tropical small-scale fisheries: integrated assessment in French Guiana. Mar. Policy 44, 397–405.
Cohen, P.J., Cinner, J.E., Foale, S., 2013. Fishing dynamics associated with periodically harvested marine closures. Glob. Environ. change 23 (6), 1702–1713.
Conchedda, G., Lambin, E.F., Mayaux, P., 2011. Between land and sea: livelihoods and environmental changes in mangrove ecosystems of Senegal. Ann. Assoc. Am. Geogr. 101 (6), 1259–1284.
de Araujo Barbosa, C.C., Atkinson, P.M., Dearing, J.A., 2016. Extravagance in the commons: resource exploitation and the frontiers of ecosystem service depletion in the Amazon estuary. Sci. Total Environ. 550, 6–16.
Decker, D., Riley, S., Siemer, W., 2012. Human Dimensions of Wildlife Management. Johns Hopkins, Baltimore, Maryland.
Dichmont, C.M., Ellis, N., Bustamante, R.H., Deng, R., Tickell, S., Pascual, R., et al., 2013. EDITOR'S CHOICE: evaluating marine spatial closures with conflicting fisheries and conservation objectives. J. Appl. Ecol. 50 (4), 1060–1070.
FAO, 2016. The State of World Fisheries and Aquaculture 2016. Contributing to food security and nutrition for all. Rome. 200 pp.
Forsyth, T., 1998. Mountain myths revisited: integrating natural and social environmental science. Mt. Res. Dev. 18 (2), 107–116.
Fox, H., Christian, C., Nordby, J.C., Pergams, O., Peterson, G., Pyke, C., 2006. Perceived barriers to integrating social science and conservation. Conserv. Biol. 20 (6), 1817–1820.
Frisch, A.J., Cole, A.J., Hobbs, J.P.A., Rizzari, J.R., Munkres, K.P., 2012. Effects of spearfishing on reef fish populations in a multi-use conservation area. PLoS One 7 (12), e51938.
Giri, C., Ochieng, E., Tieszen, L.L., Zhu, Z., Singh, A., Loveland, T., et al., 2011. Status and distribution of mangrove forests of the world using earth observation satellite data. Glob. Ecol. Biogeogr. 20 (1), 154–159.
Glaser, M., Christie, P., Diele, K., Dsikowitzky, L., Ferse, S., Nordhaus, I., et al., 2012. Measuring and understanding sustainability-enhancing processes in tropical coastal and marine social–ecological systems. Curr. Opin. Environ. Sustain. 4 (3), 300–308.
Gopinath, G., 2010. Critical coastal issues of Sagar Island, east coast of India. Environ. Monit. Assess. 160 (1–4), 555–561.
Goreau, T.J., Hayes, R.L., 2009. Effects of rising seawater temperature on coral reefs. Fish. Aquac. V, 266. Encyclopedia of Life-Support Systems.
Gunderson, L., Holling, C.S., 2002. Panarchy. Island Press, Washington DC.
Gurney, G.G., Melbourne-Thomas, J., Geronimo, R.C., Aliño, P.M., Johnson, C.R., 2013. Modelling coral reef futures to inform management: can reducing local-scale stressors conserve reefs under climate change? PloS One 8 (11), e80137.
Hernández-Delgado, E.A., 2015. The emerging threats of climate change on tropical coastal ecosystem services, public health, local economies and livelihood sustainability of small islands: cumulative impacts and synergies. Mar. Pollut. Bull. 101 (1), 5–28.
Hoegh-Guldberg, O., 2011. Coral reef ecosystems and anthropogenic climate change. Reg. Environ. Change 11 (1), 215–227.
Holdschlag, A., Ratter, B.M., 2013. Multiscale system dynamics of humans and nature in the Bahamas: perturbation, knowledge, panarchy and resilience. Sustain. Sci. 8 (3), 407–421.
Jackson, J., et al., 2014. Status and Trends of Caribbean Coral Reefs: 1970-2012. Global Coral Reef Monitoring Network.
Ledford, H., 2015. How to solve the world's biggest problems. Nature 525, 308–311.
Leenhardt, P., Teneva, L., Kininmonth, S., Darling, E., Cooley, S., Claudet, J., 2015. Challenges, insights and perspectives associated with using social-ecological science for marine conservation. Ocean Coast. Manag. 115, 49–60.
Liu, J., Dietz, T., Carpenter, S.R., Folke, C., Alberti, M., Redman, C.L., et al., 2007. Coupled human and natural systems. AMBIO a J. Hum. Environ. 36 (8), 639–649.
Madin, E.M., Ban, N.C., Doubleday, Z.A., Holmes, T.H., Pecl, G.T., Smith, F., 2012. Socio-economic and management implications of range-shifting species in marine systems. Glob. Environ. Change 22 (1), 137–146.
Máñez, K.S., Holm, P., Blight, L., Coll, M., MacDiarmid, A., Ojaveer, H., et al., 2014. The future of the oceans past: towards a global marine historical research initiative. PloS One 9 (7), e101466.
Maynard, J.A., Beeden, R., Puotinen, M., Johnson, J.E., Marshall, P., Hooidonk, R., et al., 2015. Great Barrier Reef No-take Areas Include a Range of Disturbance Regimes. Conservation Letters.
McClanahan, T.R., Cinner, J.E., Graham, N.A.J., Daw, T.M., Maina, J., Stead, S.M., et al., 2009. Identifying reefs of hope and hopeful actions: contextualizing environmental, ecological, and social parameters to respond effectively to climate change. Conserv. Biol. 23 (3), 662–671.
Moberg, F., Rönnbäck, P., 2003. Ecosystem services of the tropical seascape: interactions, substitutions and restoration. Ocean Coast. Manag. 46 (1), 27–46.
Montambault, J.R., Wongbusarakum, S., Leberer, T., Joseph, E., Andrew, W., Castro, F., et al., 2015. Use of monitoring data to support conservation management and policy decisions in Micronesia. Conserv. Biol. 29 (5), 1279–1289.
Nature, 2015a. Mind meld. Nature 525, 289–290.
Nature, 2015b. Why Interdisciplinary research matters. Nature 525, 305.
Pikitch, E.K., Santora, C., Babcock, E.A., Bakun, A., Bonfil, R., Conover, D.O., et al., 2004. Ecosystem-based fishery management. Science 305 (5682), 346–347.
Riegl, B.M., Sheppard, C.R., Purkis, S.J., 2012. Human impact on atolls leads to coral loss and community homogenisation: a modeling study. PloS One 7 (6), e36921.
Rosenfield, P.L., 1992. The potential of transdisciplinary research for sustaining and extending linkages between the health and social sciences. Soc. Sci. Med. 35 (11), 1343–1357.
Rowland, M.J., Ulm, S., 2012. Key issues in the conservation of the Australian coastal archaeological record: natural and human impacts. J. Coast. Conserv. 16 (2), 159–171.
Sandberg, A., 2010. Institutional challenges to robustness of delta and floodplain agricultural systems. Environ. Hazards 9 (3), 284–300.
Silva, R., Martínez, M.L., Hesp, P.A., Catalan, P., Osorio, A.F., Martell, R., et al., 2014. Present and future challenges of coastal erosion in Latin America. J. Coast. Res. 71 (sp1), 1–16.
Spalding, A.K., K. Biedenweg, A. Hettinger, and M. Nelson. Demystifying the human dimension of ecological research. For Front. Ecol. Sci. (under review).
Speers, A.E., Besedin, E.Y., Palardy, J.E., Moore, C., 2016. Impacts of climate change and ocean acidification on coral reef fisheries: an integrated ecological–economic model. Ecol. Econ. 128, 33–43.
Strang, V., 2009. Integrating social and natural science in environmental research: a discussion paper. Environ. Dev. Sustain. 11, 1–18.
Tavares, D.C., Guadagnin, D.L., de Moura, J.F., Siciliano, S., Merico, A., 2015. Environmental and anthropogenic factors structuring waterbird habitats of tropical coastal lagoons: implications for management. Biol. Conserv. 186, 12–21.
Turner, K., 2000. Integrating natural and social science in coastal management. J. Mar. Syst. 25.
Turner, R.A., Cakacaka, A., Graham, N.A.J., Polunin, N.V.C., Pratchett, M.S., Stead, S.M., Wilson, S.K., 2007. Declining reliance on marine resources in remote South Pacific societies: ecological versus socio-economic drivers. Coral Reefs 26 (4), 997–1008.
UN, 2011. Atlas of the Oceans: Facts. Accessed 29 September, 2016. http://www.oceansatlas.org/facts/en/.
Unsworth, R.K., Hinder, S.L., Bodger, O.G., Cullen-Unsworth, L.C., 2014. Food supply depends on seagrass meadows in the coral triangle. Environ. Res. Lett. 9 (9), 094005.
Van Noorden, R., 2015. Interdisciplinary research by the numbers. Nature 525 (7569), 306–307.
Valiela, I., Bowen, J.L., York, J.K., 2001. Mangrove forests: one of the World's threatened major tropical environments. Bioscience 51 (10), 807–815.
Valiela, I., 2006. Global Coastal Change. Wiley & Sons.
Vilardy, S.P., González, J.A., Martín-López, B., Montes, C., 2011. Relationships between hydrological regime and ecosystem services supply in a Caribbean coastal wetland: a social-ecological approach. Hydrol. Sci. J. 56 (8), 1423–1435.
Viseu, A., 2015. Integration of social science into research is crucial. Nature 525, 291.
Weijerman, M., Fulton, E.A., Kaplan, I.C., Gorton, R., Leemans, R., Mooij, W.M., Brainard, R.E., 2015. An integrated coral reef ecosystem model to support resource management under a changing climate. PloS One 10 (12), e0144165.
Welch-Devine, M., Campbell, L., 2010. Sorting out roles and defining divides: social sciences at the World Conservation Congress. Conserv. Soc. 8, 339–348.