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Creating space for interdisciplinary marine and coastal research: five dilemmas and suggested resolutions

THEMATIC SECTION
Interdisciplinary Progress in Environmental Science & Management

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SUMMARY

Important changes are needed to disciplinary theories and methods to support interdisciplinary and integrated ocean and coastal management policies and implementation. This review argues that theories and methods should conform to a perspective that ocean management is a societal activity with diverse goals ideally informed by interdisciplinary information. The review focuses on the integrated coastal management (ICM) and marine ecosystem-based management (EBM) frameworks and the marine protected areas (MPA) management tool. It begins by suggesting that at present there is a notable imbalance in the degree of effort allocated to monitoring the ecological and social dimensions of ocean resource use and policy processes. Based on how Western society and an influential epistemic community construct 'the environment' and society's relation to the environment, natural sciences play an inordinately important role in the description of the problem and policy recommendations. The discourse advocating for a global networks of marine protected areas, without adequate consideration of society impacts and responses, represents an example of this imbalance. Rebalancing the contributions of scientific disciplines encounters various dilemmas with epistemological, methodological and sociological dimensions. The analysis concludes with suggestions for balancing ocean and coastal interdisciplinary research and reframing key issues, creating self reflexive and multidisciplinary research teams, and reworking educational programmes.

Keywords: coastal, ecosystem-based management, integrated coastal management, interdisciplinary research, marine, marine protected area

INTRODUCTION

This review paper primarily considers the role and practice of research to inform ocean policy making and the realized or potential role of interdisciplinary research (IR). IR can be defined as investigations which link epistemologies, theories, methods and skill sets across disciplines, which had previously been pursued independently, to create synthetic understandings (Pickett *et al.* 1999). IR, as conceptualized here, goes beyond the linking of disciplines, theories and methods within the natural, physical or social sciences, to consider the more challenging linkages between these realms.

The rationale for this review is grounded in a growing interest in IR-based environmental policy making (Pickett *et al.* 1999; Tress *et al.* 2005; Omenn 2006), while the current state of ocean-relevant IR and the policy conditions to foster such IR are inadequately developed at the present (Mascia *et al.* 2003; Campbell 2005). This review considers a variety of reasons for the current state of ocean-relevant IR and IR-based ocean policy making, and will focus on one of the key hindrances to progress, namely how ocean environmental problems are constructed (Steinberg 2001). Currently, natural sciences dominate the construction of environmental problems and there is little integration of natural and social science. IR will never be adequately developed unless there is a significant demand for synthetic information with adequate human and financial resources.

The predominant environmental policy process has assumed, implicitly or explicitly, that the key knowledge gap to effective policy making is inadequate knowledge of ecological function (Christie *et al.* 2002; Ruckleshaus *et al.* 2009. With this construct, the priority has become developing adequate understandings of biology, non-human population dynamics, ecological communities and ecosystem function. Such information has been fed into the policy process, with the expectation that it will provide the key to raising awareness of environmental problems and lead to policy solutions. This has been a generally failed experiment in policy making, resulting in incomplete understandings of scale and interrelationship, inadequate policies and frustrated scientists of various disciplines (including ecologists). As an alternative, if environmental problems are construed as imbalances in coupled social-ecological systems, then the role of IR necessarily expands within the policy-making process. A comprehensive, effective and balanced policy process requires detailed empirical understandings of not only ecological, biological and physical processes, but also humanistic, ethical and social processes, derived from both basic and applied research.

A review of the predominant discourse surrounding ocean decline is a useful starting point. The decline of ocean

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resources and ecosystems has received considerable attention within the marine scientific community and popular media (Pauly *et al*. 1998; New York Times 2006; Worm *et al*. 2006, 2009; Halpern *et al*. 2008; Rosenthal 2008). This rapid growth in coverage is likely due to a confluence of conditions, including the worrisome degree of ecosystem decline in many locations and an increased ability to create and analyse global data sets. Active organizations, such as The Communication Partnership for Science and the Sea (COMPASS, URL http://www.compassonline.org) have created influential links between scientists documenting ocean decline and mass media outlets. Until recently, society did not know the extent, both geographic and ecological, of ocean condition decline. It is not an understatement that entire ecosystems, such as coral reefs (Pandolfi *et al*. 2003), are threatened at previously undocumented levels. There are virtually no pristine areas of the ocean today (Halpern *et al*. 2008). Such assessments are remarkably important, but incomplete, to inform effective policy responses. The question remains, how best to use this information, and what additional IR and synthetic analysis is necessary to shape societal policy and behavioural response? More importantly, what is likely to succeed in reversing these trends? The second question requires a broad consideration of empirical and ethical information, and is dependent on IR analysis across natural and social science disciplinary lines. It also requires a reconsideration of the role of formal science in defining the discourse surrounding policy formulation.

In contrast to the scientific and popular interest in determining the severity of ocean environmental decline, defining the role of IR, exploring the epistemological assumptions of science and defining the role of disciplines in science-based policy-making processes has been surprisingly of relatively minor interest. Research tends to be focused on defining the problem and solution, rather than focused on how the research and policy processes evolve and articulate. While concentrating on the role of science and perspectives of scientists may seem esoteric, the reliance on a narrow range of disciplines, methods and perspectives determines the suite of policy frameworks and ocean management tools. As documented in this review, part of the explanation for the narrow range of topical consideration is the preponderance of disciplinary analysis informing policy. The use of fully integrated IR linked to policy-making process within adaptive planning cycles is exceedingly rare in the marine realm, despite generally agreement about what constitute best practices and growing interest in IR. IR is lacking in at least four key aspects of the ocean policy-making process: (1) the definition of the policy challenge, (2) documentation of environmental change, (3) identification of appropriate interventions, and (4) the evaluation of policy effectiveness. This condition has many implications, both in terms of grounding policy in a more comprehensive understanding of context and in terms of designing workable and effective policy.

The development and role of IR should be considered within the emergence and influence of policy frameworks and management tools over time and in terms of how scientific knowledge is used in the policy-making process.

OCEAN MANAGEMENT FRAMEWORKS AND MANAGEMENT TOOLS

To narrow the analysis to a manageable scope and elucidate the roles of disciplinary and IR in coastal and marine policy, this review will focus on two important ocean management frameworks, namely integrated coastal management (ICM) and ecosystem-based management (EBM), and one management tool, namely marine protected areas (MPAs). These frameworks and this tool are highly influential, and widely applied in the case of ICM (Olsen 2003; Pandolfi *et al*. 2003; Mora *et al*. 2006; World Bank 2006; Mcleod & Leslie 2009). Other management tools, such as marine spatial planning (Crowder *et al* 2006; Foley *et al*. 2010), are increasingly used, but not yet well enough established to provide insight into the practice and influence of IR. The emergence and diffusion of modern management frameworks, such as ICM and EBM, are rarely described (Courtney & White 2000; World Bank 2006; Pietri *et al*. 2009), and comparing these frameworks in distinct contexts requires some degree of generalization. This interpretation is based on what is available in the peer-reviewed literature documenting framework evolution, relevant studies of multidisciplinary environmental inquiry, personal research and policy experience in various countries, and access to a broad professional network including scientists, academics and policy makers. In addition to introducing and reviewing this subject, this analysis seeks to provide impetus for future empirical work.

Assessing management framework assumptions and tendencies

ICM has been defined as 'a process by which rational decisions are made concerning the conservation and sustainable use of coastal and ocean resources and space. The process is designed to overcome the fragmentation inherent in single-sector management approaches . . . in the splits in jurisdiction among different levels of government, and in the land-water interface' (Cicin-Sain & Knecht 1998, p. 1).

EBM for the oceans has been defined in a consensus statement signed by over two hundred academic scientists and policy experts as 'an integrated approach to management that considers the entire ecosystem, including humans. The goal of ecosystem-based management is to maintain an ecosystem in a healthy, productive and resilient condition so that it can provide the services humans want and need. Ecosystem-based management differs from current approaches that usually focus on a single species, sector, activity or concern; it considers the cumulative impacts of different sectors' (McLeod *et al*. 2005).

Integrative frameworks are intended to improve management within and across sectors (such as fisheries,

forestry and water) and, therefore, are by definition multidisciplinary. However, the histories, theoretical frames and literatures underpinning ICM and EBM are notably distinct. In the global North, ICM emerged as a form of planning intended to ensure rational and appropriate use of coastal and nearshore areas. The seminal texts were written by political scientists (Cicin-Sain & Knecht 1998) and natural scientists with extensive coastal management experience (Kay & Alder 2005). The lead journals examining the practice of ICM, namely *Ocean and Coastal Management* and *Coastal Management*, were established by B. Cicin-Sain and M. Hershman, a political scientist and legal scholar, respectively. ICM was diffused to the global South by Northern academic and policy institutions (Olsen 2003), and subsequently made context appropriate over decades of implementation experience through close collaboration with developing country practitioners (Courtney & White 2000; Olsen & Christie 2000; Christie *et al*. 2005).

The disciplinary starting point underpins a framework and shapes its goals. ICM starts from planning theories and tools, and looks to applied natural science or monitoring information for guidance on determining benchmarks and limits to resource use or ecosystem impacts. (The distinction between science, as a form of basic inquiry, versus applied monitoring and assessment is an important one, but will not be explored in detail. All science referred to in this paper is applied, by definition, since it responds to and informs a policy making process.) ICM practice and literature focuses considerable attention on formal and informal governance processes and the means to encourage and sustain cross-institutional collaboration (Olsen 2003; Christie *et al*. 2005; Lowry *et al*. 2005).

EBM is emerging as an influential framework for ocean environmental policy making. The emergence of frameworks such as EBM is grounded in new understandings of the scale and severity of ocean decline, and seems to have emerged from concerns that previous frameworks, such as ICM, are inadequate or not based on a proper balance of disciplinary considerations. EBM for marine and coastal areas draws distinct epistemological and disciplinary roots from ICM. The seminal books and articles on marine EBM are edited or written by natural scientists (Lackey 1998: Francis *et al*. 2007; McLeod & Leslie 2009). The primary goal of EBM is to maintain ecosystem function and, in turn, maintain associated ecosystem services (UNEP [United Nations Environment Programme] 2006; McLeod & Leslie 2009). This goal, therefore, tends to privilege two disciplines, ecology and economics, in order of relative importance (Arkema *et al*. 2006). There is a strong trend within the EBM prescriptive literature toward scaling up management to 'ecologically relevant' scales, meaning those scales at which critical oceanographic and ecological processes occur and within ecosystem boundaries as identified (McLeod & Leslie 2009). Management recommendations are focused on maintaining large-scale ecological processes and maintaining ecosystem integrity through a consideration of connectivity of ecosystems and marine species populations. The large marine ecosystem (Sherman *et al*. 2005) and biodiversity hotspots planning models (Conservation International 2010) are examples of management scales reliant on EBM conceptualizations. Ecological analyses of large-scale global change processes promote such scaling (Pauly *et al*. 1998; Pandolfi *et al*. 2003; Mora *et al*. 2006; Worm *et al*. 2006; Halpern *et al*. 2008).

Limited human dimensions research has been conducted in association with EBM (Arkema *et al*. 2006), and careful comprehensive evaluation of this framework and associated programmes is still lacking. McLeod and Leslie (2009) is currently the leading statement defining the EBM framework and describing nascent EBM programmes, with an emphasis on the USA. Christie *et al*. (2007) reviewed EBM literature, attempting to locate this emerging and influential framework in relation to the relatively well-established practice of ICM in the Philippines, a country with long-standing experience with ICM and ocean policy experimentation (Christie *et al*. 2007). Their study identified some degree of apprehension and confusion among Filipino marine resource management practitioners, who perceived greater overlap than distinction between their integrative frameworks. Interviews and focus groups indicated concern over the rapid adoption of EBM, when ICM had only recently been understood, institutionalized and legally mandated after decades of effort, and expressed mild amusement over the need to wrap old ideas in new packaging (Christie *et al*. 2007). Concern exists that the proposed intervention at ecosystem scale may far exceed institutional capacity and contradict cultural and political tendencies toward decentralization and community-level practice (Aswani *et al*. 2011). Notably, the metrics of progress toward EBM distilled from both broad literature review and practice in the Philippines are not wholly distinct from those of ICM; rather they stress different aspects of marine systems and management challenges (Christie *et al*. 2007; Kaufman *et al*. 2009).

Some IR and social science relevant studies of EBM have been conducted as part of a National Center for Ecological Analysis and Synthesis Center (NCEAS) working group project (see URL http://www.nceas.ucsb.edu/projects/11281). This comparative study on workable governance frames and trade-offs associated with these large-scale management efforts reviewed the emergent EBM efforts in the Caribbean large marine ecosystem (LME) (Fanning *et al*. 2009), Benguela Current LME (Cochrane *et al*. 2009), Hawaii (Tissot *et al*. 2009) and the Philippines (Armada *et al*. 2009; Christie *et al*. 2009*a*, *b*; Eisma-Osorio *et al*. 2009; Lowry *et al*. 2009; Pietri *et al*. 2009). Thirteen academics and practitioners identified the following general categories of themes as essential to feasible EBM:

- development of leadership and awareness,
- development of hybrid institutions or novel institutional collaborations,
- establishment of clear and fair rules with conflict resolution mechanisms,
- experimentation and adaptation,

Table 1 Criteria for interdisciplinary evaluation of ecosystem based management (EBM) programmess that emerge from EBM field efforts (Christie 2009*b*).

Category	*Criteria*
Process	Planning processes and policies consider local context
	Transparent and participatory decision making processes used for programme planning and evaluation
	Social and natural science–generated information and local knowledge influence planning
	The EBM programme area and goals defined to consider ecological scale and interactions, while considering governance feasibility (e.g. management areas represent ecological boundaries while considering institutional jurisdictions and capacities)
	Planning processes and policies evolve based on monitoring information and experience
	Education programme developed to raise awareness about ocean conditions, consider tradeoffs, and disseminate lessons among practitioners and appropriate constituencies
	Sustained commitment to EBM is fostered
	Planning processes consider trade-offs and establish means to equitably distribute costs and benefits while establishing conflict resolution mechanisms
Output	Reference points for resource extraction (e.g. catch-per-unit-effort or biomass) and environmental integrity (e.g. biodiversity, habitat condition) established at a precautionary level
	A suite of management tools, including but not limited to MPAs, employed to address resource and habitat goals
	Multi-sectoral planning and implementation organizations, which are responsive to ecological scales, established and supported
	Formal legal and policy frameworks established to foster EBM
	Human and institutional capacity increased to respond to demands of EBM

- development of interdisciplinary programme evaluation, and
- diffusion of lessons learned through leadership networks.

Basic criteria for an interdisciplinary evaluation emerged from these EBM field efforts, and fall into the general categories of process and outcome criteria (Table 1).

Despite limited experience and critical review, several programmes have adopted EBM, using high profile policy documents (CEQ [Council of Environmental Quality] 2009) and supported by significant investment from largely USA-based donors, such as the Moore Foundation, Packard Foundation, Pew Charitable Trusts and the United States Agency for International Development. The rapidly expanding influence of EBM may be grounded in a sense of urgency and frustration promoted by a sense of failure by ICM and fisheries management to slow or reverse the decline of critical habitats and associated marine organisms on a broad scale (Beatley *et al*. 2002; Pandolfi *et al* 2003; Mora *et al*. 2006; New York Times 2006; Worm *et al*. 2006; Rosenthal 2008) and the belief that ecological considerations are ignored during policy-making processes (Ruckelshaus *et al*. 2009).

While ICM emerged from the planning and applied social sciences and engaged the applied natural sciences as necessary, EBM emerged from the applied natural sciences and is, as necessary, engaging planners and social scientists (particularly economists). Each framework tends to prioritize particular issues, analyses and policies. For example, within the 19 chapters of a recent book on EBM in the oceans (McLeod & Leslie 2009), 14 of the first authors were ecologists or oceanographers, two were economists and three were policy, legal or social science experts. All seven of the chapters reviewing 'EBM in practice' had a lead author who was a natural scientist; this is notable because, presumably, natural scientists are not formally trained in the methods or theories of programme evaluation or case study analysis, although they may have been involved in numerous policy processes. EBM is rapidly evolving, however, and hopefully will become profoundly interdisciplinary, in order to improve its ability to respond effectively to the diverse challenges facing marine policy makers and resource-dependent communities as they strive for sustainability.

Linking management frameworks to practice through management tools

Management frameworks are linked to practice through the use of particular management tools. For example, for ocean and marine resources, closed seasons or catch limits for fisheries and spatial planning to direct patterns of resource use through zoning or marine protected areas may be used as management tools. IR is needed to design, evaluate and adapt these tools and their application to specific locations. Particular challenges and opportunities emerge when trying to balance and integrate disciplines as part of evaluative IR (Tress *et al*. 2005; Campbell 2009). An exploration of these characteristics may best be expressed as a series of dilemmas that face the researcher and policy maker. The following analysis focuses on the marine protected area as an increasingly popular management tool generating considerable research attention, employed within both ICM and EBM frameworks.

Dilemma 1: imbalance of natural and social science

MPAs may be defined as 'a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of

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Table 2 MPA-related research activities. NA = not applicable.

Topic	*Social science*	*Natural science*
Pre-MPA marine use patterns	Study of spatial distribution and intensity of uses	Impact of current uses on marine resources and habitats
Impact of MPA on fishery	Impact on distribution of fishing effort and gear types	Impact on fish catch, biodiversity, and biomass
Economic impact of MPA on fishery	Pre and ongoing monitoring of fish yields and profits	NA
Human and institutional capacity requirements	Capacity needs and opportunities assessment	NA
Socioeconomic impacts of MPA	Monitoring of costs and benefits and their distribution	NA
MPA management effectiveness	Assessment of management challenges, opportunities, responses and outcomes	Assessment of attainment of fishery or environmental goals

nature with associated ecosystem services and cultural values' (Dudley 2008, p. 8).

This spatial management tool has many goals, ranging from environmental restoration, to tourism development, to preservation of historic sites (World Bank 2006). The rules associated with MPAs include complete prohibition of extractive activities to limitation of particular forms of fishing or other activities (World Bank 2006). MPA governance ranges from community-based, to co-management, to centralized approaches (Christie & White 2007). The specific research methods used to design and evaluate vary in response to the MPA goals and form. MPAs developed to improve fisheries management may require stock assessments, in addition to habitat studies while MPAs developed for biodiversity conservation may emphasize habitat and life history studies. All MPA types benefit from social science studies of, for example, governance and social dynamics (Mascia 2001; Christie *et al.* 2003*c*). MPA ecological goals are unattainable in the long term if social and governance dynamics are poorly understood and managed (Christie 2004). The need for balanced and integrated assessments is increasingly apparent and acknowledged in the practitioner and scientific literatures (Kaufman *et al.* 2009; Shackeroff *et al.* 2009). A relatively small, but growing, group of scholars and practitioners are researching critical MPA interdisciplinary knowledge gaps (for example Aswani & Hamilton 2004; Christie 2004; Cinner *et al.* 2005; Pollnac *et al.* 2010), but interdisciplinary information is generally inadequate and underused in policy making.

A comprehensive MPA design and evaluation research programme would, at a minimum, consider a range of issues and social and natural science methods (Table 2). However, with the possible exception of the Great Barrier Reef National Marine Park, few MPAs have undergone such this type of interdisciplinary review.

The relative balance of research remains skewed toward accounts of declining ocean conditions and debates over ecological impacts of marine and coastal policies and MPAs (Campbell *et al.* 2009). There are many plausible explanations for this lack of balance and integration between MPA-relevant social and natural science research. The next two dilemmas introduce two explanations.

Dilemma 2: Overreliance on a particular worldview and science-policy epistemic community

Levins and Lewontin (1985, p. 267) stated: 'Scientists, like other intellectuals, come to their work with a worldview, a set of preconceptions that provides the framework for their analysis of the world. These preconceptions enter at both an explicit and an implicit level, but even when invoked explicitly, unexamined and unexpressed assumptions underlie them'. The goals and objectives of policies are profoundly influenced by shared social constructions of the ocean. Whether the ocean is conceived of as a place of commerce, military opportunity or locus for important biodiversity, is directly related to distinct social constructions which are historically embedded and discernable (Steinberg 2001).

Berger and Luckmann (1967) wrote that '. . .reality is socially constructed and the sociology of knowledge must analyze the processes in which this occurs. . . It will be enough. . .to define 'reality' as a quality appertaining to phenomena that we recognize as having a being independent of our own volition (we cannot 'wish them away'), and to define 'knowledge' as the certainty that phenomena are real and that they possess specific characteristics.'

Berger and Luckmann (1967) further clarified other empirically grounded and practical considerations, that:

- knowledge and perceived reality are socially relative, and influenced by factors such as class, education, race and gender;
- specific patterns of knowledge and perceived reality pertain to certain social contexts which are describable;
- over time, subjective meanings tend to evolve into positions assumed to be factual;
- and, most importantly, human thought is subject to the influences of its social context which leads to ideological positions of a social group.

The internalization of a particular worldview is unavoidable. Few scientists or policy makers are aware of the dimensions of their worldview regarding key variables such as knowledge and resource abundance. The lack of realization and understanding of the biasing tendencies of an individual's worldview is limiting, and raises the potential for conflicting and uncompromising ideological positions.

The future of marine resource management, especially in a globalized and diverse context, will hinge on a degree of self-awareness, compromise and flexibility. Marine-policy relevant social research has usually focused on the resource users and constituencies associated with marine policy intervention rather than on the wider community conducting the science and setting policy priorities. Reviews of the culture of science and the science-policy complex, usually by critical theorists interested in science studies (for example Lowe 2006), generally remain outside the management and policy-making discourse.

The influence of worldviews on scientific research is complex, subtle and undeniable and occurs at individual and societal levels (Kuhn 1970). Whether those perspectives become ideological, or a shared belief system, and influential depends on whether opportunities and resources emerge to create or influence potent epistemic communities through which to diffuse ideas (Haas 1990; Morris & Mueller 1992; Rogers 2003). An epistemic community is an influential group of socially connected people who share common worldviews.

One such epistemic community influenced policy development for the Mediterranean Sea in a process that parallels the current discourse and process for global MPA networks. 'The Med Plan's successful creation was promoted by a community of ecologists and marine scientists... According to the explanation suggested here, if a group with a common perspective is able to acquire and sustain control over a substantive policy domain, the associate regime will become stronger and countries will comply with it. Such groups are more likely to be consulted after a crisis, especially when policy makers are uninformed about the technical dimensions of the problem at hand and are uncertain about the costs and benefits of international cooperation. New national policies, often in compliance with the regime, would then reflect the interests of the group consulted and empowered, and the duration of the new policies would depend upon the group's ability to consolidate and retain its bureaucratic power. The substantive nature of the regime would reflect the group's cause-and-effect beliefs . . .' (Haas 1990, p. 380).

The ways in which environmental problems are constructed and, in turn, what types of information are considered critical to their resolution determine the range of policy options. Adler and Haas (1992, p. 374) concluded after reviewing various empirical studies that 'The impact of epistemic communities is institutionalized in the short term through the political insinuation of their members into the policy making process and through their ability to acquire regulatory and policymaking responsibility and to persuade others of the correctness of their approach'. The EBM and MPA advocacy epistemic community has become remarkably influential and created a well-defined policy agenda which has diffused through influential conservation, resource management and donor institutions (and some government institutions). One example of the growing influence of the EBM epistemic community is the appointment of academic, marine biologist and enthusiastic MPA and EBM proponent Dr Jane Lubchenco (Lubchenco *et al.* 2003) as head of the US National Oceanographic and Atmospheric Administration (NOAA).

The discourse within and produced by this epistemic community to influence policy has distinct characteristics which make it particularly influential by some accounts (for example journal impact factor, raising awareness of ocean decline), but also potentially limited in its ability to develop feasible and IR-informed policies at a global scale. High impact scientific assessments present early accounts of how ocean conditions are declining on a large scale and what should be done to reverse these trends. The common form of a number of these articles (for example Pauly *et al.* 1998; Roberts *et al.* 2001; Lubchenco *et al.* 2003; Mora *et al.* 2003; Pandolfi *et al.* 2003) follows the outline of: (1) ocean conditions are declining globally and precipitously, (2) society is responsible for this decline, (3) MPAs are a preferred and under-realized policy option, and (4) ambitious systems of large MPAs are required. These MPAs are commonly offered as a means to return to historic baseline conditions in at least some places, a recommendation that suggests a particular relationship (as minimal as possible) and position of society with regard to nature (separate) (Campbell *et al.* 2009). It is notable that most of the high impact global assessments and proponents for ambitious global MPA systems are generated by scientists and conservationists from the global North. This may be owing partly to the fact that the Northern academic community has greater access to and interest in publishing in these scientific journals, or could be because the academic community in the South is less comfortable with such large-scale policy agendas and favours priorities that elevate the needs of impoverished people. This topic would benefit from additional investigation.

Advocating for global MPA networks commonly overlooks various important social considerations. How MPAs affect various and complex human communities and the level of acceptance of MPAs by a diverse society is little documented and examined. Alternatives, trade-offs and governance feasibility are rarely considered. A global network, especially one proposed by Northern scientists and conservation groups, is almost certain to create controversy in the global South (Agardy *et al.* 2003; Oracion *et al.* 2007; ICSF [International collective in Support of Fishworkers] 2008; Aswani *et al.* 2011) and may create a sense of disempowerment and isolation in marginalized fishing communities in developing countries (Jones 2009). The under-examination of power dynamics between social groups has been identified as a key challenge to functional governance (Jentoft 2007). MPA-advocating studies tend to conflate utilitarian with biodiversity goals, giving the impression that biodiversity conservation and fisheries benefits, for example, may be equally maximized (Jones 2006). In other words, all boats may (and likely will) not rise equally with MPA implementation and rent capturing by influential social groups is likely without mechanisms for equitable distribution of benefits (Christie 2004; Christie *et al.* 2005; Oracion *et al.* 2005).

Simplified arguments are often applied in the explanation of complex environmental problems and to advocate for particular solutions. Human overpopulation is frequently offered as the fundamental cause of Malthusian environmental collapse and suffering (Hardin 1968, 1974). Malthusian conceptualizations are cited as an explanation for overfishing (Pauly 1990). Disagreement with this line of reasoning may be viewed as disinterest in protecting the Earth's vulnerable ecosystems, as if arguing for the rights of marginalized people implies a lack of interest in protecting the world's environment (but see Vandermeer 1996 and Brechin *et al.* 2003 for alternative views). Constrained lines of reasoning, while readily understood, reduce and limit the role of IR within policy design or evaluation. The argument's construct allows for little meaningful engagement of social sciences beyond economics focused on determining ecological services associated with marine systems and MPAs (Campbell *et al.* 2009).

In conclusion, while consensus is emerging that ocean conditions are frequently in a state of decline and that well-designed and implemented MPAs have potential to redirect society's overexploitation of resources, the creation of partially, and mainly ecologically, informed MPA mandates is contested by those at the periphery of MPA science (Trist 1999; Walley 2004; Oracion *et al.* 2005; ICSF 2008). The current scientific discourse is heavily influenced by the perspectives of a particular epistemic community's views which tend to under-represent complicating social dynamics, alternative policy options and social science inputs. It is not merely a matter of overlooking social sciences, rather this group actively selects a particular narrative and suite of scientific information. This narrative agrees with their worldviews and social constructions of the environment (Berger & Luckman 1967). The implications for people and ocean conditions are serious, since MPAs founded on an incomplete understanding are likely to fail in most places in the long term (Christie 2004; Christie *et al.* 2005; Charles & Wilson 2009; Pollnac *et al.* 2010). Policies based on dire assessments without consideration of critical process elements might ultimately undermine longer term and widespread MPA success (Agardy *et al.* 2003) and generate conservation islands surrounded by a sea of highly degraded areas (Agardy *et al.* 2011; Vandermeer 1996).

Considerable IR effort will be required to uncover and systematically consider why the above narrative is generated, why it has become so influential, and how it shapes the range of management options available. This research should be conducted in the spirit of creating a full and balanced scientific understanding and feasible policies, rather than, on the one hand, dismissing the utility of scientific documentation of environmental decline or, on the other hand, justifying MPAs and EBM.

Dilemma 3: Emergent integration of natural and social sciences and inherent tensions

Many of the underlying epistemological foundations, methods, and goals of natural and social sciences are distinct (Pickett *et al.* 1999; Campbell 2005; Campbell *et al.* 2009). Excessively reductionist and positivist approaches to understanding biological or social processes have been challenged in the social and natural sciences, but for different reasons. There has been a movement toward synthetic thinking within the environmentally-focused natural sciences. The emergence of ecology and conservation biology is an attempt to view biological relations from a synthetic non-reductionist perspective (Vandermeer 1996). The emergence of resilience theories in ecology raises the importance of non-linear, dramatic and somewhat unpredictable change in ecosystems (Gunderson & Holling 2001). Within the social sciences, the very role of scientific methods has been questioned. The emergence of postmodernism, a movement which questions Cartesian modes of research and objectivity, has been particularly influential in the social sciences. Political ecology, as an influential progeny of postmodernism, emphasizes issues of power, oppression and social construction of the environment (Peet & Watts 2004; Vandermeer & Perfecto 2005). The critique of 'mainstream' environment management efforts, which are cast as hegemonic, is controversial, partly because it questions the privileged and influential role that natural science and scientists occupy in defining issues and prescribing solutions (Chapin 2004; Lowe 2006). In large part, postmodern social scientists are at the periphery of the environmental management and associated natural science discourse, while there are rare exceptions that generate discussions among donors and conservationists (Chapin 2004).

Besides epistemological debates, additional methodological and ethical constraints tend to separate natural and social sciences. For the ecological assessment of MPAs, the gold standard of study design is the before–after control-impact (BACI) design (Kaufman *et al.* 2009), a standard rarely attained since pre-MPA data are rare and environmental conditions inside and outside MPAs vary. For social systems, pre and post data are almost never collected. In this sense, the challenges of natural and social MPA science overlap. But the social scientist faces unique challenges; isolating particular variables in complex social systems is exceedingly difficult and humans communicate about and adapt quickly to change (Pickett *et al.* 1999). People are engaged in many economic, social and cultural activities simultaneously in relation to any environmental condition or policy. In a complex world, the variables of interest cannot be adequately isolated, nor can social experiments be conducted which may have unintended negative consequences for society. For example, poverty may influence coastal community receptivity to MPAs, but poverty cannot be isolated from many other associated variables, and there is general unwillingness to apply the treatment (MPAs) across a spectrum of relatively wealthy to relatively poor communities as part of an ethically questionable social experiment.

The optimal means to generate social knowledge of power and oppression is debated within the social sciences. Traditional social science, which 'extracts' knowledge from

informants, and participatory social science, which 'co-creates' knowledge with informants, coexist within the social sciences (Fals- Borda 1987; Freire 1993). While most academic institutions favour scientific over participatory methods, academic communities engaged in participatory research exist on most campuses with underpinnings from seminal works (see for example Freire 1993). The emergence of participatory or rapid rural appraisals in the 1990s (Chambers 1994) and subsequent participatory coastal resource assessments (Deguit *et al.* 2004) represent the practical application of participatory theories and methods expressed by intellectuals largely from the global South (for example Fals- Borda 1987; Freire 1993).

Bridging the epistemological, methodological and ethical divides of the natural and social sciences or, greater yet, overcoming the opposing scientific and postmodern intellectual camps, is extraordinarily difficult. Perhaps the full integration of social and natural sciences is neither possible nor desirable, especially if important social MPA design criteria are obfuscated by ecological ones. Stoffle *et al.* (2010, an anthropologist, recommended separate but parallel social and natural science MPA research, to be eventually rectified in the design process. The natural tensions and distinctive perspectives within parallel processes may be useful and result in a plurality of understandings. Integrative analysis may explain how societies and individuals respond to environmental cues or environment shifts (Aswani & Hamilton 2004; Cinner *et al.* 2005; Pollnac *et al.* 2010), but may not be the most effective approach to investigating other important processes such as the detailed understanding of formal institutional design, environmental histories, or class and race relations (Campbell *et al.* 2009).

Dilemma 4: Balancing mandate dependent and mandate independent research

The role of science within environmental policy making is changing. The marine scientist as an advocate of social policy is relatively new and simultaneously applauded and vilified (Pauly 2009). Discussions about desired environmental states, and more specifically MPAs, tend to polarize constituency groups, including researchers (Campbell *et al.* 2009). Some of the polarization may be attributed to the definitions used by ecologists and fisheries scientists to set thresholds for overexploitation (Hilborn 2007) and differences between researchers' interpretations of the goals and consequences of MPAs. The Souffrière MPA in St Lucia provides an illustrative example of polarization based on distinct interpretations of outcomes. Roberts (2001) characterized the Souffrière MPA in Saint Lucia as an unqualified success story with both positive ecological impacts and social acceptance. Sandersen and Koester (2000) provided a detailed description of the management process for this same MPA and identified management conflicts and difficulties. Trist (1999), a political ecology geographer, provided a detailed historic review of the evolution of the Caribbean from a place of subsistence to one of global tourism; the Souffrière MPA was characterized as part of this transformation, with marginalization of, and resistance by, local fishers. Notably, the more recent and influential paper by Roberts (2001) did not cite the work of the other more critical scholars. The distinct methods, perspectives and journals allow for narrow interpretations. The examination of reasons for such distinct interpretations is uncommon in the marine policy and scientific literature used by ocean policy makers. The emphasis has been on describing the proximate environmental condition and policy efficacy (what Christie *et al.* 2003*c* refer to as 'MPA mandate dependent' topics), rather than examinations of the appropriateness of the policy (i.e. MPA) and why scientists reach distinct interpretations of common cases (examples of mandate independent topics). Scientists, including social scientists, aspire to studying both applied and basic questions. Stated more forcefully, social scientists working on environmental issues are not willing to limit their studies and research output to 'solve problems' of conservation and articulation of conservation planners and communities (Campbell 2005).

Dilemma 5: Balancing global and local studies

The widespread debates over whether MPAs are intended mainly for biodiversity conservation, fisheries management, or both (Hilborn *et al.* 2004; Jones 2006) are rarely located within comparisons of contextual particulars. Increasingly, with the development of spatially explicit global datasets and global information system (GIS) enabled presentations, important large ecological changes have been discerned (Pauly *et al.* 2005; Worm *et al.* 2006; Halpern *et al.* 2008). The sophisticated ecological trend analysis is not matched with similarly impressive analytics for ocean and coastal use, values and ecosystem services, governance and MPA policies, either as a result of limited data or by design (Campbell *et al.* 2009; Shackeroff *et al.* 2009). The mismatch of scale for current global analyses with policy recommendation is methodologically multifaceted. First, the prioritization of MPA evaluative metrics is often arbitrary. The selection of data layers for GIS interpretations can be driven by the availability of data and influenced by subjective prioritization. For example, Mora *et al.* (2006) raised awareness of the condition of reefs and the inadequacy of coral reef MPA coverage. They advocated for large and closely-spaced MPAs across the world. This interpretation is based on a layering of data in descending order of importance: regulation on extraction, incidence of poaching, risk to external impacts, MPA size and isolation. Little beyond anecdotal justification for inclusion of variables was provided, including the supplemental methods section of the paper, and no MPA social science studies were cited, despite the policy subject matter (Mora *et al.* 2006). The minimum size of the MPAs that met Mora *et al.*'s (2006) criteria for an effective coral reef MPA (an area $\geq$10 km^2), was based solely on ecological criteria and thus they regarded most community-based MPAs (which are understandably below this size cut-off) as ineffectual. Such categorization contradicts the extensive positive accounts of moderately sized MPAs (Halpern 2003; Russ *et al.* 2004) especially when networked (Gaines *et al.*

2010). The constrained selection of variables to measure the broad concept of MPA effectiveness is representative of a particular suite of disciplinary perspectives; mostly notably, that what really counts is the protection of the ecosystem.

Ideally both global and local studies inform understanding of MPA impact and strategy. The initial MPA literature consisted primarily of site-specific case studies, which limited potential for generalization (Russ & Alcala 1999). Subsequent meta (Halpern 2003) and comparative studies (Pollnac *et al.* 2001; Christie *et al.* 2009*a*) allowed for generalization. While meta and comparative studies elucidate general principles, robust inductive case studies provide the details necessary to understand local dynamics, which are clearly important to MPA impact and success (Pickette *et al.* 1999; Christie *et al.* 2009*b*; Shackeroff *et al.* 2009). They allow for an understanding of context-dependent cultural constructs of the environment (Campbell *et al.* 2009). The explanations for, and exceptions to, general patterns emerge best from carefully constructed local case studies. Case studies can provide detail accounts of complex interactions within the specific policy realm and will not dismiss important outliers based only on statistical trends (Pickett *et al.* 1999; Russ & Alcala 1999; Christie *et al.* 2002; Yin 2008). Outliers either in favour of or opposed to MPAs can have a marked impact of their progress (Christie *et al.* 2003*a*). The scientific community may be compelled by the general and comparative studies, while the practitioner and policy maker remain interested in the particulars of their site of interest. The diffusion of case-specific information through social and learning networks clearly influences perceptions by resource users and other MPA constituencies (Rogers 2003; Pietri *et al.* 2009).

Changing course: toward more effective interdisciplinary research

Analysis of the role and dilemmas for marine policy IR, with an emphasis on ICM, EBM and MPAs, suggests a course forward to improve IR The following is a mixture of systemic and conceptual ideas for future IR with emphasis on incremental and practical steps.

Reassessing the starting point and disciplinary balance of knowledge and policy creation

Providing a more pluralistic form of research to guide coastal and marine policy will require reconceptualization of environmental problems and solutions. A fully social ecological conceptualization of problem and solution implies equal attention is paid to both social and ecological aspects. Environmental frameworks and policies, which are social constructs of which ecological conditions are only one of many considerations, are most effective when grounded in reliable and detailed understandings. For ethical, theoretical and practical reasons, the human dimension should not be reduced to mainly economic calculations of, albeit important, ecosystem services or quantified general principles (Campbell *et al.* 2009). Just as robust ecological research must span the breadth of natural history, population dynamics and genetics, social research should include, at a minimum, attempts to understand the social context over time, the environmental management process, institutional design principles, human adaptation and social impacts of policy with a consideration for justice (Campbell *et al.* 2009; Jones 2009).

Recasting the position of society within social ecological research will create opportunities for balanced IR. In the predominant narrative of ocean decline and global policy response, society is generally reduced to the role of perpetrator of environmental degradation, with humans located outside of nature (Campbell *et al.* 2009). The conclusion that ocean resources are in a state of decline in many places is important and accurate, and has generated considerable impetus to alter ocean policy. Relatively little is known about the conditions and mechanisms through which society either prevents environmental degradation or actively restores environment. For example, until the seminal work of political scientist Ostrom (1990) and others, the seemingly inevitable 'tragedy of the commons' was a predominant explanation for why much of the non-private environment was in decline (Hardin 1968). Casting society as both perpetrator of environmental degradation and advocate of environmental sustainability will allow for more meaningful research, theory and policy.

Understanding the historic and contemporary influences on worldviews of social groups and how these shape responses to particular ocean policy is a practical and largely unexploited opportunity. Making known the worldviews of ocean natural and social scientists and how these worldviews influence scientific descriptions of the ocean and ocean policy will improve ability to interpret scientific conclusions. The lack of self-reflective research within the science policy making community is problematic on many levels. First, on a scientific basis, it results in an obvious gap in understanding how science and policy priorities are created. Second, and pragmatically, it reduces the ability to create successful, broadly acceptable and sustainable policies. Policies should not be predicated on constrained information sources and assumptions of what policies are preferable and feasible. The opportunities for IR on such topics are broad and could make an important contribution to the creation of successful ocean and coastal environmental policy.

Another pragmatic area for coastal and ocean IR is the creation and application of multi-method evaluative research. To date, despite mandates to establish global MPA networks and large marine ecosystem management systems (Sherman *et al.* 2005), and rapidly growing interest in EBM (McLeod & Leslie 2005; CEQ 2009), the evaluative efforts are commonly ad hoc and inappropriately scaled. Evaluation began with useful case studies of management effectiveness of MPAs (see for example White *et al.* 2002) and LMEs (for example Cochrane *et al.* 2009; Fanning *et al.* 2009). Only few and limited comparative studies of the human and management dimensions of MPAs (Pollnac *et al.* 2001, 2010; Cinner *et al.* 2007; Christie *et al.* 2009*a*) and marine EBM (Christie *et al.* 2009*b*) exist. Global assessments attempting social ecological

metrics are challenged by limited data which, in turn, limits metrics and ultimately the usefulness of such assessments. Mora *et al*. (2006) reduced the human dimensions of coral reef MPA success to an overly constrained suite of variables. Pollnac *et al*. (2010) reduced ecological effectiveness to a ratio of fish density inside and outside MPAs. The reliance on primarily social or ecological, superficially global or context-bound case studies is problematic and should limit confidence that global MPA schemes are feasible (Christie *et al*. 2009*b*). In short, the evaluative research completed or underway is not scaled properly to the problems or the management interventions underway to help ensure feasibility or capture lessons.

Applied marine IR would need to consider methodological issues of specificity and generalization. Consistent methods will need to be used for monitoring particular outcomes of management interventions (for example MPA impact on biodiversity and biomass inside and outside MPAs or socioeconomic impacts of MPAs). The bias toward quantitative or modelled results, based on a tendency to view quantitative results as rigorous while qualitative results are dismissed as anecdotal and subjective, should be resisted on methodological, practical and educational grounds (Pickett *et al*. 1999; Campbell *et al*. 2009). Qualitative social data which maintain the narrative of informants and complement general patterns with specific and, perhaps non-statistically significant, results are essential to a complete understand of complex phenomena. Such site-specific and detailed research will improve ability to explain, at a scale meaningful to policy makers and impacted communities, why patterns emerge from comparative research. Creation of publication review standards for such IR is underway, but requires editorial guidance to reduce the tendency of reviewers to retreat to their disciplinary and methodological biases (Pickett *et al*. 1999; Campbell 2005; Campbell *et al*. 2009).

Social ecological research will need to be conducted over time to identify patterns of change. Social ecological outcomes are related to the duration of implementation (see Russ *et al*. 2004) and management concerns change from attainment of primary MPA implement (for example enforcement) to distribution of benefits (Pollnac & Pomeroy 2005; Pajaro *et al*. 2010). The costs and benefits of MPAs change over time.

IR will need to bridge the scientific/non-scientific gulf. Environmental policy, perceived as legitimate by diverse social groups, can be generated by participatory IR (Fals-Borda 1987). Interdisciplinary participatory research offers an opportunity to create partnerships with communities impacted by environmental policies, many of which have important non-scientific knowledge and may, through the research process, become aware of social ecological dimensions of the ocean and policy processes in a manner that fosters their commitment to sustainable practices (Pomeroy *et al*. 2004). Their knowledge and perspectives may complement and challenge the perspectives of scientific researchers. Tropical coastal inhabitants are commonly generalist farmer-fishers, and therefore are aware of critical social ecological linkages. The poor and marginalized are obvious 'experts' on the impacts of poverty, a key social variable defining policy options (Fals-Borda 1987; Freire 1993). These social groups are most interested in research which directly addresses a tangible problem which they face.

The current separation of research and action is grounded in a commitment to a particular form of scientific inquiry. Praxis, the melding of research with action in an iterative process, provides a potentially complementary research frame to applied research which typically ends with policy recommendations (Lather 1986). Pragmatically speaking, self-compliance with ocean policy is essential given limitations in enforcement capacity. Rules which are derived of participatory processes are frequently perceived of as more legitimate, which in turn increases compliance (Kuperan & Sutinen 1998; Pollnac *et al*. 2001; Christie *et al*. 2009*a*). Therefore, fostering policy processes based on inclusive research programmes is practical and increases the likelihood of success.

Setting high standards for all relevant research will foster IR. Meaningful and useful IR will not occur if policy makers mainly rely on rigorous ecological impact assessments and anecdotal socioeconomic information or policy evaluations. Marine policy practitioners and independent researchers should collaborate in developing supportive applied research programmes to identify theory and practical lessons in a systematic manner. Researchers will need to retain some independence to ensure objectivity and freedom of expression. Their efforts, however, can be collaboratively designed with practitioners and programme constituents to help ensure that questions are practical and broadly interesting.

While it is not commonly discussed, the conduct of successful IR research is, as with environmental management, dependent on the quality of interactions between individuals involved in the research endeavour. The balance of disciplinary and multidisciplinary perspectives working in concert is complex and requires mutual respect, trust and transparency (not unlike any complex institution; Pickett *et al*. 1999; Tress *et al*. 2005). Such teams should be guided by individuals with interdisciplinary training and leadership qualities (Tress *et al*. 2005). The research team may wish to integrate policy makers and practitioners as researchers, research design consultants and reviewers. A degree of theoretical, methodological and epistemological 'tension' is appropriate to ensure that researchers are challenged to respond to constructive criticism while conducting research. The design of multidisciplinary research that uses complementary methods (for example quantitative and qualitative, natural and social science) will increase the likelihood of robust conclusions based on triangulation of methods and completeness of analysis.

One such programme, the ICM Sustainability Research Project (ICMSRP), relied on social and natural science, and both quantitative and qualitative research to identify why ICM programmes tended to collapse after donor and technical assistance withdrawal in the Philippines and Indonesia

(Christie 2005; Christie *et al.* 2005; Lowry *et al.* 2005; Pollnac & Pomeroy 2005). This three-year effort involving an international team of 15 researchers from natural and social sciences, research and practice began with a commonly-defined question, planned for integration from the onset, emphasized basic and applied research, and resulted in a sense of collegiality; some of the hallmarks of successful IR (Pickett *et al.* 1999; Campbell 2005; Tress *et al.* 2005). Within this realm of inquiry, the following constitutes an example of how complementary methods function. Quantitative survey research methods determined, amongst other variables, that participatory processes were strong predictors of MPA success (as measured in multivariate manner) in nine sites (Pollnac & Pomeroy 2005) and that MPA success was reduced when tourism business owners were directly involved in community-based MPA implementation processes (Thiele *et al.* 2005) or captured the majority of economic benefits (Oracion *et al.* 2005). Qualitative research provided detailed narratives of why conflict emerged between tourism and fishing social groups based on distinct definitions of MPA goals and distribution of benefits (Christie *et al.* 2003*b*; Christie 2004). These findings were related directly to long-term biological conditions in MPA study sites (Christie 2005). Findings were translated into empirically-grounded education materials used in training programmes (Milne *et al.* 2003) and served to validate findings and encourage realistic policy recommendations. The creation of coherent, multidisciplinary and multi-method explanations for complex phenomena is attainable and productive, but takes time and commitment to generating a common language and common meaning (Tress *et al.* 2005; Pickett *et al.* 2009).

The reformation of educational programmes to train interdisciplinary and integrative researchers and policy makers requires ongoing support if environmental IR is to flourish (Zarin *et al.* 2003). Environmental studies programmes at North American and European universities are in a process of rapid evolution. Leading universities have created environment programmes drawing together diverse disciplines and interdisciplinary faculty members and students. Education programmes should include coursework and support for student research in epistemology, science studies, interdisciplinary theory and methods, and scientific and participatory methods. Students will need to be educated in the theories and methods across disciplinary boundaries and exposed through practical experiences to the perspectives and interests of diverse social communities. There is room for growth; educational materials to train the next generation of interdisciplinary scholars and policy makers are not as advanced as disciplinary programmes.

Finally, an investment in applied IR commensurate with the problems and impacts of global ocean policy trends is needed. As a provocative but reasonable solution to the challenges identified in this review, I suggest that equal amounts of funding be applied to the social and natural science components of marine IR, with a prioritization of research that is comprehensively and simultaneously social and natural science inquiry. Such a reworking of funding priorities based on parity would increase the possibility for balanced and meaningful IR. While some may argue that the current funding imbalance is appropriately due to the elevated expense of natural science versus social research, the paucity of ocean social science highlights the immediate need for rebalancing. High quality, comparative social science requires significant funding commensurate with the scale of the issues identified in order to be successful. While a plea for additional social science research funding may seem self-serving, this suggestion is made from a pragmatic perspective. Investment in appropriately scaled and complete IR research could improve success for policies which are expensive and necessary, given the decline of ocean resources and biodiversity. Marine and coastal policies are in a state of evolution, and such IR research could support a constructive recalibration of concepts at a critical juncture.

Having identified areas for improvement and opportunities for IR within the realm of marine and coastal policy, further attention to balance within and between disciplines and research and policy making will continue to improve understanding of the ocean and associated societies. The need and impetus for such research is greater now than ever.

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