MINI REVIEW

A mismatch of scales: challenges in planning for implementation of marine protected areas in the Coral Triangle

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Keywords
Conservation action; conservation area design; conservation planning; Coral Triangle; local; regional; scale.

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Received
8 January 2010
Accepted
14 June 2010

Editor
Belinda Reyers

doi: 10.1111/j.1755-263X.2010.00134.x

Abstract

Regional systematic conservation planning is an effective approach to marine protected area (MPA) network design, ensuring complementarity, and functional connectivity of areas. However, regional planning and local conservation actions do not properly inform one another. One outcome is the failure of regional designs to guide conservation actions. Another is that site-based MPAs constitute collections rather than functional systems for marine conservation. Understanding decisions related to spatial scale in conservation planning is essential for the development of ecologically functional networks of MPAs. Decisions about scale require that planners address trade-offs between the respective advantages and limitations of different considerations in several parts of the planning process. We provide the first comprehensive review of decisions about spatial scale that influence planning outcomes. We illustrate these decisions and the trade-offs involved with planning exercises undertaken in the Coral Triangle. We provide a framework in which decisions about spatial scale can be made explicit and investigated further. The framework helps to link theory and application in conservation planning, facilitates learning, and promotes the application of conservation actions that are both regionally and locally significant.

Introduction

Declining fisheries and increasing deleterious human impacts on the marine environment have prompted international commitments for increasing protection of the ocean, ideally through systematic conservation planning (Sala *et al.* 2002; Wood *et al.* 2008). Systematic conservation planning (hereafter "conservation planning") is an explicit framework for locating and designing actions in time and space to promote the conservation of biodiversity and sustainable use of natural resources. It involves many decisions about spatial scale. Spatial scale (hereafter "scale") is defined here by extent and resolution of study regions, data, and areas of assessment. Effective resource management will also require understanding of other scale-related aspects of any study region, such as institutions, knowledge, governance, and power relations (Bulkeley 2005; Berkes 2006; Cash *et al.* 2006), but these are beyond the scope of this review. Five of 11 stages of the process of conservation planning (Pressey & Bottrill 2009) require decisions about scale. These decisions address ecological and social considerations and influence the final configuration of conservation actions. In marine environments, decisions about scale include (1) the extent and delineation of the planning region; (2) the resolution of data to represent biophysical and human attributes of the region (Margules *et al.* 2002; Ban *et al.* 2009); (3) the size and delineation of planning units for assessment and comparison (Pressey & Logan 1998); (4) marine protected area (MPA) network design (Halpern & Warner 2003); and (5) the extent and delineation of actions, including implementation of MPAs. We define an MPA here as a multiple use area in which extractive use is regulated, for example, by permanent no-take reserves.

Regional-scale planning initiatives identify areas where some form of local-scale conservation action should occur, assuming that ecologically functional networks of complementary actions will result (Franklin 1993; Poiani *et al.* 2000). Following Pressey & Bottrill (2009), we define "regional" scale qualitatively as demarcating common "patterns and processes of biodiversity and human uses." This allows planners to consider the spatial context for conservation decisions, complementarity and connectivity between areas, threats to natural features, and relationships between different human activities. Most regional-scale assessments are prioritization exercises only: they do not directly inform local-scale actions. However, the importance of linking regional assessments to local actions is increasingly recognized (Knight *et al.* 2006). Understanding scale-related decisions in conservation planning is therefore essential if regional planning is to have local outcomes.

Globally, marine conservation action commonly results from local or site-based initiatives, focused only on the issues and values of one or a few communities. Within the South Pacific, a social network of over 500 communities across 15 countries and territories (the Locally Managed Marine Area network) has established MPAs that include small (usually <0.5 km^2) no-take reserves (Govan *et al.* 2009). In the Philippines, there are more than 1,000 community and local government MPAs (Weeks *et al.* 2010). Local initiatives can be rapidly implemented because they address local issues in a culturally sensitive manner (Govan *et al.* 2009). However, while locally motivated MPAs have benefits for biodiversity and sustainable harvest, they have failed to coalesce into systems of complementary, functionally connected areas (Sala *et al.* 2002), and are unlikely to sustain regional-scale processes or associated biodiversity. Numerous site-based initiatives might, however, be the first significant step toward the creation of ecologically functional MPA networks (Lowry *et al.* 2009).

We define the mismatch of scales in conservation planning as the failure of regional-scale planning and local-scale actions to inform one another. The advantages of regional planning include its broad perspective on complementarity and functional connectivity. The advantages of local actions are their ownership and support by affected stakeholders. In addition, local actions better match the scale of government jurisdictions to which management of natural resources is being devolved in several Asian and Pacific countries (Foale & Macintyre 2000; White 2008). The importance and urgency of bringing together these two scales of activity are nowhere better illustrated than in the Coral Triangle (CT).

The CT comprises the Philippines, Malaysia, Indonesia, Papua New Guinea, the Solomon Islands, and East Timor. Of about 350 million people living in the region, more than 120 million depend directly on local marine resources (CTI Secretariat 2009a). The CT is the global center of marine biodiversity and a global priority for conservation (Roberts *et al.* 2002; Green & Mous 2008; CTI Secretariat 2009a). In 2007, the CT Initiative—the world's largest conservation initiative—was launched to develop approaches to mitigate threats to marine resources, with over U.S. $500 million committed. Donors include the United States, Australia, the Global Environment Facility, and USAID (CTI Secretariat 2010b). Sustainable resource use within the CT depends on integrated management including, importantly, the effective implementation of comprehensive, ecologically representative, and biologically connected MPA networks (Roberts *et al.* 2001; White 2008).

Challenges in bridging the gap between regional planning and local action are acute in the CT because: (1) central governments have limited influence over marine resource management; (2) data for regional planning are minimal and mainly at coarse resolutions; and (3) options for conservation are constrained by social, economic, and political complexities, such as high dependence on marine resources and unresolved boundaries of customary tenure. Here, we develop a framework to discuss decisions about scale in conservation planning and explore how these decisions ameliorate or exacerbate the mismatch between regional planning and local action. We discuss the five kinds of decisions about scale (Figure 1) in the sections that follow, describing key considerations and the necessary trade-offs between them. We illustrate the decisions in marine conservation initiatives directed at the establishment of MPA networks within the CT. Given the few published conservation planning initiatives within the CT, we also use examples from Pacific Island nations. Opportunities and constraints on conservation actions are similar in both contexts, including dependence on fishing for protein, customary tenure and boundary issues, and central governments with limited resources for marine conservation. We finish by outlining the implications of decisions about scale for future conservation planning processes within the CT and elsewhere to more effectively translate plans into actions.

Extent and delineation of the planning region

Delineating the planning region—the geographic domain within which areas are evaluated and compared as candidates for conservation action (Figure 2B)—is a prerequisite for planning (Pressey & Bottrill 2009). At least four considerations are important (Figure 1): (1) the extent of bioregions (or ecoregions) (Beck & Odaya 2001); (2) the extent of governance and cultural systems (Brunckhorst

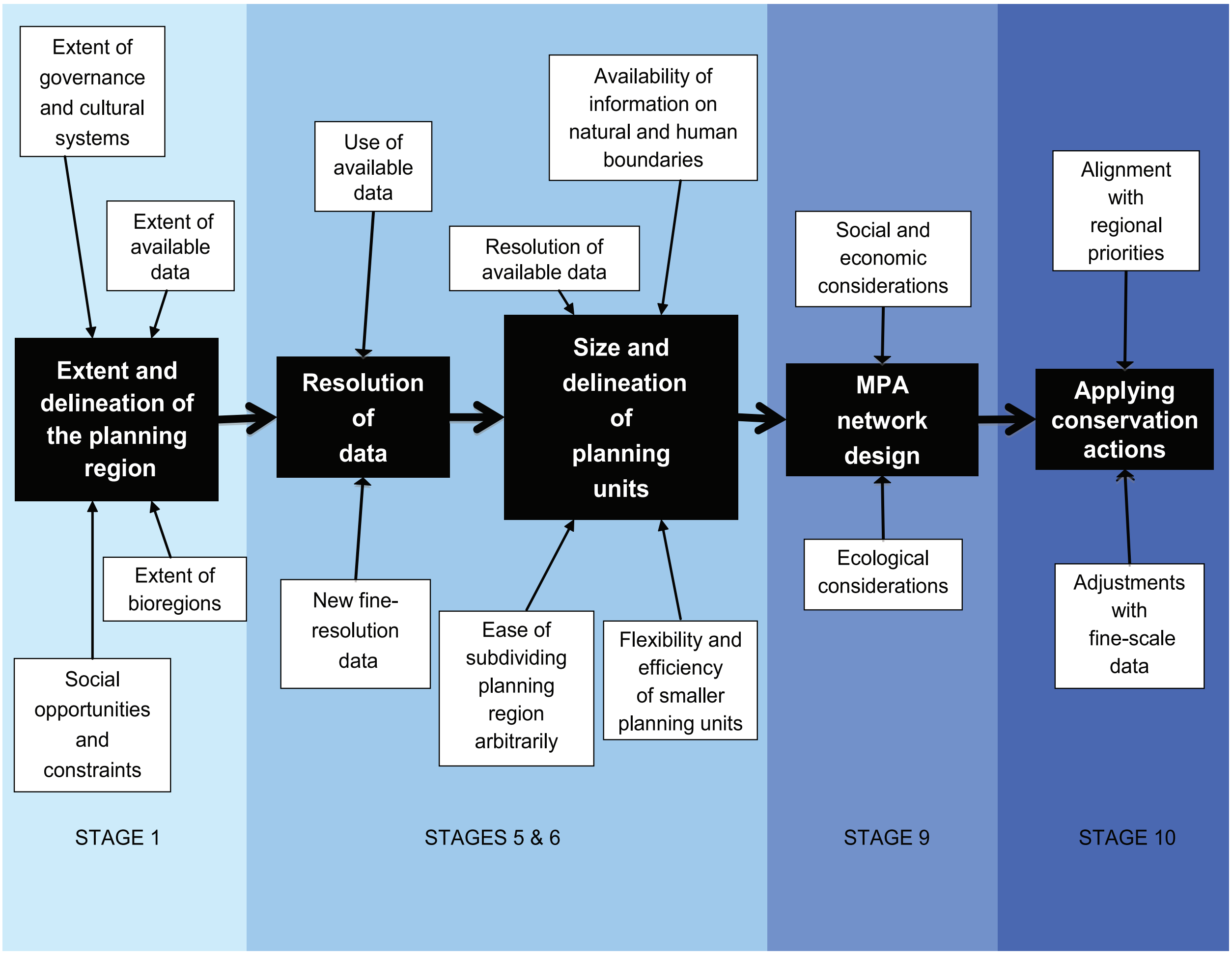

Figure 1 Decisions relating to spatial scale made during a conservation planning process (black boxes) and considerations that influence those decisions (white boxes). Planners will face trade-offs between the advantages and limitations of adjusting their decisions to competing considerations. Stages in the conservation planning process are adapted from those in the framework for systematic conservation planning proposed by Pressey & Bottrill (2009). Of their 11 stages, decisions related to scale that we consider here are made within five stages: (1) scoping and costing; (5) compiling data on socioeconomic variables; (6) compiling data on biodiversity and other natural features of interest; (9) selecting new conservation areas; and (10) applying conservation actions.

& Bridgeway 1995); (3) the extent of available data for planning (Pressey 2004); and (4) social opportunities and constraints for conservation action (Figure 1; Table 1). As we discuss below, when choosing among these considerations, planners have no single, correct prescription for identifying planning region boundaries. Instead, they will face trade-offs between the respective advantages of large and small extents and alignment of regional boundaries with other kinds of information.

Extent of bioregions

Bioregions have relatively homogeneous biological and physical composition, distinct from adjacent regions, and are large enough to encompass ecological and evolutionary processes (Spalding *et al.* 2007). Working within bioregions (Figure 3A) enables planners to compare areas with similar physical and biological compositions while also considering extensive processes that promote species' persistence and ecosystem functions (Margules & Pressey 2000; Olson & Dinerstein 2000). Marine bioregions, in the order of 10^4–10^5 km^2, have been delineated within the CT by international NGOs (Green & Mous 2008). Although extensive planning regions aligned with bioregions are advantageous ecologically, their large size can conflict with the considerations below that make smaller regions more manageable. In practice, planning regions delineated in the CT encompass only parts of bioregions

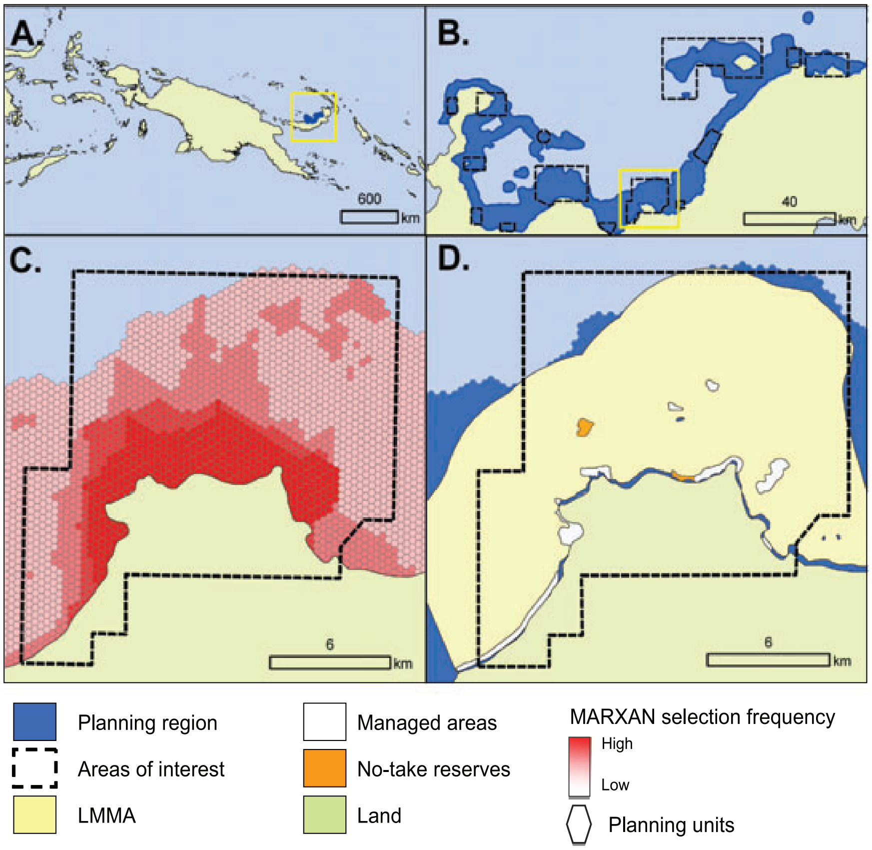

Figure 2 Differences in scale considered during the systematic conservation plan undertaken for Kimbe Bay (see Green *et al.*, 2009 for further information). (A) The island of New Guinea and surrounding islands of Indonesia, Papua New Guinea, and the Solomon Islands, with yellow box highlighting the location of the Kimbe Bay planning region. (B) The Kimbe Bay planning region resulted from trade-offs involved when deciding the extent and delineation of the planning region (Figure 1). The dashed lines represent areas of interest (AOI) or the areas within the planning region identified as conservation priorities where further work was focused. Tarobi AOI is highlighted by the yellow box. (C) The Tarobi AOI showing selection frequency of planning units analyzed by MARXAN. The pattern of selection frequency resulted partly from trade-offs regarding the size and delineation of planning units (Figure 1). Areas with darker shades of red had higher selection frequencies and were assessed to have higher value for the achievement of representation targets. (D) The locally managed marine area (LMMA), covering 202 km^2, is a general use zone recognized by local communities. Managed areas within the LMMA total 8.9 km^2 and include habitat protection zones, sacred sites, and preservation and conservation areas. The no-take reserves are a subset of the managed areas and cover 0.7 km^2. These managed areas are the results of trade-offs involved in applying conservation actions (Figure 1).

(Table S1). These studies considered that smaller, biologically distinctive regions were more suitable for the design and management of MPA networks because they combined relatively uniform natural attributes, similar human activities, and aspects of governance that facilitated management (Green *et al.* 2004; Green & Mous 2008).

Extent of governance and cultural systems

Uniform governance and cultural systems are generally much less extensive than bioregions in the CT (Figures 3A and B). In much of the CT, except for East Timor and Malaysia, resource management has been decentralized to local governments (Alcala & Russ 2006; Siry 2006) or is held by kinship groups (Carrier 1987; Johannes 2002), delegating decision making to those most reliant on natural resources for their livelihoods. For example, customary tenure regimes of the Solomon Islands and Papua New Guinea govern resources along hundreds of meters to a few kilometers of coastline (Foale & Macintyre 2000). This is likely a result of central governments within these countries acknowledging their limited reach in relation to resource management as compared to more developed countries (Figure 4). Planning regions aligned with bioregions will therefore encompass multiple governance and cultural systems in much of the CT, with

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Table 1 Decisions about scale, considerations that shape decisions, and trade-offs

Decisions about scale	Considerations	Trade-offs
Extent and delineation of the planning region	(1) Extent of bioregions (2) Extent of governance and cultural systems (3) Extent of available data (4) Social opportunities and constraints	Competing considerations: 1 and 2 and 3 and 4 —Delineating the planning region based on bioregion boundaries to maximize the ecological effectiveness of management actions. —Using governance and cultural boundaries to facilitate coordination and management. —Limiting the planning region to areas where consistent fine-resolution data are available to promote unbiased area selection. —Adjusting the planning region to benefit from social opportunities and avoid constraints to promote effective action.
Resolution of data	(1) Use of available data (2) New fine-resolution data	Competing considerations: 1 and 2 —Working with the resolution of available data to focus time and funds on immediate action. —Collecting new fine-resolution data to better reflect the variability of the natural and human attributes of the planning region and so improve planning decisions.
Size and delineation of planning units	(1) Flexibility and efficiency of smaller planning units (2) Resolution of available data (3) Availability of information on natural and human boundaries (4) Ease of subdividing the planning region arbitrarily	Competing considerations: 1 and 2 —Selecting small planning units to maximize flexibility in configuring potential MPAs and minimize the total cost of achieving objectives. —Adjusting planning unit size to the generally coarse resolution of available consistent data (unless rigorous procedures can be applied to downscale data and understand resultant errors). Competing considerations: 3 and 4 —Delineating planning units based on information on natural and human boundaries to facilitate the transition from regional design to local actions. —Using arbitrary boundaries to facilitate the subdivision of the planning region for regional design and avoid boundary-related ownership issues (although the conversion of arbitrary unit-to-unit of conservation action might entail additional later costs).
MPA network design	(1) Ecological considerations (2) Social and economic considerations	Competing considerations: 1 and 2 —Designing extensive MPAs to maximize their effectiveness in achieving ecological objectives. —Addressing social and economic constraints with small MPAs that facilitate the application of actions.
Applying conservation actions	(1) Alignment with regional priorities (2) Adjustment with fine-scale data	Competing considerations: 1 and 2 —Attempting to apply actions that are aligned with regional priorities to implement a theoretically functional and resilient MPA network. —Departing judiciously from regional priorities and adjusting MPA design as local insight reveal new information, thereby facilitating the application of actions.

application of conservation actions challenged by negotiating agreeable outcomes for multiple parties. Governance and cultural heterogeneity in the CT therefore encourages smaller planning regions with corresponding advantages for effective action. Boundaries based on customary tenure or provincial or district governance have therefore been used in Pere in Papua New Guinea and Karimunjawa and Berau in Indonesia (Table S1, rows E, I, and J). The boundaries for Kimbe Bay (Table S1, row B) were based primarily on biophysical data, then modified to account for provincial and village boundaries.

Planning regions, rather than being predefined, can also emerge from local initiatives, determined by social or cultural connections such as language groups and religion. Two regional conservation initiatives (Table S1, rows A and D) started as local conservation actions but then expanded. In Cebu (Philippines), the planning region was based on biophysical information and a social network among communities implementing MPAs for livelihood or conservation purposes (Table S1, row A). Social networks encouraging conservation action are becoming more prominent globally (e.g., Govan *et al.*

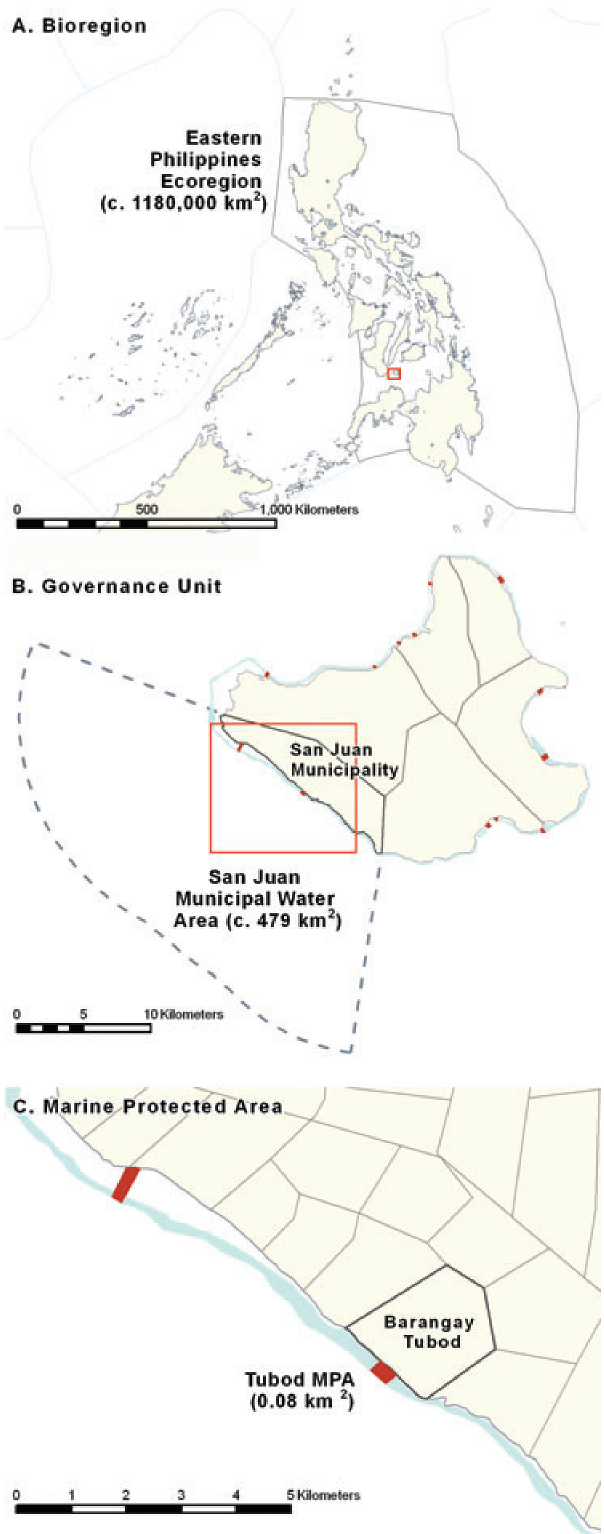

Figure 3 Contrast in extent of bioregions (or ecoregions), governance units, and marine protected areas (MPAs) in the Philippines. (A) The Eastern Philippines Marine Ecoregion (Green & Mous 2008). Bioregional classifications such as this are often recommended as appropriate planning regions. The small red rectangle is the approximate extent of part B. (B) A municipality in the Philippines. Municipalities are the most important governance units for coastal resource management in the country. MPAs are generally established cooperatively by municipal and barangay (local) governments. Small red dots indicate the location of no-take MPAs on the island of Siquijor. Red rectangle indicates the approximate extent of part C. (C) A barangay and its no-take reserve (Tubod MPA) within the San Juan Municipality. No-take reserves of this size are commonly established in the Philippines (Weeks *et al.* 2010).

2009) and are considered critical to successfully scaling up conservation initiatives by promoting communication, learning, identification of common problems, and coordination (Pretty & Smith 2004; Lowry *et al.* 2009). The initiative within the Roviana and Vonovana Lagoons (Solomon Islands) incorporated areas associated with the Christian Fellowship Church (Aswani 1999; Aswani & Lauer 2006) and has proven effective in encouraging resource protection. The wider potential of religious groups, language groups, and other cultural groups to define planning regions has yet to be investigated. In the CT, planning regions that emerged by consolidation of local initiatives are much smaller than bioregions (Table S1, rows A and D).

Extent of available data

Ideally, planning regions would have consistent biophysical, economic, and social data. Otherwise, conservation attention will be biased toward areas with more data (Margules *et al.* 2002; Pressey 2004). In reality, very few regions have consistent data at a suitable resolution for conservation planning. Most data within the CT are limited in extent, highly fragmented, and spatially biased toward NGO offices and research stations (Johannes 1998; Christie *et al.* 2009). Therefore, planners face a trade-off: limit planning regions to the extent of available fine-resolution datasets (usually very small areas) for unbiased selection of areas; or combine all available data (coarse- and fine-resolution) for regions delimited using bioregional, governance or cultural boundaries, resulting in biased, or less efficient planning processes (Margules *et al.* 2002). Within the CT, planners chose inconsistent data across regions aligned with biological and/or governance boundaries (Table S1).

Social opportunities and constraints

Institutional capacity and support for conservation actions can indicate strongly whether conservation actions will be feasible (Cowling & Wilhelm-Rechmann 2007). For example, regional conservation initiatives of The

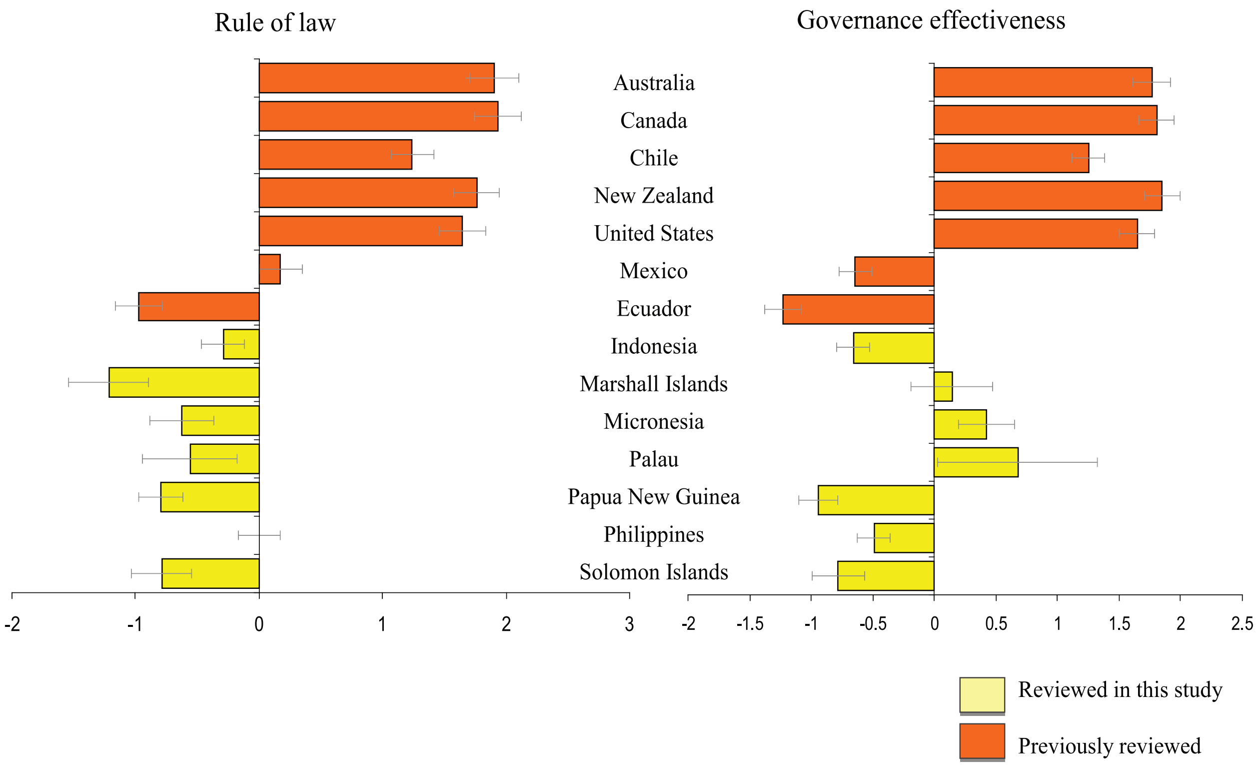

Figure 4 Governance effectiveness and rule of law indicators in countries with conservation planning exercises for MPA networks. Countries shown are those covered by Leslie (2005), grouped as "previously reviewed," and by this study, grouped as "reviewed in this study." Conservation plans have been undertaken more extensively and over a longer period in developed countries with strong governance and rule of law. Conservation plans are now being developed for Pacific and CT countries with weaker governance and rule of law, limiting the applicability of planning models from developed countries. Governance effectiveness and rule of law indicators are from 2008 governance indicators in Kaufmann *et al.* (2009). Governance effectiveness includes the "perceptions of the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies" (Kaufmann *et al.* 2009), indicating the likelihood of the application of conservation actions by central governments. Rule of law includes "perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts" (Kaufmann *et al.* 2009), indicating the likelihood of enforcement of resource management regulations by central governments. Both the governance effectiveness and rule of law scores lie between −2.5 and 2.5 and higher scores indicate better governance effectiveness and rule of law.

Nature Conservancy (TNC) in the CT are in areas where TNC or Mahonia Na Dari (a local NGO) previously established relationships with communities (Green & Mous 2008). Conversely, political unrest, poor governance, or corruption might lead planners to avoid areas because of risk to staff or poor prospects for effective conservation action. Considerations of opportunities and constraints are likely to constrain the extent of planning regions and shape their boundaries, while also facilitating the application of conservation actions.

Resolution of data

Data extent is related to both consistency and resolution. We focus here mainly on data resolution (see above for consistency). The examples provided predominantly concern biophysical data because these have been the focus of much of the planning research to date. Issues regarding resolution of social and economic data, however, are likely to be similar. As surrogates for biodiversity (e.g., marine habitats) used in conservation planning are defined more finely, their representation within existing protected areas can change, the total area required to represent them increases, and the relative conservation value of planning units alters (Pressey & Logan 1995; Rouget 2003). Consequently, choices about data resolution inevitably influence which and how many areas are identified for conservation actions. Two considerations (Figure 1) will influence the resolution of data used for MPA design: (1) use of available data and (2) collection of new fine-resolution data (Figure 1; Table 1). Planners must trade-off the respective advantages of working immediately with available data, despite their limitations, and spending time and money to collect new information (Table 1).

Use of available data

Using available data allows the planning process to proceed without delay, minimizing the progressive attrition of natural features. In addition, resources that would be used for further data collection can be used for applying actions (Grantham *et al.* 2009). However, available data are likely to have limitations. The extent and resolution of data are positively correlated (Donald & Fuller 1998), so large planning regions are likely to have consistent data available only at coarse resolution while coverage of fine-resolution data will generally be patchy. Methods are available to combine data at different resolutions while maximizing accuracy and currency (Keith & Simpson 2008), but the resulting composite data will inevitably result in biased selection of conservation areas. Based on statements about data in the CT, all spatially explicit data were used, independent of their resolution, and generally in combination with new data (Table S1).

New fine-resolution data

Although time-consuming and expensive, collecting additional fine-resolution data has two related advantages. First, fine-resolution data better represent spatial variability in biodiversity (and probably in social and economic attributes), which is obscured by coarse-resolution data (Rouget 2003; Banks & Skilleter 2007). Second, collection of additional fine-resolution data throughout the planning region will allow for more consistency in the design of potential MPAs. In the Kimbe Bay planning process, TNC undertook new data collection for six of the eight datasets used. Aswani & Lauer (2006) collected indigenous knowledge on habitats, spawning and nursery sites, and fishing grounds when planning MPAs in Roviana and Vonovana Lagoons (Table S1, row B and D).

Size and delineation of planning units

Planning units are the spatial units of assessment and comparison used in most planning exercises that employ decision-support software and are the building blocks of regional MPA designs (Figure 2C). Four considerations (Figure 1) influence choices about the size and delineation of planning units: (1) the greater spatial flexibility and efficiency of using smaller planning units; (2) matching the resolution of the available data; (3) availability of information on natural and human boundaries suitable for defining planning units; and (4) ease of subdividing the planning region arbitrarily (Figure 1; Table 1). When choosing among these considerations, planners will make two trade-offs. The first, concerning planning unit size, is between the relative advantages of working with smaller planning units and respecting the (usually coarse) resolution of available data that often requires larger planning units. The second, concerning delineation of planning units, is between the relative advantages of using human and natural boundaries or deriving them arbitrarily (Table 1).

Flexibility and efficiency of smaller planning units

The total area required to reach representation targets for features (e.g., habitat types) depends on planning unit size: small planning units are more efficient than large planning units, requiring less total area to achieve targets (Pressey & Logan 1998). Smaller planning units are also likely to achieve targets with smaller overall costs measured in other ways, for example, as opportunity costs to communities. Smaller planning units can also be clustered more flexibly to create more appropriate protected area configurations (Rouget 2003). For the two studies that reported on planning units, sizes varied from 10 to 15 ha to allow for spatial precision in selecting areas of interest (Table S1 rows, B and F).

Resolution of available data

Without rigorous procedures for downscaling, working with planning units smaller than the actual data resolution has no benefit for interpreting those data and overstates their quality. For example, resource maps at 1:100,000 have recommended minimum mapping units (smallest recognizable polygons) of 40 ha (Hupy *et al.* 2004), even though finer resolution variability is expected. Using planning units (or pixels in geographic information systems) smaller than this size confers no advantage for interpreting data, unless the data can be downscaled and the resulting uncertainties considered explicitly (e.g., Gardner *et al.* 2008). In the CT, satellite imagery (15–60 m spatial resolution, or 1:20,000 to 1:24,000) has been widely used to construct habitat maps (Table S1, rows B, D, F, G, and J). The minimum mapping unit from these data varies from 1.6 to 2.3 ha (Hupy *et al.* 2004). These and other data (for which information on resolution is unavailable) were recorded for planning units of 10–15 ha (Table S1, rows B and F), thereby respecting the spatial limitations of the data. In some cases, there might be advantages in using planning units smaller than the minimum data resolution, for example, to identify specific fine-resolution areas of interest to communities and managers. A disadvantage of this approach will be an increased need to adjust regional designs as actions are applied because data are more likely to be found incorrect at local scales (below).

Availability of information on natural and human boundaries

The delineation of planning units can be arbitrary (e.g., hexagons, Figure 2C), based on ownership or political (e.g., district) boundaries, based on natural boundaries (e.g., coral reef edges), or derived from some combination of these (e.g., Lewis *et al.* 2003). Explicit consideration of human and natural boundaries can aid the transition from MPA network design to applying conservation actions. For example, it is easier to implement conservation actions within a planning unit that falls within a single governance unit than one that falls across a boundary. However, data on fine-scale natural or human subdivisions are generally unavailable across whole planning regions in the CT. Boundaries of customary tenure, for example, are often unresolved, and attempts to delineate them can lead to conflict, a detrimental outcome for resource management (Akimichi 1995; Foale & Macintyre 2000).

Ease of subdividing the planning region arbitrarily

Delineating planning units arbitrarily is a simple way of subdividing the planning region, avoiding problems surrounding social boundaries. In addition, the use of arbitrary boundaries avoids funds and time being spent on the collection of boundary-related data, although there might be consequent later costs in reinterpreting arbitrary boundaries for conservation actions. In all cases in the CT, arbitrary planning units derived from square or hexagonal grids were the preferred option for the NGO planners involved (Figure 2C) (Table S1).

MPA network design

During the design stage, planners make decisions about the size and configuration of either generic conservation areas or areas designated for different conservation actions, influenced by ecological, social, and economic considerations. We focus here on considerations for no-take reserves because these involve the most restrictive management. Similar considerations will have to be addressed for other management practices such as gear or catch restrictions. For no-take reserves, planners will be faced with trade-offs between the respective advantages of large and small areas (Figure 1; Table 1).

Ecological considerations

A large literature discusses the ecological and fisheries considerations involved in decisions about the size and configuration of no-take reserves, for example, the "single large or several small" (SLOSS) debate (Kingsland 2002; Halpern & Warner 2003). Ecological considerations, such as protecting extensive processes and species with large home ranges, have been reviewed comprehensively elsewhere (Roberts *et al.* 2001; Palumbi 2004) and arguments prevail for larger no-take reserves (e.g., at least 10 or 20 km across). However, no-take reserves of this extent are not necessarily feasible in some CT countries because of social and economic constraints.

Social and economic considerations

The social and economic context of the CT favors smaller no-take reserves (Figure 2D; Figure 3C) (Aswani & Hamilton 2004a; Cinner 2007). Most coastal communities in the CT are highly dependent on marine resources for subsistence and commerce (e.g., Burke *et al.* 2002). Most artisanal and subsistence fishermen operate small vessels close to home, for example, on inshore reefs (Aswani & Lauer 2006), and women contribute to household subsistence by gleaning in intertidal areas (Vunisea 2008). While near-shore no-take reserves close to villages are preferred because of easier enforcement (Aswani & Hamilton 2004a; Aswani & Lauer 2006; McClanahan *et al.* 2006), these are also more costly to villagers who generally have limited ability to switch fishing grounds or livelihoods. Large no-take reserves in coastal areas therefore disproportionately constrain the livelihoods of some communities (Foale & Manele 2004), while numerous small no-take reserves distribute their costs and benefits more equitably between communities and avoid conflict (Aswani & Hamilton 2004a).

Applying conservation actions

The transition from MPA network design to applying actions on the ground or in the water will be influenced by two main sets of considerations (Figure 1; Table 1). First, regional priorities (areas identified for generic or specific conservation actions during regional-scale design) can inform where actions are applied, including the implementation of MPAs, education and awareness campaigns, alternative livelihoods, and incentives for conservation (Salafsky *et al.* 2008; Kapos *et al.* 2009). Second, new fine-resolution data that become available or useable for the first time when actions are applied will cause planners to depart from regional-scale prescriptions to some extent (Table 1). There are no consistent guidelines for deciding on the extent to which conservation actions should align with regional priorities or be adjusted to accommodate new fine-resolution data. Planners face trade-offs between the respective advantages and limitations of each choice. A dynamic interaction between regional plans and local actions is likely needed to reconcile these two sets of considerations and to implement an ecologically functional MPA network (Pressey & Logan 1998).

Alignment with regional priorities

MPA networks designed at a regional scale can incorporate information on complementarity and extensive ecological processes such as larval dispersal and river plumes. Strategic decisions about MPA size and placing are intended to promote the persistence of species within individual MPAs and the network as a whole, resulting in a theoretically functional and resilient system (Botsford *et al.* 2001; Sala *et al.* 2002). However, the data on which MPA design is based are always limited and to some extent incorrect. Locating actions only in regional-scale priority areas can therefore ignore unforeseen constraints in these areas and opportunities elsewhere, lead to regional designs being difficult to apply, and fail to address the limitations of regional-scale data on biodiversity. Difficulties in implementing regional scale plans have been found in Wakatobi and Karimunjawa, Indonesia (Table S1, rows H and I). The advantages of aligning actions with the regional design must be weighed against those of altering this design as new data become available, usually at a local scale.

Adjustment with fine-scale data

Fine-scale variability in biodiversity, costs, threats, and opportunities within the planning region will shape where, when, and how conservation actions are eventually applied. Fine-scale social complexity, such as customary tenure boundaries, resource use patterns, and community support for conservation, influence the potential to implement MPAs (Figure 2D; Figure 3C) (Aswani & Hamilton 2004b; Christie *et al.* 2009). However, at a regional scale, much of this information is difficult or impossible to collect. For example, many customary tenure boundaries are not mapped (Johannes 2002). Adjusting MPAs to local information, and thereby departing to some extent from regional design, will increase local support and compliance with resource regulations. In Kimbe Bay, fine-resolution customary tenure information was used after regional design of areas of interest to negotiate managed areas with communities (Table S1, row B; Figure 2D).

Discussion

We provide the first comprehensive review of decisions about spatial scale that influence conservation planning outcomes, including the effectiveness of actions (Kapos *et al.* 2009). Our study provides a framework in which these decisions can be made explicit and investigated further and illustrates trade-offs particularly for the CT. Explicitness about the considerations that shape decisions about scale in different contexts, and how these considerations are weighed against one another, will help to link theory and application in conservation planning and facilitate learning so that planners can make better decisions in the future (Knight *et al.* 2006).

Decisions about scale require planners to deal with trade-offs between the respective advantages and limitations of different approaches (Table 1). When choosing among considerations that influence decisions about scale, planners have no prescribed, correct approach. Instead, they need to anticipate what balance between considerations will be most effective in their particular ecological, social, and economic context. The trade-offs identified in this review are relevant globally, and to terrestrial and freshwater as well as marine realms. They will, however, be resolved differently in CT countries than in countries where conservation planning has been developed and extensively applied (e.g., Australia or the United States) (Leslie 2005). For example, the central governance of most countries in which MPA planning exercises were reviewed by Leslie (2005) was relatively strong, with better implementation and enforcement of policies than in the CT countries (Figure 4), and less dependence on resources for subsistence.

The social, political, and economic context of the CT countries drives many decisions about scale to respond to local perspectives. This is often critical for the application of actions to be feasible. However, while these perspectives shape trade-offs in the CT differently than in developed countries, an essential role remains for regional-scale conservation planning in this region. Community-driven conservation efforts can achieve local resource management objectives but will not achieve regional conservation objectives without a broader planning outlook (Weeks *et al.* 2010). Regional conservation planning provides the essential context for resource management decisions, allowing planners to coordinate individual actions for complementarity, connectivity, and the avoidance of threatening processes (Pressey & Bottrill 2009). With regional perspectives, individual community-based and government-initiated actions can add up to more than the sum of individual parts: they can contribute to ecologically functional systems (Groves *et al.* 2002). This will be critical if management actions are to be resilient to emerging threats in the CT such as climate change. Nonetheless, for the potential of regional-scale perspectives to be realized in the CT, heightened awareness of extensive ecological processes, and education about the foundations of effective marine conservation are needed.

To bridge the gap between regional-scale planning and local-scale action, a dynamic interaction between them will be needed so that both perspectives progressively inform one another. For information to flow between regional designs and local actions and for coordination to occur among different local actions, marine conservation needs (1) strengthening of institutional capacity and (2) consistent engagement between community groups, NGOs, and all levels of government. In addition, those involved in marine conservation must make long-term commitments to their regions (Christie et al 2009). These issues are beginning to be addressed by NGOs in the CT where NGOs intend to work collaboratively for long periods and strengthening resource management legislation and capacity building have prepared the ground for the development of effective regional designs (e.g., in the Solomon Islands by TNC and the Locally Managed Marine Area Network). Some of these projects are not only tackling threats to resources such as overfishing and pollution, but also the root causes of such threats, including population growth (White *et al.* 2005).

Acknowledgments

We thank Nate Peterson, Nygiel Armada, Shankar Aswani, and Stuart Campbell for information on several conservation initiatives in the Coral Triangle. We also thank Alison Green, Alan White, Joanne Wilson, Maria Beger, Umiich Sengebau, and Geoff Lipsett-Moore for their time in providing us with additional resources and invaluable comments on the manuscript. MM thanks Andrew Knight for inspiring discussion. RLP and NCB acknowledge the support of the Australian Research Council.

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Table S1: Summary of regional conservation planning case studies reviewed.

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