A Synthesis of Marine Conservation Planning Approaches

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Abstract: *In the last decade, there has been increasing interest—particularly among international nongovernmental and multilateral development organizations—in evaluating the effectiveness of conservation and development projects. To evaluate success, we need more comprehensive and case-specific information on how conservation decisions are made. I report on a database that synthesizes information on 27 marine conservation planning cases from around the world. I collected data on each case's geographic scale, primary planning objective and outcome, legal and institutional context, degree of stakeholder involvement, and the ecological criteria and tools used to facilitate conservation decisions. The majority of cases were located in North and Central America, were regional in nature, and had biodiversity conservation as the primary planning objectives. Outcomes included priority-setting plans and implementation of marine reserves and other types of marine protected areas. Governments and local nongovernmental organizations led more participatory processes than national and international nongovernmental organizations. Eleven cases considered ecological criteria first, whereas 16 relied on integrated criteria (ecological plus socioeconomic data and other pragmatic considerations) to select priority areas for conservation and management action. Key tools for data integration and synthesis were expert workshops, maps, and reserve-selection algorithms (i.e., computer-based tools for priority setting and reserve design). To facilitate evaluation of success, future documentation of marine conservation planning cases should include a standard set of ecological, social, economic, and institutional elements. To develop standards for effective marine conservation, a more diverse set of documented cases is needed; for example, those that failed were located outside North and Central America, focused on the local geographic scale, or were motivated by objectives other than biodiversity conservation.*

Key Words: ecoregional planning, marine protected areas, marine reserves, priority-setting approaches, reserve selection algorithms, systematic planning

Síntesis de Estrategias de Planificación de Conservación Marina

Resumen: *En la última década ha habido mayor interés—particularmente entre organizaciones internacionales no gubernamentales y de desarrollo multilateral—en evaluar la efectividad de los proyectos de conservación y de desarrollo. Para evaluar el éxito, requerimos de información, integral y de casos específicos, sobre como se toman decisiones de conservación. Analicé una base de datos que sintetiza información sobre 27 casos de planificación de conservación marina alrededor del mundo. Para cada caso, recolecté datos de la escala geográfica, del objetivo primario de planificación y su producto, del contexto institucional y legal, el grado de participación de los interesados y de los criterios y herramientas ecológicas utilizadas para facilitar las decisiones de conservación. La mayoría de los casos se localizaron en Norte y Centro América, fueron de naturaleza regional, y tuvieron como objetivos primarios de planificación a la conservación de biodiversidad. Los productos incluyeron planes de definición de prioridades y la implementación de reservas marinas y otros tipos de áreas marinas protegidas- Las gobiernos y organizaciones no gubernamentales locales condujeron*

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más procesos participativos que las organizaciones no gubernamentales nacionales e internacionales. Once casos consideraron criterios ecológicos en primera instancia, mientras que 16 se basaron en criterios integrales (datos ecológicos y socioeconómicos y otras consideraciones pragmáticas) para seleccionar áreas prioritarias para la conservación y acciones de manejo. Las herramientas clave para la integración y síntesis de datos incluyeron talleres de expertos, mapas y algoritmos para la selección de reservas (i. e., herramientas de cómputo para la definición de prioridades y el diseño de reservas). Para facilitar la evaluación de éxito, la futura documentación de casos de planificación de conservación marina deberá incluir un conjunto estándar de elementos ecológicos, sociales, económicos e institucionales. Para desarrollar estándares para la conservación marina efectiva se requiere de un conjunto más diverso de casos documentados; por ejemplo, aquellos que fracasaron estaban localizados fuera de Norte y Centro América, estaban enfocados en la escala local o estaban motivados por objetivos distintos a la conservación de la biodiversidad.

Palabras Clave: algoritmos para selección de reservas, áreas protegidas marinas, estrategias para el establecimiento de prioridades, planificación ecoregional, planificación sistemática, reservas marinas

Introduction

Marine ecosystems face increasing threats from both land- and sea-based anthropogenic activities, including pollution, exploitation, invasive species, habitat degradation and loss, and climate change (Pew Oceans Commission 2003; U.S. Commission on Ocean Policy 2004; Millennium Ecosystem Assessment 2005). Mitigating these threats requires a suite of strategies, including developing institutions and incentives that encourage conservation and sustainability, building awareness of the value of biodiversity, and protecting key species and ecosystems through protected areas and other area-based management strategies (Salafsky et al. 2002). Implementation of protected areas and other area-based management strategies, in particular, requires that priorities be set in a geographically explicit manner so as to make efficient use of limited resources. Such priority setting is often referred to as systematic conservation planning and is based on clear objectives, with specific conservation targets and an explicit and transparent decision-making framework (Margules & Pressey 2000). Although the primary planning objective is often biodiversity conservation (Groves 2003; Noss 2003; Redford et al. 2003), other objectives may include sustaining ecosystem services, preserving cultural and spiritual values, and providing places for research and education (Daily et al. 2000; National Research Council 2001).

In the last decade, there has been increasing interest—particularly among international nongovernmental and multilateral development organizations—in evaluating the effectiveness of conservation and development projects (Margoluis & Salafsky 1998; Salafsky et al. 2002; Conservation Measures Partnership 2003; Saterson et al. 2004). Evaluation is needed to learn which conservation approaches work and why, to demonstrate the impact of conservation, and to provide public and internal accountability (Stem et al. 2005). Success may be defined by a multitude of social, economic, political, cultural or ecological criteria but should be explicitly linked to the project's objectives and specific activities (Conservation Measures Partnership 2003; Saterson et al. 2004). To evaluate success, more comprehensive and case-specific information on how conservation decisions are made is needed (Conservation Measures Partnership 2003; Saterson et al. 2004). Ideally, such documentation would include information on project objectives and outcomes, the decision-making process, and measures of success (Kleiman et al. 2000).

Although governments and nongovernmental organizations have engaged in systematic conservation planning for decades, few comparative analyses of the approaches taken on land exist (Johnson 1995; Redford et al. 2003) or in the sea (Beck 2003; Lourie & Vincent 2004). Marine conservation planning efforts have benefited greatly from the more developed science and practice of terrestrial conservation planning (Beck 2003). Nonetheless, knowledge of differences between terrestrial and marine systems—in terms of both the biogeophysical realm (Carr et al. 2003) and resource management and governance institutions (National Research Council 1997)—suggests that an explicit synthesis and evaluation of marine conservation planning approaches is needed. Here I report on a database designed to facilitate the documentation and synthesis of marine conservation planning approaches globally and describe preliminary trends that emerge from the cases in the database thus far. To explore the ecological and social elements that contribute to conservation success, I focused on the following questions: Where have marine conservation planning cases been well documented? What was the geographic extent of these cases, and who participated? What contributions did natural science make to the planning processes? What attributes were shared among successful cases, and how can this information be used to develop standards for effective marine conservation planning?

Methods

To investigate the ecological and social attributes that contribute to conservation success, I conducted an initial survey of marine conservation planning processes globally and assembled a list of 90 cases (available on request from H.M.L.). Based on this initial survey, I developed a database in Microsoft Excel (Seattle, Washington, U.S.A.) that captured the major features of each case (available on the Web, see Supplementary Material). I collected data on each case's geographic scale, primary planning objective and outcome, legal and institutional context, degree of stakeholder involvement, and the ecological criteria and tools used to facilitate conservation decisions. To fully evaluate conservation success, data on monitoring, the social and economic criteria used to make decisions, and indicators of project success also would be useful. These variables were not available for most cases, however, so they were not included in the database. In terms of geographic scale, each case was scored as local (i.e., limited to one community), regional (i.e., transcending state or national boundaries), national, or global. When possible, information was collected on the spatial extent of both the planning region and individual planning units.

Each case focused on one of three outcomes: marine reserve implementation, implementation of a less restrictive type of marine protected area (MPA), or priority-setting plans. Although these three outcomes are not mutually exclusive, in each case a primary outcome was apparent. Marine reserves (or no-take areas) are areas of the ocean completely protected from all extractive or destructive activities, except as necessary for monitoring to evaluate reserve effectiveness (National Research Council 2001; Lubchenco et al. 2003). Marine protected areas include all area-based management efforts designated to enhance conservation of marine resources or meet other objectives of ocean management (National Research Council 2001; Lubchenco et al. 2003). The actual level of protection of living marine resources within a particular MPA varies considerably. Priority-setting plans are portfolios or lists of priority areas used to direct conservation and management activities such as MPA implementation or environmental education. The term *priority setting* encompasses biodiversity conservation planning (Groves 2003) and marine regional planning (Beck 2003). I use the former term because not all priority-setting plans in the marine environment are focused primarily on biodiversity conservation (Table 1, Bahamas and Fiordland cases).

Information from a variety of natural and social science disciplines can be used to inform conservation planning decisions and thus is relevant to evaluating conservation success. As a starting point, I focused on how natural science was used to help make conservation planning decisions. Preliminary examination of the cases suggested three major roles for natural science in marine conservation planning: (1) to inform selection of conservation targets; (2) to provide guidance on the choice of ecological criteria used to select priority areas; and (3) to develop and apply scientific tools for information synthesis and priority area selection.

Conservation targets include species and ecosystems, physical features, or a combination of biotic and abiotic elements (Groves et al. 2002). In many cases, marine habitats serve as biodiversity surrogates and are assumed to incorporate other targets such as species (Beck 2003).

Most conservation planning processes, particularly those focused on reserve or MPA implementation, are based on explicit ecological or socioeconomic criteria used to identify priority areas (Johnson 1995). In each case, I examined which ecological criteria were used to inform decision making. These criteria were adapted from a review of ecological criteria for marine reserve design conducted by Roberts et al. (2003) and included elements related to biodiversity values, sustaining marine fisheries and other ecosystem services, and the degree of anthropogenic and natural threats.

Scientists also may design and apply tools for data integration and synthesis as part of conservation planning efforts. Such tools help ensure a transparent and defensible process and make the most efficient use of available resources (Margules & Pressey 2000). Three main decision-support tools were used: expert workshops, maps, and reserve selection algorithms (i.e., computer-based tools for priority setting and reserve design). Expert (or Delphi) workshops bring together people knowledgeable about the ecological, social, and economic aspects of the identified study region (Groves 2003). Maps included analog, digital, and geographic information system (GIS) sources. Computer-based tools for reserve design included heuristic and simulated annealing algorithms (e.g., SPEXAN, SITES, and MARXAN) used to generate networks of protected or priority areas (Possingham et al. 2000; Palumbi & Warner 2003).

Full documentation was not available for any of the cases I surveyed initially, so I selected 27 focal cases based on the following criteria: (1) the case included, but was not necessarily restricted to, coastal and marine areas and had explicit spatial boundaries; (2) the planning process was led by an identifiable institution, and more than one group of stakeholders was involved; (3) specific planning objectives and conservation targets were articulated; (4) the planning process was either completed or sufficiently developed to result in specific, real-world marine conservation and management activities; and (5) documentation of at least 60% of the variables in the database was available from English-language publications (including journal articles, organizational reports and documents, and Web sites). In all cases, I conducted interviews with key informants who participated in the planning processes to verify the accuracy of data collected from the written documents and to fill in missing information.

This paper is not meant to be exhaustive, but rather to stimulate dialog. To my knowledge, this work is the first effort to synthesize such detailed information on a number of marine conservation planning cases globally. Some caution is warranted in interpreting these data, however.

Table 1. Key features of the 27 focal marine conservation planning cases examined.

Location	*Scale*	*Primary objective**	*Primary outcome*	*Lead entity and partners*	*Planning region size (km^2)*	*Primary conservation targets*	*Reference*
Bahamas	national	1	priority-setting plan	Bahamas Reef Environment Educational Foundation, Bahamas Dept. of Fisheries	20,000	reef and mangrove habitat; commercially valuable fisheries	Stoner et al. 1999
Bering Sea, Russia and U.S.A.	regional	2	priority-setting plan	Nature Conservancy (TNC), World Wildlife Fund (WWF)	1,432,965	unique species or habitat assemblages, areas of outstanding abundances, key to ecological phenomena, e.g., migration	Banks et al. 1999
British Columbia Central Coast, Canada	regional	2	MPA network	Living Oceans Society	22,303	primarily habitat types, but also species of special concern	Ardron et al. 2002
Central Caribbean Ecoregion	regional	2	priority-setting plan	TNC, Biodiversity Support Program, U.S. Agency for International Development	2,654,945	natural communities, including coral reefs and coral-associated species	Sullivan Sealey & Bustamante 1999
Channel Islands National Marine Sanctuary, U.S.A.	regional	1,2	MPA network	U.S. National Marine Sanctuary Program, state of California	4,295	primarily habitat types, also species of special concern	Airamé et al. 2003
Chile: Caleta El Quisco Management & Exploitation Area	local	1	MPA	Sindicato del Quisco (local fishers' cooperative)	not available	commercially valuable species	Castilla & Fernandez 1998
Chile: Punta El Lacho, Las Cruces	local	3	marine reserve	Estacion Costera de Investigaciones Marina, Universidad Catolica de Chile	not available	intertidal habitat	Castilla & Duran 1985
Coral reef hotspots	global	2	priority-setting plan	Conservation International (CI), various universities, NGOs, U.N. Environment Programme	284,300	restricted-range coral reef species as indicators of reef biodiversity hotspots globally	Roberts et al. 2002
Eastern Africa Marine Ecoregion	regional	2	priority-setting plan	WWF	727,174	six coastal habitats (mangroves, reefs, seagrass beds, wetlands) and number of species of special concern (e.g., birds, mammals, turtles, sharks)	Horrill 2002

(continued)

Table 1. (continued)

Location	Scale	Primary objective*	Primary outcome	Lead entity and partners	Planning region size (km^2)	Primary conservation targets	Reference
Fiordland, New Zealand	regional	1, 2	priority-setting plan	Guardians of Fiordlands's Fisheries & Marine Environment	4,076	marine habitats, communities, and biodiversity (including indicator and exploited species) that represent Fiordland's marine environment or are hotspots of biodiversity	Guardians of Fiordland's Fisheries & Marine Environment 2003
Florida Keys National Marine Sanctuary: sanctuary preservation areas, U.S.A.	regional	2	reserve network	U.S. National Marine Sanctuary Program	9,500	habitat types of interest and degree of user conflict	Bohnsack 1997
Galapagos Islands, Ecuador	regional	2	reserve network	Charles Darwin Research Station, Galapagos National Park Service, WWF	6,177	coastal and nearshore habitat types and species of special concern	Bensted-Smith 2002
Global	global	2	priority-setting plan	World Bank, World Conservation Union, and Great Barrier Reef Marine Park Authority (GBRMPA)	361,059,000	ecosystems and species of special concern	Kelleher et al. 1995
Global 200	global	2	priority-setting plan	WWF	361,059,000	ecoregions, i.e., relatively large areas delineated by biotic and environmental factors that regulate the structure and function of ecosystems within them and focal taxa	Olson & Dinerstein 2002
Great Barrier Reef Marine Park: Representative Areas Program, Australia	regional	2	reserve network	GBRMPA	345,400	ecosystems primarily and unique species	Day et al. 2003
Gulf of California, Mexico	regional	2	reserve network	Scripps Institution of Oceanography, WWF	120,000	primarily habitat types; also reef species richness, spawning aggregation sites, and sites with lower fishing pressure	Sala et al. 2002
Mesoamerican Reef: Mexico, Belize, Guatemala, and Honduras	regional	2	priority-setting plan	WWF	464,263	focal taxa, guilds, and habitats used as surrogates for species occurrences	Kramer et al. 2002

(continued)

Table 1. (continued)

Location	Scale	Primary objective*	Primary outcome	Lead entity and partners	Planning region size (km^2)	Primary conservation targets	Reference
Mid-Atlantic Priority Ocean Areas, U.S.A.	regional	2	priority-setting plan	Natural Resources Defense Council	367,000	habitats of high biodiversity, organismal abundance, or of importance for threatened and endangered species	Azimi 2001
New Zealand as of 2002	national	3	reserve network	New Zealand Department of Conservation	160,000	habitat types of interest, particularly unique ones	Walls 1998
Northern Gulf of Mexico Ecoregion, U.S.A.	regional	2	priority-setting plan	TNC, U.S. Environmental Protection Agency	33,600	eight biological communities/habitat types and five primary species of interest	Beck & Odaya 2001
Northwest Atlantic (Gulf of Maine/Bay of Fundy/Scotian Shelf/Georges Bank), U.S.A. and Canada	regional	2	priority-setting plan	WWF, Conservation Law Foundation, other NGOs	800,000	seascapes as proxies for biological communities, habitats, and species of interests and distribution of focal species and ecological processes	Day & Roff 2000
Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve's Reserve Preservation Areas, U.S.A.	regional	2	MPA network	U.S. National Oceanic and Atmospheric Administration	341,360	protected species and ecosystems of interest	http://hawaiireef.noaa.gov/
Philippines	national	2	priority-setting plan	CI, Philippine government, universities	2,200,000	habitats (e.g., mangroves, reefs, and seagrass beds) and species of special concern (e.g., dugong, cetaceans, elasmobranches, turtles)	Ong et al. 2002
San Juan County Bottomfish Recovery Zones, U.S.A.	local	1	MPA	San Juan County Marine Resources Committee	2,435	historically productive bottomfish habitats	Klinger 2001
South Africa	national	2	priority-setting plan	government of South Africa	1,050,000	vulnerable habitats and species (particularly endemic, rare, exploitable species)	Hockey & Branch 1997
Tortugas Ecological Reserve, Florida Keys National Marine Sanctuary, U.S.A.	regional	2	marine reserve	U.S. National Marine Sanctuary Program	9,500	habitats, high biodiversity areas, areas of importance to commercially and recreationally valuable species	http://www.fknms.nos.noaa.gov/tortugas
Willamette Valley-Puget Trough-Georgia Basin Ecoregion, U.S.A. and Canada	regional	2	priority-setting plan	TNC, Washington Dept. of Natural Resources, Fish and Wildlife, U.S. Fish and Wildlife Service	15,097	134 targets, including 40 ecosystem types and 94 focal species	Beck 2003

**Primary planning objectives: 1, sustainable fisheries; 2, biodiversity conservation; 3, scientific research.*

In some cases the primary objective and other key variables had to be inferred because they were not explicitly reported. The iterative nature of planning processes may complicate interpretation of the stakeholder groups involved and the criteria and tools used. This database can serve as a prototype of what could be a very useful resource for future planning, implementation, and evaluation of marine conservation efforts.

Results

Characteristics of the Focal Cases

The majority of the 27 focal cases were in North and Central America (Table 1). Thirteen were within the U.S. Exclusive Economic Zone (0 to 200 nautical miles offshore). Seventeen cases had "regional" planning areas, meaning they transcended political boundaries and were based primarily on biogeographic boundaries. Three cases were global in focus. The geographic scale of the nonglobal cases varied from 2,435 to 2,654,945 km^2, with an average region size of 486,618 km^2 and median size of 160,000 km^2 (Table 1).

Biodiversity conservation was the primary objective in 22 cases (Fig. 1a, Table 1). Creation of areas for scientific research was the lead objective in two cases, and sustainable fisheries were the primary objective in five cases (Fig. 1a). Two cases had dual primary aims of biodiversity conservation and sustainable fisheries: Channel Islands, United States (Airamé et al. 2003), and Fiordland, New Zealand (Guardians of Fiordland's Fisheries & Marine Environment 2003).

Planners selected priority or protected areas in each case based either on a standardized set of units (e.g., 2.5-km^2 hexagons or 1° grid squares) or on a set of differently sized units delineated by environmental or political factors. Of those cases for which planning unit size was reported, two-thirds included variably sized units. The mean size of individual planning units ranged from 0.3 to 1.1×10^6 km^2, with an average of 67,000 km^2 and a median of 740 km^2 ($n = 22$ cases). As planning region increased, mean individual priority area and total protected or priority area increased ($n = 21$ cases).

Governments and nongovernmental organizations both led planning processes (Table 1). Governments were more active in MPA and reserve implementation efforts. Nongovernmental organizations dominated initiatives focused on priority-setting plans. Universities and multilateral institutions (e.g., World Conservation Union) rarely played a lead role. Based on the average number of stakeholder groups involved in cases led by each institution type, government and local nongovernmental organizations led more participatory processes than national and international nongovernmental organizations (Fig. 1b). Completed or more fully developed processes seemed to include more stakeholder groups.

Outcomes of Marine Conservation Planning

Of the 27 marine conservation planning cases evaluated, 15 focused on production of priority-setting plans (Table 1), which were particularly common at the regional and global political scales. Four cases involved implementation of marine reserves or reserve networks; the other eight focused on the implementation of other types of MPAs or MPA networks. At the local and regional scales,

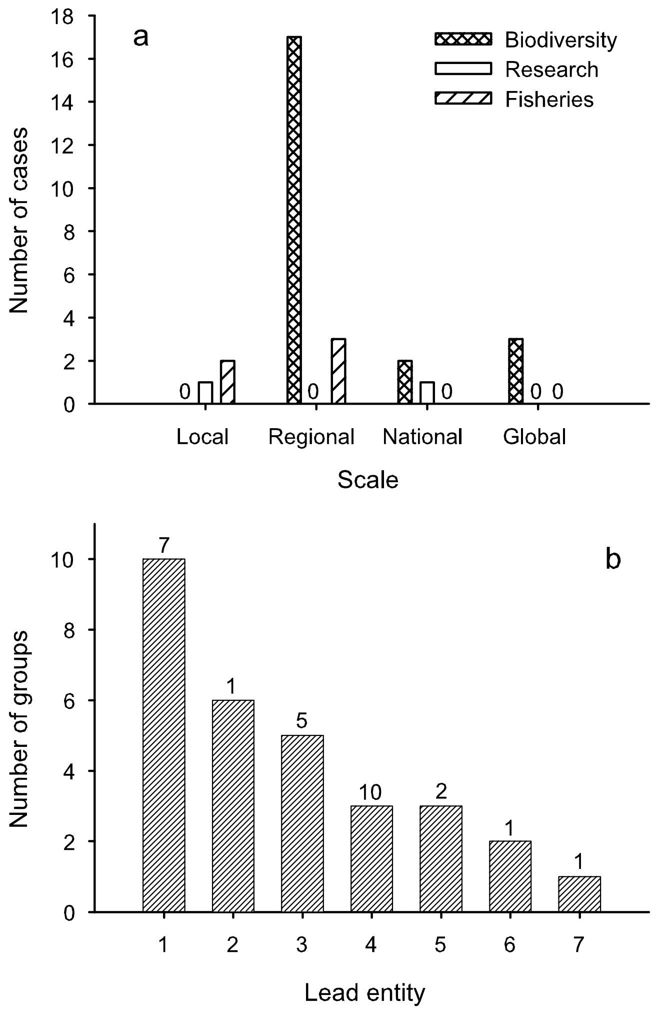

Figure 1. (a) Objectives and (b) stakeholder involvement in the marine conservation planning cases. Primary objectives included biodiversity conservation, areas for scientific research, and sustainable fisheries management. The mean number of stakeholder groups involved in each process is presented as a function of the type of lead institution. Institution types: 1, federal government; 2, county government; 3, local nongovernmental organization (NGO); 4, international NGO; 5, national NGO; 6, multilateral institution; and 7, university. The number of cases per institution type is listed above each bar.

cases tended to focus on marine reserve or MPA implementation.

An example of a priority-setting plan is the Mid-Atlantic case led by the Natural Resources Defense Council (NRDC). The Council convened scientists with expertise in Mid-Atlantic marine species and ecosystems to identify priority areas. Participants chose candidate areas based on seven major criteria and their knowledge of the region. They produced a composite map of all the candidate sites. Areas of great overlap were designated priority areas (Azimi 2001; L. Speer, personal communication). As a first step, NRDC used the portfolio of priority areas to advocate for changes in fisheries management through the Mid-Atlantic Fishery Management Council process (L. Speer, personal communication).

An example of MPA network implementation took place in the Channel Islands National Marine Sanctuary. The sanctuary and state of California jointly coordinated a marine reserve working group, which was charged with designing a network of reserves and other less-restrictive types of MPAs to meet biodiversity conservation and fisheries management objectives (Airamé et al. 2003). The 2-year process was highly participatory and public. State-of-the-art natural and social science information generated by scientists from government, nongovernmental organizations, and universities played key roles. In April 2003, California implemented an MPA network that encompasses approximately 25% of state waters surrounding the Channel Islands; complementary federal action is expected in 2006 (http://www.cinms.nos.noaa.gov/marineres/enviro_review.html).

Role of Natural Science in Marine Conservation Planning

Decision makers considered both fine-scale (species) and coarse-scale targets (ecosystems, habitats) in 25 of the 27 cases (Table 1). Although the majority of cases emphasized ecosystem-based approaches, 25 cases included some species-level targets, often those deemed focal, keystone, or umbrella species (see supplementary material in online article).

Planners considered ecological criteria first in 11 of the 27 cases, whereas they relied on integrated criteria (ecological plus socioeconomic data and other pragmatic considerations) in 16 cases to select priority areas for conservation and management action. None of the documented cases considered social and economic criteria first. Explicit ecological criteria were considered in 26 cases. Nongovernmental organizations tended to give ecological criteria priority, whereas government-led initiatives tended to integrate social and economic criteria into the decision-making processes earlier and more explicitly. Presence of species of special concern, representation of biogeographic regions and habitat types, and inclusion of vulnerable habitats and life stages were considered in at least 20 of the 27 cases (Fig. 2). The criterion

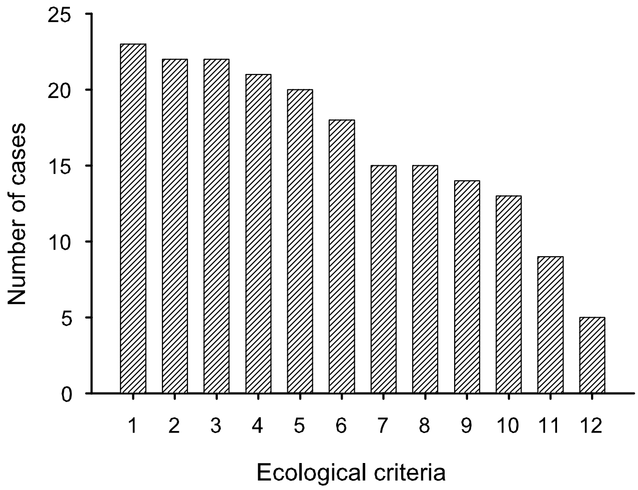

Figure 2. Ecological criteria used to inform marine conservation decisions were scored as "included" if they were articulated in the published documentation or in interviews. Criteria: 1, species of special concern; 2, biogeographic representation; 3, habitat representation; 4, vulnerable habitats; 5, vulnerable life stages; 6, exploitable species; 7, connectivity; 8, ecosystem functioning; 9, anthropogenic catastrophes; 10, size; 11, natural catastrophes; and 12, ecosystem services.

considered least often was the provision of ecosystem services such as nursery grounds for fisheries, clean water, protection from storm damage, and areas for recreation (Peterson & Lubchenco 1997).

Connectivity was included as a criterion in 15 cases. Marine scientists have documented multiple mechanisms by which marine ecosystems are connected through the movement of nutrients and other resources (Duggins et al. 1989; Bustamante et al. 1995), larvae (Palumbi & Warner 2003), or adult organisms (Johnson et al. 1999). Such linkages are critical to the maintenance of functioning marine populations and ecosystems and enable populations, species, and ecosystems to persist at spatial scales beyond that of a single site (Lubchenco et al. 2003; Roberts et al. 2003). In addition, 17 cases mentioned the desirability of a network approach in drafting priority areas for conservation. Interestingly, there was not a one-to-one coherence between these two variables. That is, not all processes that alluded to networks necessarily considered connectivity explicitly, or vice versa. The term *network* can have more than one connotation, which may explain the discrepancy. For some decision makers, a network is simply a set of complementary sites. For others, the term relates to connectivity and the ecological relationships and processes that link sites in the network.

In terms of scientific tools, expert workshops were used in all 27 cases. Experts were most often scientists and resource managers, but in some cases included other stakeholders such as fishers and local residents. In some cases, such as in the Eastern African Marine Ecoregion (Horrill 2002) or the Galapagos Islands of Ecuador (Bensted-Smith 2002), expert workshops were used to develop a common vision of conservation action for the area. In other cases, such as in the Bering Sea (Banks et al. 1999) and the Mid-Atlantic region (Azimi 2001), the assembled experts actually drew lines on maps and produced a list of priority areas for conservation action.

Maps were used to help make decisions in 24 cases. The distributions of habitat, target species, or resource use (e.g., fishing, recreation) were mapped in GIS in at least 17 cases. In the northwestern Hawaiian Islands, for example, National Oceanic and Atmospheric Administration staff initially relied on nautical charts and sketched in information from scientists, managers, fishers, and conservationists about fisheries effort and vulnerable habitats to locate the Sanctuary Preservation Areas (R. Griffis, personal communication). Researchers from Scripps Institute of Oceanography and the World Wildlife Fund used GIS to visualize the distributions of habitat, reef fish, and fishing pressure in the Gulf of California (Sala et al. 2002).

Computer-based tools for priority setting and reserve design (i.e., reserve-selection algorithms such as SPEXAN, SITES, and MARXAN) were used in eight cases. These tools were used to identify potential networks of sites that met explicit conservation objectives. Conservation goals (e.g., representation of a certain proportion of marine populations or habitats) were formulated as constraints within a cost function (Possingham et al. 2000). In the northern Gulf of Mexico, for example, The Nature Conservancy used SITES to help prioritize coastal and marine activities in the region (Beck & Odaya 2001). In the Gulf of California, Sala et al. used MARXAN to help create alternative reserve network configurations that met biodiversity objectives while minimizing costs to fishers in the region (Sala et al. 2002). In the Great Barrier Reef Park of Australia (S. Slegers, personal communication) and in the Channel Islands of southern California (Airamé et al. 2003), stakeholder groups explored possible reserve network configurations with similar tools. The Gulf of California and Australia cases were among the first marine applications to explicitly incorporate socioeconomic constraints by using reserve-selection algorithms, which enabled planners to examine the trade-offs among different conservation goals and network configurations. All eight of these cases are part of ongoing marine conservation planning efforts.

Discussion

Evaluating Conservation Success

Measuring the effectiveness of a conservation project requires an explicit link between project objectives, activities, and indicators of success (Conservation Measures Partnership 2003; Saterson et al. 2004; Stem et al. 2005). Indicators of success should be focused on specific conservation objectives and be measurable, precise, consistent, and sensitive (Conservation Measures Partnership 2003). In addition to biological indicators, social, political, and economic data are needed (Saterson et al. 2004; Stem et al. 2005). The 27 focal cases were all "successes" in the sense that their objectives, outcomes, and decision-making processes were well documented and had some measure of stakeholder support. Almost every case had a clear primary planning objective; in the majority of cases, this was biodiversity conservation. It was much less common to have specific, lower-level objectives that met the standards of the Conservation Measures Partnership (2003): "impact oriented, measurable, time limited, specific, and practical." Also, the majority of cases focused on the regional scale, where the planning region was delineated based on biogeographic rather than political boundaries. The planning processes—from identifying objectives and conservation targets, integrating relevant information, and identifying priority areas for conservation and management to implementing appropriate strategies—engaged multiple institutions and stakeholder groups.

In several cases—Gulf of California (Sala et al. 2002), Channel Islands (Airamé et al. 2003), Willamette Valley-Puget Trough-Georgia Basin ecoregion (Ferdana 2002; Beck 2003), and Great Barrier Reef (Day et al. 2003)—the integration of natural science knowledge into the planning processes was particularly well documented and transparent. These cases serve as successful models, at least in terms of the detail, extent, and clarity with which key features of each case were conveyed in printed and online materials and the degree to which natural science was used. Ecologists from academia, government, and nongovernmental organizations were key players in each case, providing technical expertise and detailed knowledge of the ecological dynamics of the regions of interest. Also, conservation targets and tools were well matched to the primary planning objectives. That is, all four cases relied primarily (although not exclusively) on information about habitat and ecosystem conservation targets to set conservation goals and select priority areas that met their primary objective, mainly biodiversity conservation. This trend differed from some earlier cases (e.g., Bering Sea), where priority setting relied more heavily on species-based conservation targets even though the stated primary objective also was biodiversity conservation. This difference may have partly been due to the availability of information or to variation in the lower-level, more specific objectives in each case. This topic warrants further research. Although including both species and ecosystem-based targets resonates with current scientific understanding, there have been few systematic tests of the value of using species versus ecosystems as targets in marine systems (Ward et al. 1999; Gladstone 2002).

Ideally, conservation success would be evaluated by comparing a random sample of cases (a mix of successes and failures) based on clear and standardized ecological, social, and economic indicators. As of December 2003, however, such indicators were available for few of these cases. That is not to say that these cases will not be evaluated in the future; for example, in the Channel Islands (NOAA 2003; CDFG 2004) and Great Barrier Reef (http://www.reeffutures.org/topics/monitoring/review.cfm) monitoring is ongoing. Also, in Fiordland, New Zealand, planners have identified a number of social and ecological indicators of success (Guardians of Fiordland's Fisheries & Marine Environment 2003). In other cases, it may be that monitoring plans and results exist but have not been widely disseminated.

The database that I created, along with other recent efforts (Beck 2003; Lourie & Vincent 2004), provides a strong starting point for assessing success of marine conservation planning cases and developing standards of effective practice. Ideally, documentation of marine conservation planning cases would include a standard set of ecological, social, economic, and institutional elements so that cases could be more systematically compared. Future documentation of marine conservation planning efforts should include the following elements: (1) location; (2) geographic scope (e.g., the size of the planning region, planning units, and priority areas); (3) primary planning objectives and specific measurable lower-level objectives; (4) primary obstacles or threats to achieving the planning objectives; (5) primary and secondary outcomes, including unexpected outcomes; (6) chronology of the planning process (e.g., length and planning and implementation milestones); (7) lead institution and partner organizations; (8) degree and form of stakeholder involvement; (9) key legal, institutional, and social mechanisms used to achieve the planning objectives; (10) primary conservation targets and quantitative conservation goals; (11) ecological, social, economic, and pragmatic criteria used to select priority areas; (12) scientific tools used; (13) monitoring (e.g., lead institution, social, economic, and ecological indicators of project success), and temporal extent and frequency of monitoring; (14) project evaluation (e.g., links among indicators and planning objectives, outcomes, targets, and goals); and (15) sources of information and key contacts.

With further development of case-specific, comprehensive databases like this one, we would be in a markedly better position to develop scientifically informed standards of marine conservation planning and to advance the protection of marine biodiversity and sustainable use of marine resources. I reported on a number of the above elements, including geographic scale, primary planning objective and outcome, legal and institutional context, degree of stakeholder involvement, and the ecological criteria and tools used to facilitate conservation decisions. In addition, data on the social and economic context and outcomes of each case are needed (Christie et al. 2002; Pomeroy et al. 2004; Stem et al. 2005). Neither socioeconomic nor monitoring data were available for most cases, indicating the need for more documentation and synthesis in these areas. Also, it would valuable to document more cases that were located outside North and Central America, were focused on the local geographic scale (particularly those led by local organizations or coalitions of stakeholders and institutions), or were motivated by objectives other than biodiversity conservation. We need more examples of failed cases, as well. Evaluation of success will require synthesis and collaboration across disciplines and among scientists and practitioners (Saterson et al. 2004).

Outstanding Research Questions

Targeted research in several areas would strengthen the scientific basis of marine conservation planning and contribute to more effective evaluation of project success. First, approaches to integrating information on ecological and evolutionary processes into marine conservation planning need further development and testing. The importance of integrating process information into conservation planning decisions is increasingly recognized because ecological and evolutionary processes underlie the persistence of target populations, species, and ecosystems (Noss 1996; Cowling et al. 1999; Olson et al. 2002). Yet few marine conservation planning processes explicitly have incorporated ecological processes as targets or constraints (see Bering Sea, Gulf of California, and Northwest Atlantic cases for exceptions). Critical ecological processes include larval dispersal, migration, spawning and reproduction, recruitment, and trophic cascades and other interspecific interactions. The spatial distribution of such processes often has been linked with upwelling and productivity gradients (Menge et al. 2004; Leslie 2005), oceanic fronts (Malakoff 2004), or other oceanographic features. Consequently, oceanographic phenomena may serve as proxies for ecological processes in some cases, although see Barber et al. (2002) for a notable exception.

Second, it would be productive to examine in greater detail how reserve-selection algorithms have been applied in marine conservation planning thus far and in which social and ecological contexts they have been most useful. Eight of the 27 focal cases used siting tools, and several other applications have been initiated since I conducted this synthesis (for a list of MARXAN marine applications, see http://www.ecology.uq.edu.au/index.html?page=29781). Moreover, applications to date have focused primarily on representing marine habitats and focal species to meet biodiversity conservation objectives. They have not explicitly integrated ecological concepts such as metapopulation dynamics, larval dispersal, or disturbance, even though these factors are widely recognized as important (Allison et al. 2003; Beck 2003; Roberts et al. 2003). Some planners have incorporated these factors through expert review (as in the Willamette Valley-Puget Trough and Gulf of Mexico cases) after using an algorithm to generate preliminary network configurations (Beck & Odaya 2001; Z. Ferdana, personal communication). Others have used features of the algorithms to implicitly incorporate connectivity (Sala et al. 2002; Airamé et al. 2003; Day et al. 2003). This research need relates closely to the earlier discussion regarding ecological processes. The large-scale distribution patterns of marine species and habitats that are the focus of most marine conservation planning activities are dynamic in space and time and can be generated by ecological processes (such as dispersal and predation) that operate on local spatial scales (Guichard et al. 2004). Consequently, it would be worthwhile to explore how reserve selection algorithms could be adapted to more explicitly integrate information on the local processes that drive population, community, and ecosystem dynamics (Guichard et al. 2004; Williams et al. 2004).

Finally, further research is needed on the realized outcomes, costs, and benefits of marine conservation planning. Considerable resources have been invested in generating and synthesizing scientific knowledge to inform marine reserve design and other planning activities. These efforts have yielded substantial dividends in terms of project implementation and advancement of marine conservation science. Now, greater attention should be focused on evaluating project success. That is, do these activities make a measurable difference in terms of the health and resilience of marine populations, species, ecosystems, and associated human communities? With better documentation of the planning, implementation, and monitoring phases of marine conservation and development projects, scientists and practitioners will be in a considerably stronger position to evaluate the ecological, social, economic, and institutional dimensions of success and to develop standards for effective marine conservation practice.

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Supplementary Material

The following supplementary material is available for this article online:

Appendix S1. Database of major features of ~~90~~ cases 27
of marine conservation planning processes. This material is available as part of the online article from http://www.blackwell-synergy.com.

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