Integrating Science into the Design of the Tortugas Ecological Reserve

ABSTRACT

The Tortugas Ecological Reserve, the largest fully protected marine reserve in the U.S.A., was implemented in July 2001 after a successful, three-year collaborative effort. A key facet of this process was the direct involvement of scientists and the acceptance of their information by the various stakeholders collaborating on the reserve’s design. This paper describes how scientific information was ultimately influential in the siting and sizing of the reserve. Case studies such as this may benefit those attempting to use science to inform decisions in marine protected area planning.

INTRODUCTION

Marine reserves (called ecological reserves in this paper) are well-defined areas of the ocean fully protected from human disturbance (primarily fishing) for the purpose of biodiversity protection, fisheries enhancement, or protection of some unique feature or artifact (NRC, 2000). They may be independent units or a subset of a larger marine protected area (MPA), an area of the ocean reserved by law or other means to protect part or all of the natural and cultural resources therein (Presidential Executive Order 13158). Marine reserves are increasingly being used around the world as a conservation tool (Gubbay, 1995). However, less than one percent of the world’s oceans are protected by marine reserves (Pahumbi, 2003). Implementation of marine reserves in the United States has become one of the most contentious environmental issues of the day because of the deeply rooted tradition of treating the oceans as a commons to be exploited with impunity. As an ocean conservation ethic slowly takes hold in the United States and as natural resources become more scarce, acceptance of marine reserves as a legitimate approach to conservation is increasing. However, there are currently few fully protected marine reserves in the U.S.A. that can be used as examples of success, either because they have not been implemented long enough to show positive benefits or they are poorly designed and managed (Jameson et al., 2002).

The Tortugas Ecological Reserve, a fully protected marine reserve that is currently the largest such area in the United States, was recently implemented. The Tortugas Ecological Reserve is part of the Florida Keys National Marine Sanctuary, a multiple-use MPA that uses marine zoning to protect resources while allowing compatible activities. The design and implementation of the Tortugas Ecological Reserve (the reserve) is considered to be a successful example of collaborative decision-making (NRC, 2000). The community-based planning process for the reserve acknowledged the important contributions of the area’s users, and in that respect represented a significant departure from government-driven, top-down marine conservation initiatives that are often the norm in developed countries. The inclusion of citizen representatives with an equal voice in the decision-making process was significant. The public involvement aspects of the Tortugas Ecological Reserve process, though critical to its ultimate success, will not be discussed in this paper (see Delaney, 2003).

In addition to unprecedented community involvement, socio-political and economic factors weighed heavily in the outcome of the reserve process, as they do in all resource allocation decisions. Science played a crucial role in balancing short-term economic concerns with potential long-term economic and ecological benefits. Though the integration of scientific data in marine resource planning is not a novel concept (Salm and Clark, 1984, Kenchington and Hudson, 1988, Gubbay, 1995, Mascia, 2001), in the case of the Tortugas Ecological Reserve science significantly influenced the design of the reserve. This paper focuses on the methods used to integrate science into the design process and discusses how various types of data played a critical role in shaping public policy.

BACKGROUND

The Florida Keys form a 356-km island chain located at the southern tip of Florida, in the southeastern United States. The marine environment of the Florida Keys includes mangroves, seagrasses, hardbottom communities, patch reefs, and the third largest bank-barrier coral reef system in the world (Hoffmeister, 1974). Significant degradation of the Keys’ marine environment is the result, in part, of dramatic population growth throughout south Florida (USDOC, 1996). Improperly handled wastewater and stormwater contribute to the degradation of nearshore water quality (Kruczynski, 1999), seagrasses and corals are destroyed by boat groundings (Causey et al., 2000), and overfishing of dozens of key species
has depleted reef fish biomass and spawning potential (PDT, 1990, Ault et al., 1998). Intensive non-consumptive activities, such as snorkeling and SCUBA diving, also place significant pressures on coral reef resources that are exacerbated by the over three million visitors to the region annually (Leeeworthy and Vanasse, 1999).

In an effort to address these many complex threats, to provide comprehensive protection to the region, and to ensure multiple, compatible use of resources, Congress created the Florida Key National Marine Sanctuary (FKNMS or Sanctuary) in 1990 (Florida Keys National Marine Sanctuary and Protection Act, Pub. L. 101-605). The National Oceanic and Atmospheric Administration (NOAA), under the U.S. Department of Commerce, administers this and other National Marine Sanctuaries. The Sanctuary encompasses over 9800 square kilometers (km²) of coastal and oceanic waters and submerged lands (USDOC, 2000), and is managed under cooperative agreement between the State of Florida and NOAA.

NOAA implemented a comprehensive management plan for the Sanctuary in 1997 that outlined specific marine resource conservation strategies. One of these strategies, marine zoning, is used in the Sanctuary to protect diverse habitats important for maintaining natural resources and ecosystem functions, while allowing compatible activities to continue.

The zoning network established by the Sanctuary was the first of its kind in the U.S.A. (Murray et al., 1999). Five types of zones (Sanctuary Preservation Areas, Research Only Areas, Ecological Reserves, Wildlife Management Areas, and Existing Management Areas) were established and implemented in 1997 (Figure 1). During the draft management plan process (1995) an ecological reserve, one type of fully protected zone, was proposed for the remote Tortugas region of the Sanctuary but was not adopted because of insufficient natural and socioeconomic data and a resulting lack of community acceptance for the proposal. Instead, NOAA committed in the final management plan for the Sanctuary to implement an ecological reserve in the Tortugas region after a thorough review and analysis of the area (USDOC, 1996). To ensure that the unique habitats of the Tortugas were fully protected and to address the myriad of threats in the area, the Florida Keys National Marine Sanctuary initiated the design of the Tortugas Ecological Reserve in 1998. The reserve process was dubbed “Tortugas 2000,” and was designed to apply lessons learned and overcome the challenges encountered during the development of the original marine zoning plan for the Sanctuary.

### The Design Process

Tortugas 2000 occurred in three phases, beginning in April 1998 and ending in November 2000. Phase I addressed the design of the ecological reserve and culminated in June 1999 with the citizens’ Sanctuary Advisory Council (SAC) recommending a preferred boundary for the Tortugas Ecological Reserve

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**Figure 1.** The marine zoning plan for the Florida Keys National Marine Sanctuary. Ecological Reserves, Sanctuary Preservation Areas, and Research Only Areas, labeled below, are fully protected zones (graphic courtesy of Kevin Kirsch/FKNMS).
At the core of Tortugas 2000 was a 25-member working group that included Sanctuary Advisory Council members, stakeholders, and government agency representatives (Table 1). The Working Group ensured that all constituents and agencies with an interest in or concern over activities in the Tortugas were present during the design phase. A key agency partner was the National Park Service due to their trusteeship of the Dry Tortugas National Park, a 259-km² park that is surrounded by, but jurisdictionally separate from, the Sanctuary. The Park Service’s involvement in the design of the reserve was critical because of the important shallow water coral reef resources found within the park and the connectivity of those resources with surrounding Sanctuary waters (Figure 1).

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The Tortugas 2000 Working Group was charged with reviewing available scientific and socioeconomic information and making a recommendation to NOAA on the size, shape, and placement of the Tortugas Ecological Reserve. A professional facilitator guided the Working Group, which over the course of 13 months met five times to define operating goals, agree to ground rules, develop and weight criteria for the reserve, evaluate draft boundaries, and recommend a preferred boundary (Table 2).

### METHODS FOR INTEGRATING SCIENCE INTO THE DESIGN PROCESS

The design of the Tortugas Ecological Reserve was an iterative, dynamic process in which the Working Group began with a foundation of knowledge on the Tortugas region and then learned as a group about various attributes of the region as information became available.

Because of its remoteness, there was not a great deal of widely shared knowledge about the Tortugas among the Florida Keys community when the Working Group first convened in April 1998. Two types of information available to the Working Group and public at that time were traditional knowledge from fishermen and scientific knowledge from the few researchers who had worked in the area. Both types of information were valued equally in the design process and were purposefully incorporated into it.

### Working Group

The most critical method by which science was integrated into reserve design was through the inclusion of scientists on the Working Group who were both knowledgeable about the Tortugas region and about marine reserves. Two types of scientists were represented on the Working Group: research scien-

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**Table 1. The Tortugas 2000 Working Group. Research scientists are denoted by a single asterisk and research administrators are denoted with a double asterisk.**

<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation</th>
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<tbody>
<tr>
<td>Dr. James Bohnsack*</td>
<td>NOAA Fisheries</td>
</tr>
<tr>
<td>Dr. Robert Brock**</td>
<td>National Park Service</td>
</tr>
<tr>
<td>Mr. John Brownlee</td>
<td>Saltwater Sportsman magazine–recreational fishing</td>
</tr>
<tr>
<td>Maj. Bruce Buckson</td>
<td>Florida Marine Patrol</td>
</tr>
<tr>
<td>Mr. Billy Causey</td>
<td>Florida Keys National Marine Sanctuary</td>
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<tr>
<td>Dr. Felicia Coleman*</td>
<td>Florida State University and Gulf of Mexico Fishery Management Council</td>
</tr>
<tr>
<td>Mr. Ed Conklin</td>
<td>Florida Dept. of Environmental Protection</td>
</tr>
<tr>
<td>Mr. Ben Cowie-Haskell</td>
<td>Florida Keys National Marine Sanctuary</td>
</tr>
<tr>
<td>Ms. Fran Decker</td>
<td>Citizen</td>
</tr>
<tr>
<td>Mr. Don DeMaria</td>
<td>Commercial spearfishermen</td>
</tr>
<tr>
<td>Mr. Richard Diaz</td>
<td>Commercial lobster trapper</td>
</tr>
<tr>
<td>Dr. Nicholas Funicelli**</td>
<td>U.S. Geological Survey</td>
</tr>
<tr>
<td>Mr. Peter Gladding</td>
<td>Commercial handliner</td>
</tr>
<tr>
<td>Mr. Andy Griffiths</td>
<td>Commercial charter fishing</td>
</tr>
<tr>
<td>Ms. Deborah Harrison</td>
<td>World Wildlife Fund</td>
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<tr>
<td>Mr. David Holtz</td>
<td>The Ocean Conservancy</td>
</tr>
<tr>
<td>Mr. Anthony Iarocci</td>
<td>Monroe County Commercial Fishermen, Inc.</td>
</tr>
<tr>
<td>Dr. Joseph Kimmel**</td>
<td>NOAA Fisheries</td>
</tr>
<tr>
<td>Mr. Don Kincaid</td>
<td>Citizen- recreational diving</td>
</tr>
<tr>
<td>Mr. Peter Moffitt</td>
<td>South Atlantic Fishery Management Council</td>
</tr>
<tr>
<td>Dr. Erich Mueller*</td>
<td>Mote Marine Laboratory</td>
</tr>
<tr>
<td>Dr. Russell Nelson**</td>
<td>Florida Fish and Wildlife Conservation Commission</td>
</tr>
<tr>
<td>Mr. Gene Proulx</td>
<td>NOAA Office of Law Enforcement</td>
</tr>
<tr>
<td>Mr. Alex Stone</td>
<td>ReefKeeper International- recreational diving</td>
</tr>
<tr>
<td>BMC Bob Thomas</td>
<td>U.S. Coast Guard</td>
</tr>
</tbody>
</table>
Information provided to the Working Group

White papers

Three white papers were commissioned by NOAA and the National Park Service at the beginning of the reserve process to provide the Working Group (and through the Tortugas 2000 website, any other interested parties) with a site characterization for the region, including papers on oceanography (Lee et al., 1999), fish and fisheries (Schmidt et al., 1999), and benthic habitats (Jaap et al., 1998). The site characterization synthesized the best available information on the topic and, in the case of the fisheries section, served as a catalyst for developing a unified spatial information system incorporating several disparate datasets. These papers were invaluable in integrating science into reserve design by definitively clarifying questions from the Working Group and public, making facts and imagery about the region widely accessible, and laying the foundation for an Environmental Impact Statement for the reserve.

Informational forums

The Florida Keys National Marine Sanctuary convened two informational forums, the goals of which were: (1) present to Working Group members and other attendees the best available scientific information on the ecological and socioeconomic aspects of the area, (2) provide an outlet for community members to share their traditional knowledge and experience in the region, and (3) inform the Working Group about the area's uses. For example, the forums highlighted for the Working Group the importance of the Tortugas as a spawning area for several fish and invertebrate species, the exponential increase in fecundity with growth in fish (PDT, 1990), the importance of the Dry Tortugas as a nesting site for pelagic seabirds, the value of the area to shrimpers and dive charter operators, and the excellent water quality of the region as compared to the rest of the Florida Keys. The Working Group then used the information in developing design criteria.

Additional information

Sanctuary staff also provided each Working Group member with information relevant to reserve design throughout the process. This included peer-reviewed science papers, definition and regulations for an ecological reserve from the FKNMS management plan (USDOC, 1996), color GIS maps, design criteria, newspaper articles on the Tortugas process, and meeting summaries.

Geographic Information Systems

During the design process several types of spatial data from the region were being compiled simultaneously by different investigators. For example, while biologists were collecting fish distribution and benthic habitat data the economists were collecting data on human uses. Geographic Information Systems (GIS) data served a critical role by integrating these datasets into maps of the same scale (Franklin et al., 2001). A uniform framework was established using a spatial grid of approximately one square nautical mile (1 degree latitude by 1 degree longitude). This cell size was chosen because it adequately captured the scale of human activity and ecological phenomena (Figure 2). Digital versions of NOAA nautical charts were used as base layers in GIS maps, displaying the relevant data in a familiar context for fishermen and other Tortugas users.

This framework proved very useful for a number of reasons. First and most importantly, manipulating grid cells or raster data in GIS for drafting boundary scenarios was easy and straightforward as compared to manipulations of polygons or vector data. Secondly, because the grid cell framework was aligned with meridians, the reserve alternatives were also, resulting in straight-edged boundaries that would facilitate compliance with and enforcement of the reserve. Lastly, the one square nautical mile grid cell was a common mapping unit that most Working Group members were familiar with.
The reserve is comprised of two sections: Tortugas North at 312 km², and Tortugas South at 206 km², with a total area of 518 km².

Tortugas North protects a deepwater (30–50m) coral bank called Tortugas Bank, a portion of which was dubbed Sherwood Forest because of the abundant mushroom-shaped coral heads found there (Figure 4). Tortugas South protects Riley’s Hump, a low relief coral bank that serves as a spawning aggregation site for several fish species and some deepwater habitat (50–600m) important to a variety of ecologically and commercially important fishes and invertebrates.

An interesting result of widely sharing scientific data and information among the Working Group members and public was that some of the scientific information proved to be more influential in the reserve providing a comfortable frame of reference for quickly judging distances or the spatial extent of a proposal.

An example of the utility of GIS in this process was the mapping of fish spawning sites. The Tortugas region, particularly Riley’s Hump, has long been known to fishermen as a site of several fish spawning aggregations. Some of these sites were disclosed to researchers and subsequently mapped for the first time for use in the Tortugas 2000 process (Figure 3). These sites are further described in the results section of this paper.

RESULTS OF THE SCIENCE-DRIVEN RESERVE DESIGN PROCESS

The final outcome of the Tortugas 2000 process was the implementation of the Tortugas Ecological Reserve in July 2001. The Tortugas Ecological Reserve is located 225 km west of Key West, Florida, at the western terminus of the Florida Keys archipelago and abutting the Dry Tortugas National Park (Figure 1). The reserve is comprised of two sections: Tortugas North at 312 km², and Tortugas South at 206 km², with a total area of 518 km². Tortugas North protects a deepwater (30–50m) coral bank called Tortugas Bank, a portion of which was dubbed Sherwood Forest because of the abundant mushroom-shaped coral heads found there (Figure 4). Tortugas South protects Riley’s Hump, a low relief coral bank that serves as a spawning aggregation site for several fish species and some deepwater habitat (50–600m) important to a variety of ecologically and commercially important fishes and invertebrates.

All of the available scientific information on the Tortugas was given to the Working Group and made publicly available through the methods described above. An interesting result of widely sharing scientific data and information among the Working Group members and public was that some of the scientific information proved to be more influential in the reserve.
design process than other information. In this context we will use the term cornerstone science to refer to scientific information that is persuasive and therefore readily influences public policy. In developing criteria and objectives for the reserve, the steps of which are described later in this section, Working Group members reiterated what science was most important to their decision-making. The authors additionally received feedback from the Working Group when the information was presented.

Cornerstone science resulting from the reserve process fell into several broad categories, each with varying influence on the ultimate design of the area protected. Following are specific descriptions of cornerstone science used throughout the design process, with an explanation of why each was particularly persuasive in the public debate over creating the reserve.

**Oceanographic Information**

*Satellite-tracked drifters*

Dr. Tom Lee of the University of Miami's Rosenstiel School of Marine and Atmospheric Sciences has been studying the Florida Current and related gyres for decades (Lee et al., 1994). One of his primary techniques for doing this is through the monthly deployment of a battery-powered drifter from one of several locations along the Southwest Florida coast. Current-driven movements of each drifter are tracked by satellite for several months, providing a time-series plot of regional circulation patterns. The drifter track data provided a powerful visual aid for demonstrating the oceanographic connectivity of the Tortugas region with not only the Florida Keys, but also with the southwest coast of Florida and the southeast coast of the U.S.A. (Figure 5).

The implication of this connectivity was the potential for advective transport of fish and invertebrate larvae to vast areas downstream and upstream of the Tortugas. It was especially important to demonstrate to Tortugas fishermen the potential for larval transport, as they were faced with the possibility of giving up productive fishing grounds through the creation of the reserve.

*Drifter vials*

Also reinforcing the Tortugas’ potential as a source area for fish larvae was a drift bottle study by Domeier and colleagues, where 1000 small glass vials were released on Riley's Hump during a full moon in May 1999 to coincide with mutton snapper spawning (Domeier, 1999). The vials were weighted slightly to float just below the surface, acting as crude proxies for snapper larvae, and contained instructions...
Fish Spawning Aggregations

Several species of commercially and recreationally important reef fish aggregate to spawn at specific times of the year in the Florida Keys and Tortugas, particularly snappers and groupers (Lindeman et al., 2000). The locations and timing of these events are well known by some fishermen, who often target the aggregations in order to increase their catch (Lindeman et al., 2000). In some cases, aggregations have been decimated for so long they no longer exist (P. Gladding, pers. comm.). The snapper and grouper spawning aggregations that still occur in the Tortugas are likely due to the area’s remoteness and possibly the seasonal fishing restrictions that have existed at Riley’s Hump for several species since the mid-1990s. Historically, fishermen have been reluctant to reveal the location and timing of these events. However, after seeing aggregations diminish despite fishing restrictions in the area, several leading fishermen revealed the existence of known sites to scientists in an effort to help protect them (Figure 3). These data reinforced drifter track data, providing a useful image of the reserve’s potential to serve as a source of larvae to surrounding regions. These data also revealed that seasonal protection of Riley’s Hump was not enough, and that continuous protection with a reserve was needed as several spawning aggregations were still being heavily fished.

Fish Distribution and Abundance

Science showing the consequences of overfishing also influenced public opinion in the reserve design process. Dr. James Bohnsack (NOAA Fisheries), a member of the Working Group, and Dr. Jerry Ault (University of Miami) shared their research on the status of the snapper-grouper complex (73 species managed by the South Atlantic Fishery Management Council) in the Florida Keys. The data showed that the majority of the snapper/grouper complex (13 of 16 grouper species, 7 of 12 snapper species, and 2 of 5 grunt species) were below the 30 percent spawning potential ratio federal standard - a sign of serial overfishing (Ault et al., 1998). During the formulation of the reserve, Ault and Bohnsack conducted fishery-independent diver surveys in the Tortugas to ascertain the status of fish stocks specific to that region. Their results confirmed for the Working Group that stocks were healthier in the Tortugas than in the remaining Florida Keys, but were still in an overfished state (Schmidt et al., 1999).

Benthic Habitat Maps and Photographs

Photographs of benthic habitats, particularly coral banks, were perhaps the most visually influential data presented to the for the finder on how to report vial recovery. A total of 114 returns enabled the scientists to map the terminal location of the vials, providing a rough picture of larval dispersal potential (Figure 6). The majority of the recoveries were from the middle Florida Keys, 390 km east of the Tortugas, and some recoveries were reported from as far away as 1500 km. The duration of time between deployment and recovery roughly approximated the planktonic larval duration of mutton snapper (~30 days) (Lindeman et al., 2000). This simple study further bolstered evidence that the Tortugas may serve as a source of fish larvae.
Working Group. These photographs documented very high coral cover (>30 percent), excellent water clarity (>100'), rare corals (*Antipathes spp*.), and unique coral morphologies (Figure 4). The actual extent of this rich habitat was unknown during the Working Group’s deliberations. Subsequently, using benthic habitat data from a variety of sources including side scan sonar and diver surveys (Franklin et al., in press), it became clear that the extent of this deep coral bank habitat was much larger than the one square nautical mile portrayed in early planning maps. These data furthered knowledge that the reserve study area contained fragile coral habitats unique to the Florida Keys.

**Socioeconomics**

Dr. Vernon Leeworthy, chief economist for the National Marine Sanctuary Program, and his colleagues designed and implemented a socioeconomic survey of all users of the Tortugas study area. Through fishing license databases they identified a population of 110 commercial fishermen who used the Tortugas region as their primary fishing grounds. Leeworthy then contracted two experts already known to the fishermen to conduct the surveys. They were able to obtain confidential data from approximately 95 of the 110 fishermen on the location and quantity of catch by species, fishing costs, and their socioeconomic profile (Leeworthy and Wiley, 2000). Using these data, detailed maps were produced in GIS that showed the location of various uses and the level of use in terms of pounds of catch or person-days of time (as possible maximum values for each cell versus absolute values) (Figure 2).

The data and user maps were accepted by the Working Group and fishermen to be accurate reflections of their activities for the given year. These data and maps were extremely important in the reserve design process because they quantified the potential impact of any given proposal on each user group.

**THE INFLUENCE OF SCIENCE ON RESERVE DESIGN CRITERIA AND BOUNDARY SELECTION**

Based on the scientific information available to them, the Working Group developed a set of criteria for defining the objectives of the reserve and to aid in the selection of reserve boundaries. Table 3 lists the final criteria with their objectives. Four of the six criteria had ecological objectives that clearly reflected the cornerstone science made available to the Working Group.

The Working Group then weighted the criteria through a consensus exercise. Table 4 shows the resulting three criteria profiles with their assigned weighting. Of interest is that all of the criteria profiles included ecological objectives in their top four criteria, despite being developed by different interests seated at the Working Group table.

**Table 3. Final design criteria developed by the Working Group (USDOC, 2000).**

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Objective</th>
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<tbody>
<tr>
<td>Biodiversity and habitat</td>
<td>Try to choose an area that would contain the greatest level of biological diversity and wider range of contiguous habitats.</td>
</tr>
<tr>
<td>Fisheries sustainability</td>
<td>Try to choose an area that would provide the greatest benefit in protecting and enhancing important fish species, especially those that are rare, threatened, or depleted.</td>
</tr>
<tr>
<td>- spawning sites</td>
<td>Try to choose an area that would include significant fish spawning aggregation sites.</td>
</tr>
<tr>
<td>- full life cycles</td>
<td>Try to choose an area that would encompass all the habitats required to support the full life cycle of commercially and recreationally important fish.</td>
</tr>
<tr>
<td>Sufficient size</td>
<td>Try to choose a boundary that would encompass an area that is large enough to meet the criteria listed above and to achieve the potential benefits and goals of an ecological reserve.</td>
</tr>
<tr>
<td>Socioeconomic impacts</td>
<td>Try to choose an area and craft recommendations that would serve to minimize adverse socio-economic impacts on established users of resources in the area.</td>
</tr>
<tr>
<td>Reference area/monitoring</td>
<td>Try to choose an area that would serve as a reference or control area to facilitate the monitoring of anthropogenic impacts and to evaluate the consequences of establishing the ecological reserve.</td>
</tr>
<tr>
<td>Enforcement/compliance</td>
<td>Try to choose a boundary and craft regulations that would facilitate enforcement and encourage compliance.</td>
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</tbody>
</table>
The three criteria weighting profiles were used to develop a set of boundary alternatives for the reserve. In this step of the design process, Working Group members again revisited the scientific information and traditional knowledge available to them. The Working Group relied heavily on the GIS-based map products, described previously in this paper, to visualize borders and estimate to what extent each alternative met the reserve criteria. Initially twelve boundary alternatives were crafted by the Working Group, with two alternatives then selected as a point of departure for further discussions. These discussions led to the final selection of a compromise alternative that sufficiently addressed all of the criteria and addressed the needs of both the extractive and non-extractive users on the Working Group. The Working Group adopted the compromise alternative by consensus as the recommended preferred alternative for the Tortugas Ecological Reserve, and forwarded this recommendation to the FKNMS for consideration.

Clearly, the criteria the Working Group members chose to design the reserve and, more importantly, the weighting they assigned to those criteria, reflected the quality of scientific and traditional information made available to...
process by which the Sanctuary shared scientific and traditional knowledge was through the informational forums that were held at the beginning of the design phase. Given the broad dissemination of scientific information related to reserve design it was important for the data to be easily interpreted and understood by a variety of audiences. GIS maps based on familiar units and scales were extremely helpful for visualizing reserve boundaries and determining how alternatives would meet specific criteria and affect certain users. Lastly, it was important that science experts were seated at the table with other relevant stakeholders from project inception. Scientific data and research results should be considered alongside traditional knowledge provided by users of the area. Also, when scientific experts participate directly in the process they are able to answer questions and advise on technical matters as needed. This direct exchange of information serves to build trust and engenders a sense of accountability among the Working Group members and the public.

In the contentious debate over marine reserves, policymakers will increasingly demand that decisions be based on the best available science. The success of the Tortugas Ecological Reserve process demonstrates that science can play a pivotal role in the design of a marine reserve by a multi-stakeholder group.

ACKNOWLEDGEMENTS

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REFERENCES


