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Applying Marine Habitat Maps and Biodiversity and Resilience Assessments to Management

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ABSTRACT

Coral demographics, mortality and recruitment were combined with assessments of benthic cover types, biomass of algal functional groups, population structure of commercially and ecologically valuable reef fishes, and environmental resilience indicators, using a standardized, rapid, quantitative survey protocol. Groundtruthing was used to define the bathymetry, identify habitat classes and their spatial distribution, characterize dominant species assemblages, substrate types, and underlying geomorphology. The assessments provided information on 1) the status of coral reefs and species that create and help maintain the health of the reefs and associated habitats; 2) local and regional threats, causes, impacts, and potential mitigation strategies; and 3) patterns of recovery from past disturbances. Coral reef data were compiled in a Geographic Information System (GIS) database with satellite imagery, habitat maps, and other physical and oceanographic GIS data layers, resulting in a landscape-scale tool useful for marine spatial planning. The potential use of this information to identify sites of high resilience for inclusion into MPA networks is presented using an example from 2008 reef surveys in Al Wajh Bank, Saudi Arabia (Fig. 1).

Figure 1. Location of Al Wajh Bank in the Red Sea, Saudi Arabia.

INTRODUCTION

A resilient reef should exhibit the ability to maintain or restore its pre-disturbance structure and function without undergoing a permanent shift to a less preferred (e.g. algal-dominated) state. Quantitative, measurable indicators of resilience levels include: 1) functional group abundance, species diversity and community redundancy, with emphasis on corals, algae, large motile invertebrates and fishes; 2) the ecological interactions that drive dynamics within and among these groups; 3) habitat and environmental influences that directly affect reef-associated organisms and interactions between them; and 4) external drivers of change, including anthropogenic and climate factors, and the level of connectivity with other reefs. Measures of coral population dynamics (e.g. detailed measures of colony size and size classification for each coral) and assessment of coral recruits were conducted. High-resolution benthic habitat and bathymetric maps (Fig. 4) were developed to illustrate the spatial distribution and size of different habitat types to assist managers in marine spatial planning. The purpose of this paper is to evaluate reef resilience at two adjacent sites (Fig. 4) within the lagoon of Al Wajh Bank, Saudi Arabia.

METHODS

Coral reef rapid assessments

- Surveys combined aspects of Atlantic and Gulf Rapid Reef Assessment and IUCN Resilience Assessment of Coral Reefs.
- Quantitative data included: substrate condition, benthic cover, fish and coral community structure, biotic stressors, and environmental and anthropogenic factors.

Habitat mapping

- Acquisition of high-resolution, multispectral QuickBird satellite imagery.
- Identify habitat classes and their spatial distribution.
- Data collection for correcting atmospheric and water column attenuation (Fig. 2).

Data processing

- Training of the algorithms needed to classify habitats from multispectral satellite imagery, bathymetric, in-situ spectral, and groundtruth data.
- Create habitat and bathymetric maps (Fig. 4) and the GIS database.

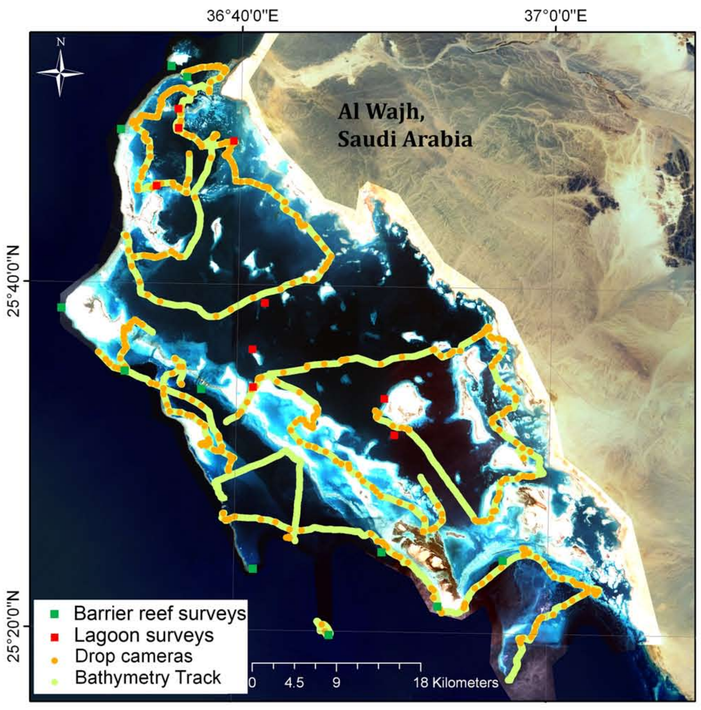

Figure 2. Map of field surveys conducted at Al Wajh Bank in 2008.

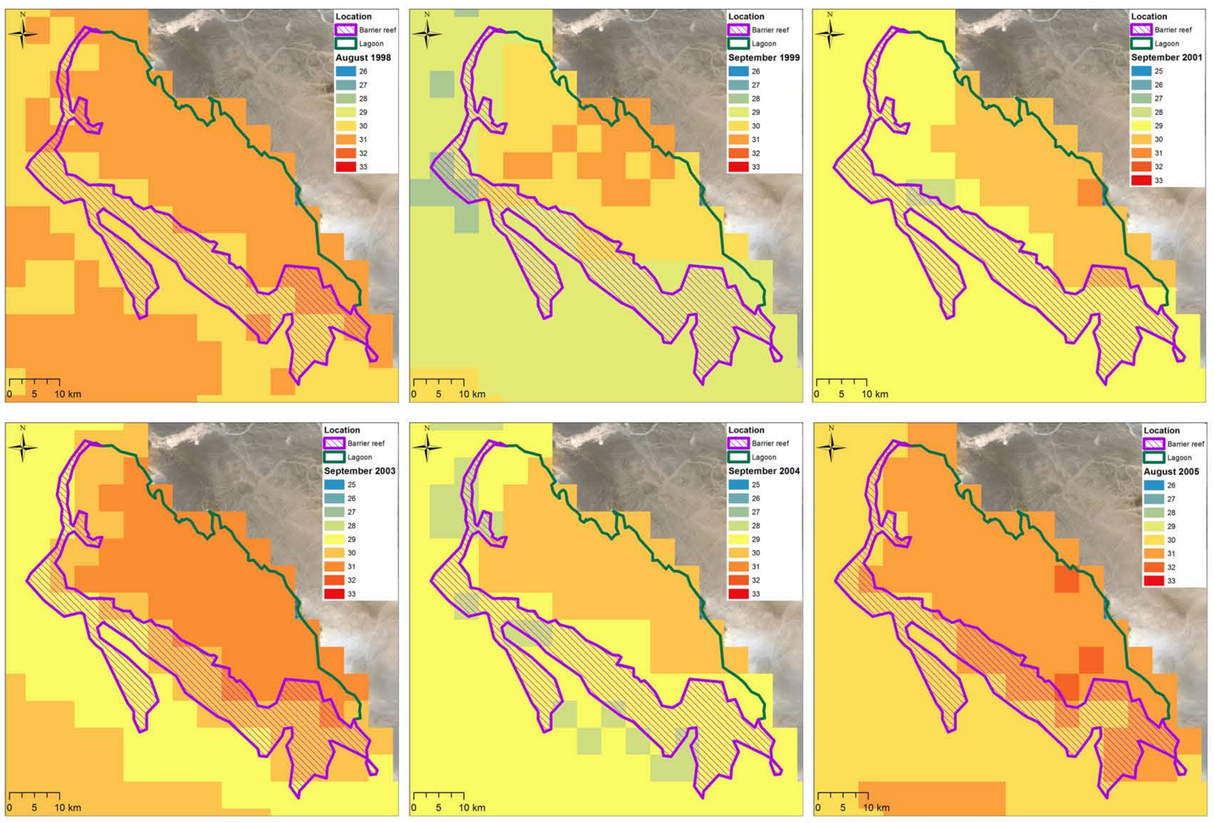

Figure 3. Select years with higher than average maximum sea surface temperatures leading up to the 2008 reef surveys indicate pooling of warm water within the lagoon and cooler water on the barrier reef.

RESULTS

Al Wajh resilience indicators

- High levels of coral recruitment over entire bank.
- Primary human impact: fishing pressure (hand lines and fish pots), particularly in the lagoon.
- Acute sea surface temperature stress was minimal from 1997-2008 on the barrier reef, but there were chronic high temperatures in lagoonal sites during late summer (Fig. 3).
- Seawater temperatures on the barrier reef are moderated by adjacent deep water, waves, winds, and strong currents.
- Lagoonal reefs, especially adjacent to wide, shallow sand flats (Fig. 4, Site 1) are exposed to heat stress due to pooling of water (Fig. 3).
- The barrier reef is perforated by several narrow channels, enhancing flushing of the lagoon.
- A greater percentage of barrier reef corals had a greater mean diameter than the lagoonal patch reefs (Fig. 5).

Identification of a resilient lagoonal reef

- Comparison of neighboring lagoonal Sites 1 and 2 revealed large variation in resilience.
- Both reefs were similar in structure.
- Moderate levels of recruitment were apparent at both sites, although higher numbers of recruits were recorded at Site 2.
- **Site 1:** Coral cover was <5%. Dead columnar and massive *Porites* framework were recolonized by corals that had subsequently died. Most surviving corals were missing 60-90% of their tissue. *Xenia* cover was high. Sediment patches and dead corals were mostly colonized by cyanobacteria. Less than 60% of *Porites lobata* colonies had just 5 cm of tissue remaining on colonies that were up to >100cm wide (Fig. 6).
- **Site 2:** Columnar and massive *Porites* framework was mostly live, with 20-50% cover. Coral population was dominated by medium to large (mean = 43 cm) *P. lobata* colonies that had low levels of partial mortality (Fig. 6). Site 2 is adjacent to one of the largest channels (Fig. 6), reducing the potential for bleaching during periods of temperature stress.

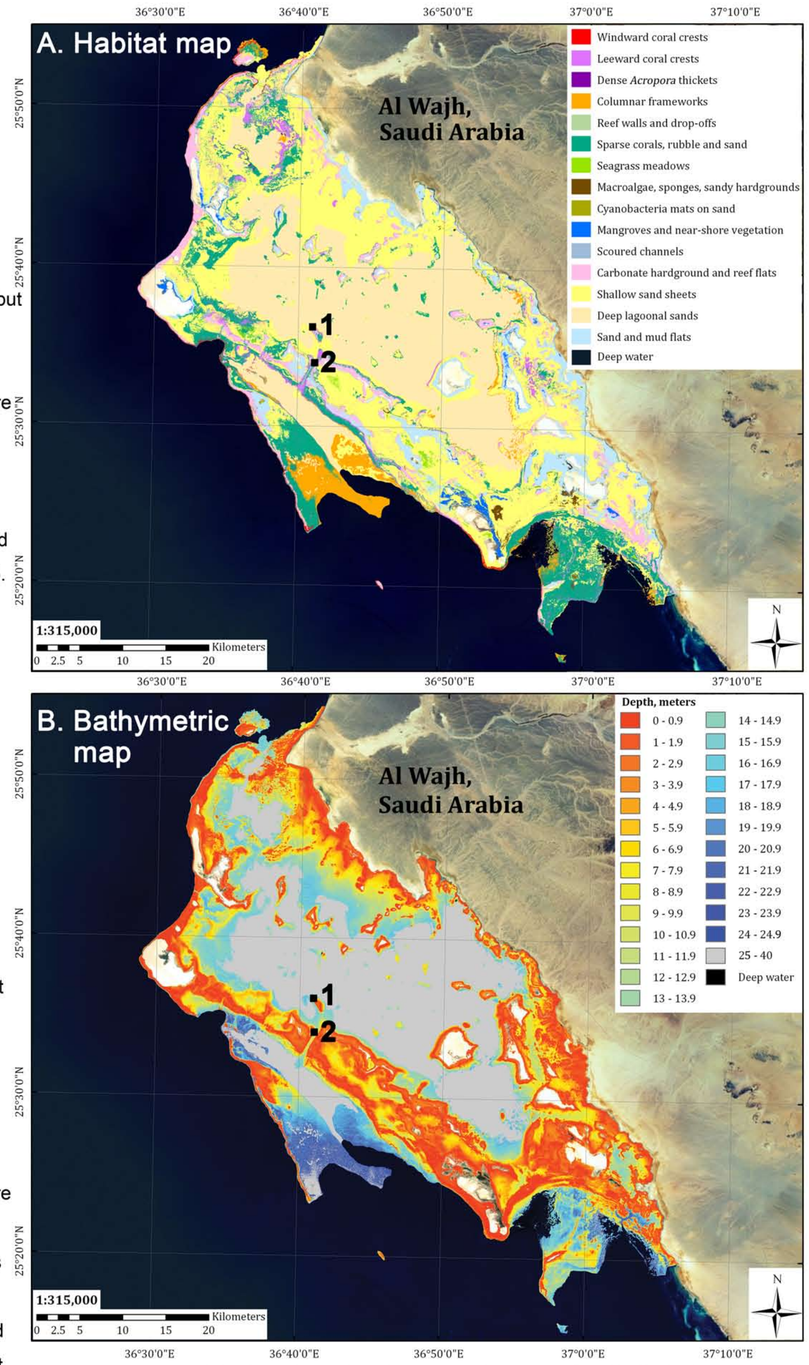

Figure 4. Habitat (A) and bathymetric (B) maps of Al Wajh Bank.

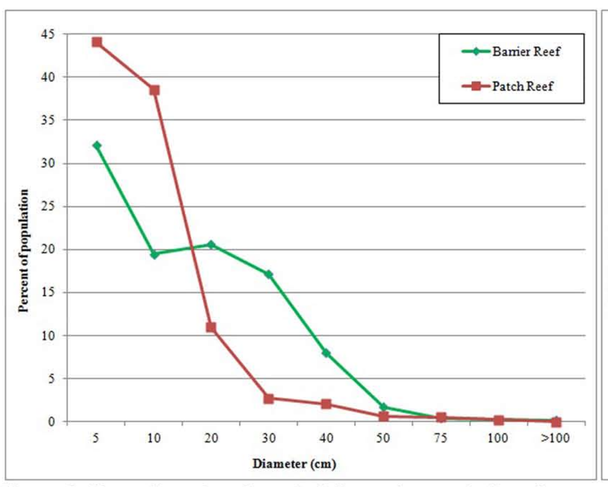

Figure 5. Mean diameter of corals (all species pooled) on the barrier reef and patch reefs.

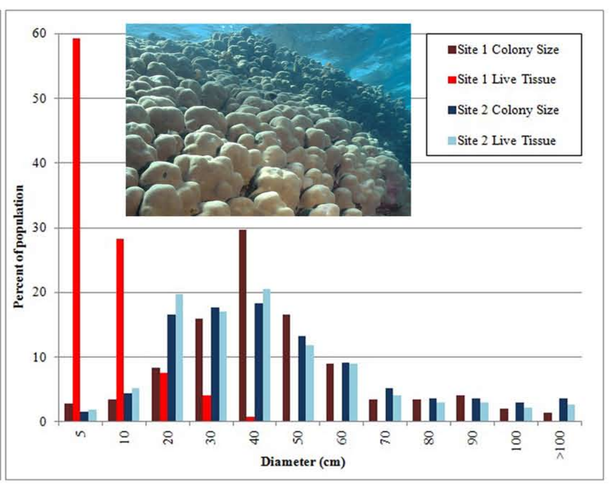

Figure 6. Population structure of *Porites lobata* at lagoonal Sites 1 and 2.

DISCUSSION

Resource managers can make informed decisions by combining habitat mapping with information from coral reef surveys. The barrier reef has greater overall mean coral size and is more resilient due to decreased temperature stress. The lagoonal patch reefs are under both increased fishing pressure and temperature stress and are smaller in size. This indicates that the pooling of warm lagoonal waters causes coral sizes to be smaller overall, in comparison to barrier reef corals. Within the lagoon at disturbed locations (e.g. Site 1), there are few large corals that have survived. High numbers of dead corals in growth position were noted and remaining live colonies were greatly reduced in live tissue size due to partial mortality. Additionally, the presence of cyanobacterial mats, few detritivores (e.g. sea cucumbers), a scarcity of large herbivores, and high cover of *Xenia* carpeting much of the *Porites* framework indicate that substrate quality is declining, all of which decrease reef resilience. Site 2 had a similar reef structure, but had less tissue loss due to decreased temperature stress. Resilient reefs, such as Site 2, that are under high human stress (e.g. fishing pressure) should have high conservation and management priority. Reefs within the lagoon are at a critical resilience threshold and could fail to recover from future disturbances unless management actions are taken.

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