Proceedings of the 11th International Coral Reef Symposium, Ft. Lauderdale, Florida, 7-11 Jul 2008
Session number 23

Management and monitoring for coral reef conservation in the Port of Singapore

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Abstract. Since its founding in 1819, Singapore has lost an estimated 60% of its coral reef area. Most of this loss is attributed to pressures from land-use necessitated by an increasing population and a fast-growing economy. Nevertheless, high species diversity remains on coral reefs, with more than 250 scleractinian species still extant. This number is more noteworthy as Singapore's total coral area covers only 1000ha. In earlier years, conservation of coral reefs was incidental, contrasting with a more intentional approach today. A major pillar of this new approach involves the setting of strict environmental quality objectives and use of real-time feedback monitoring processes. These rigorous environmental monitoring and management plans allow mitigation of impacts while allowing coastal development that is often necessary in a land-constrained situation, even when these developments are in close proximity to such reefs. In Singapore, the problem of having many stakeholders in coastal areas is exacerbated by the intensity of use resulting from very limited availability of land and coastal areas. Besides traditional coral reef conservation, approaches like active habitat enhancement measures are necessary to ensure long-term sustainability of coral reefs in the face of these pressures.

Key words: Coral, Management, Port, Feedback monitoring

Introduction

Singapore is an island nation with a land area of about 700km^2 and a population of approximately 4.8 million (Statistics Singapore 2008), giving rise to a population density exceeding 6800/km^2. This intense population pressure, coupled with the need to provide a means of income for people represent the socio-economic realities that need to be taken into account when considering conservation needs.

Modern-day Singapore was founded in 1819 by Stamford Raffles of the British East India Company, who recognized its strategic location and natural harbor. Since then, much of the coastline has been transformed from mangroves and coral reefs to one dominated by development, in particular by extensive port facilities in the south of the island. Most of the nation's coral reefs are also found off the southern coasts. An estimated 60% of the original reefs have been lost (Chou 2007).

Impetus to Conserve Marine Biodiversity

Historically, most coral reefs in Singapore were lost due to habitat destruction. Today, factors that could impact coral reefs here include land reclamation, sewage and other high nutrient effluent, industrial effluent (pollutants as well as industrial cooling water), and oil discharges from ships. One major factor is a high level of sedimentation in the water that has a smothering, as well as light attenuation (Chou 2007) impact on hermatypic corals.

In addition, management of coral reefs in Singapore is complicated by the large number of stakeholders: different government agencies hold jurisdiction for different aspects of coral reefs related to the conservation of the latter; private corporations with coastal facilities also have a stake in some coral reefs; nature or recreation groups with coral reef interests also add their voices to the stakeholder community.

In spite of these pressures and complexities in management, coral reefs and other marine habitats have shown resilience and exhibit diversity that can be considered remarkable. More than 250 species of hard corals are present in Singapore; 31 mangrove plant species, together with 11 seagrass species have also been recorded (unpublished data). Fig. 1 shows the locations of coral, mangrove and seagrass habitats in Singapore. While abundances may have declined, species richness can be considered to have remained relatively stable over the last four decades (Chou 2007).

While the continued presence of such rich biodiversity in the light of a worldwide trend of decline is a cause for optimism, it also leads to the responsibility to ensure its conservation is given commensurate consideration.

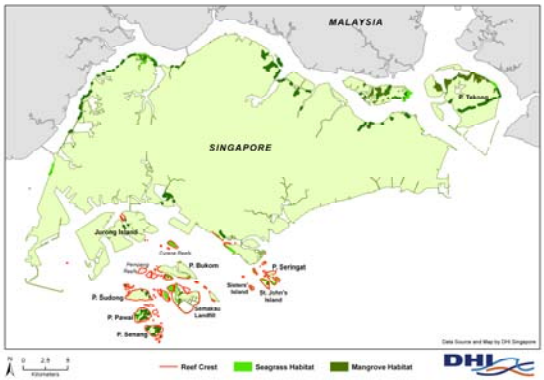

Figure 1: Singapore, showing locations of coral reef, seagrass and mangrove habitats.

Conventional Conservation Approaches Inadequate

Traditional conservation paradigms are largely dependent on protecting areas that possess significant biodiversity by designating such areas as 'no-take' or 'no-go'. In the situation specific to Singapore, i.e., multiple stakeholders coupled with size constraints leading to limited options, intense use-pressures and threats, a more holistic management approach is needed to supplement conventional conservation strategies. This type of approach is likely to be necessary to meet the challenges of conserving coral reefs that occur in close proximity to port or urban centers like Singapore.

Protection of Marine Habitats in Singapore

Prior to 2004, especially in the early days after the founding of Singapore as a port and trading post, there was very limited focus on conservation of coral reefs or other marine habitats. Any government conservation or habitat protection efforts for coral reefs was fortuitous – the result of areas being overlooked in development rather than any conscious motivation to preserve the habitat. One significant milestone related to marine conservation in Singapore occurred in 2004 with the formation of a section dedicated to this purpose in the National Parks Board (hitherto concerned with an almost exclusive terrestrial focus), marking the start of governmental intervention on the part of marine conservation.

In terms of protection of biodiversity from physical development works on coral reefs and other coastal habitats, various international best practices have been adopted in setting out the requirements for approval of such works. For each such development project approved, environmental quality objectives (EQOs), including those related to biodiversity, are set based on current information on the biodiversity at and around the development site that could potentially be impacted ('biodiversity baseline'). The EQOs will typically spell out the level of impact allowed in relation to the project ('no impact' (where no change in the quality or functionality of the habitat if expected using numerical models, and none can be detected in the field) in most cases). Compliance with these EQOs is tracked using monitoring surveys (e.g., by line-intercept transects) and other relevant impact assessment methods (e.g., measurements of water turbidity or sediment settlement). Proposed measures to mitigate any anticipated impacts are also required at pre-approval stage.

In one example of a port expansion project off the southern coast (DHI 2005), which included a land reclamation component, hydrodynamic modeling during impact assessment studies indicated that impacts from the original reclamation profile could be significantly reduced if a different profile was adopted. The original profile was subsequently altered. In addition, the reclamation sequence was optimized to minimize impacts on a nearby coral reef habitat. More than a dozen coral reef sites around the development area are regularly monitored during the period of development, and for 12 months after project completion to ensure that there are no impacts on coral reefs in spite of all the measures imposed. One of the EQOs related to this project was to ensure that suspended sediment coming out of the project site should not exceed a pre-determined level, monitored by turbidity sensors located around the site.

In such projects involving reclamation or dredging where control of suspended sediment is considered important, the conventional approach to control is to impose a cap on dredging or soil dumping rates. Such caps focus on work effort and are presumed to relate to the actual sediment released into the water in a linear and predictable manner. However, this is dependent on a number of assumptions (e.g., on sediment type, current direction and strength, and other ambient environmental factors) that may not hold in all situations. Suspended sediment rates may actually exceed acceptable levels even when contractors are completely compliant with the work effort rate limitations imposed. On the other hand, if the assumptions are overly conservative, the project may drag on longer than actually necessary, leading to impacts caused by the length of time sensitive habitats are subjected to low levels of stress from the development works.

Where it is impossible to prevent destruction of a particular coral reef, every effort is made to minimize the loss of living corals. This is

considered a management imperative, given the very limited extent of coral reefs in Singapore. Controlled translocation of coral reef organisms, with proper monitoring of success (Doorn-Groen et al. 2007) is used in such situations where a coral reef is to be destroyed after consideration of the trade-offs in the decision.

Science-Inspired Approach Towards Long-Term Sustainability of Coral Reefs

Management decisions in Singapore are guided by extensive recent baseline coral reef surveys that cover a majority of the coral reefs here. Regular monitoring is also ongoing for more than a dozen coral reef sites (within a total area of just above 1000ha (unpublished data) of coral reefs in Singapore). This is a very intensive level of study for a very small area; at the same time, hydrodynamic modeling studies covering most of these reefs are also used in management decisions, reflecting the commitment to science-informed decision-making.

Taking advantage of advances in science and technology, a real time suspended sediment feedback system comprising the turbidity sensors mentioned earlier, coupled with a hydrodynamic model incorporating ambient environmental information (Doorn-Groen and Foster 2007) is now used regularly in Singapore. This allows control to be based on the actual level of suspended sediment, rather than on an indirect factor like rate of dredging or soil dumping.

Line-intercept transects are a widely used method of quantifying the abundance (and type) of flora and fauna on coral reefs. In Singapore, results from surveys using line-intercept transects at the reef crest had been considered representative of coral reef health and diversity and used in making management decisions, even though this method only describes a narrow band of life at the coral reef crest. However, studies have shown that on many coral reefs in Singapore, a rich abundance of organisms exists at depths below the reef crest (Goh and Chou 1994, 1995; Goh et al. 1997). As a result of taking such knowledge into account, a new 'Lower Reef Survey' that estimates the rich sponge, ascidian, soft coral and gorgonian fauna has been incorporated in management-related surveys since 2006. This allows survey results used in management decisions to better represent the actual species abundance and diversity situation present on the reefs studied.

Besides stringent measures to enhance the protection of marine habitats (including coral reefs) and the use of existing knowledge of, and advancements in science and technology to enhance conservation management decisions, Singapore has also adopted a management strategy of taking proactive actions to help ensure the long-term sustainability of habitats like coral reefs.

Fragmentation of coral colonies occurs continuously on coral reefs, whether by natural or anthropogenic causes. Based on the foundation of years of research on artificial reefs and recruitment (Chou 2007), a coral nursery was established in Singapore in July 2007 as part of a partnership between the National Parks Board, the National University of Singapore, the National Environment Agency, and Keppel Corporation. Besides studying fragmentation patterns, the project aims to rehabilitate coral fragments collected from reefs throughout Singapore by keeping them at the coral nursery until they are healthy, then transplanting back to natural reefs to enhance natural coral populations.

A study of larval dispersal patterns in Singapore was commissioned to provide information on the genetic connectivity between different reefs in Singapore. Preliminary results from this study are described in Tay et al. (2008). This information will enable management actions (like enhancement transplantation) to be targeted where it will have the greatest impact.

Ultimately, even a large number of individual actions may not have the effect necessary to ensure long-term sustainability of coral reefs in Singapore. An approach to management of coral reefs and other coastal areas that is integrated to include all relevant factors is needed to ensure that such areas can be managed properly. The need for integrated coastal management is well known among scientists and managers globally, and was recently highlighted again by Chou (2007). At the close of this discussion on coral reef conservation within the waters of a busy port, it is good to remind ourselves that while we are mindful of the impacts of port-related activities, like shipping, on sensitive coral reef habitats, an estimated 80% of anthropogenic pollution in coastal areas actually originates from land-based rather than ship-based sources (UNEP GPA 2008).

Conclusions

The limited area, sizeable population, and pace of development in Singapore represent the geographical and socio-economic realities facing conservation proponents.

A holistic approach is needed. In particular, priorities of industry/port development, housing and recreation, and concerns for the protection of coral reefs need to be balanced. This means that some reefs may need to be destroyed in the face of

these societal needs. This also means that 'business as usual' will not be sufficient to ensure the conservation of this globally-threatened ecosystem in Singapore. The intentional, science-based proactive approach discussed above is necessary to ensure the sustained existence of coral reefs in Singapore and other areas sharing similar situations where intense anthropogenic pressures are unavoidable but the will to conserve is present.

Acknowledgements
The idea for this paper arose from many informal discussions among colleagues in the National Biodiversity Centre, National Parks Board and other government agencies, and with collaborators from various institutions on the projects mentioned here, as well as others, which were not specifically referred to in this paper. The manuscript also benefited from the comments of two anonymous reviewers.

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