

Developing the Concept of Building a
Coral Reef in Singapore for
Conservation, Environmental Education,
and Tourism

By
Carly Knoell
May 2008

Date: _____

Approved:

Dr. Dan Rittschof, Advisor

Masters project submitted in partial fulfillment of the
requirements for the Master of Environmental Management degree in
the Nicholas School of the Environment and Earth Sciences of
Duke University

2008

Abstract

Coral reefs are one of the most critically threatened habitats. Climate change, pollution, and direct human impact are destroying coral reefs all over the world. Singapore is a small island nation that has destroyed almost all of its natural coral reefs in order to accommodate its growing population and economy. This project proposes a conservation project including an artificial coral reef off the coast of Pulau Semakau, a small island near the main island of Singapore. The mission of this project is to combine conservation, recreation, and education to increase awareness and understanding of coral reef ecosystems and the elements that are most threatening. Additionally, this park will help Singaporeans reach the goals they have set for their city in improving the city's living environment and enhancing their natural environment.

Introduction

Oceans cover a vast majority of the earth's surface and provide large but finite amounts of resources for humans. We use the ocean for commerce and transport, minerals and energy, food and consumptive products, waste disposal, military uses, leisure and tourism. We spend considerable amounts of time researching and attempting to understand the ocean. Millions of species live in multiple types of habitats in the ocean. Many of these species travel long distances spending their lives in more than one ecosystem. One broad category of habitats that is of particular interest is coral reefs.

Coral reefs are interesting because there is still much unknown about the functions and processes of the organisms which reside in these habitats. Coral reefs have the highest biodiversity of any ecosystem found in the ocean and a majority of marine organisms spend at least one portion of their lives in the coral reef ecosystem (Moberg and Folke, 1999). Unfortunately, coral reefs are also one of the most threatened ecosystems. Climate change, pollution, and direct human impact are destroying coral reefs all over the world (Wilkinson, 1999).

The loss of coral reefs would be devastating to this planet ecologically and economically (Moberg and Folke, 1999). Coral reefs are major tourist attractions around the world and the tourism industry is one of the fastest growing potentially sustainable uses of the ocean. This industry employs thousands of people all over the world in developed and developing countries. Additionally, coral reefs are the breeding habitat for many commercial fish species (Roberts and Hawkins, 1999). The fishing industry is already experiencing the negative impacts of overfishing, and the loss of fish breeding areas would compound these effects. It will be difficult for fish populations to recover if they are to lose their breeding habitats. Fishing is an industry

that is very important to nearly every coastal country in the world and is a tradition that many could not live without.

Currently, few nations are attempting to protect coral reefs, and even less is being done to protect coral reefs at an international level (Hughes, et. al., 2003). A number of Marine Protected Areas (MPAs) have been established by nations that are beginning to recognize reefs should be conserved (Hughes, et. al., 2003). Often times, MPAs are the only protective and conservative measures that target coral reefs. Unfortunately, there are many challenges for MPAs including funding, management, and enforcement. MPAs are most typically funded by government agencies. Government funding can be unstable due to budget changes from year to year and changes in prioritization of that funding. For example, in the United States of America, funding for national security in times of war will be a priority over funding for conservation efforts such as MPAs (Male and Bean, 2005). Another challenge is that of management; it is difficult to have all stakeholders agree on the terms in which a MPA is managed. These disagreements lead to mismanagement or lack of management in order to please certain stakeholders. In the end, enforcing the regulations implemented in a MPA is difficult because of the challenges involved in tracking all actions and events taking place in the ocean.

Additionally, groups such as the United States Coast Guard have several mandates, including national security issues, illegal fishing, search and rescue efforts, which have higher priority.

Singapore is one of the many nations that have developed MPAs to attempt conservation and protection of their marine resources and habitats. The three MPAs in Singapore are Sungei Buloh Wetland Reserve (<http://www.sbwr.org.sg/>), Labrador Nature Reserve (http://www.nparks.gov.sg/nature_labrador.asp), and Southern Islands Nature Reserve.

Currently Sungei Buloh is the only reserve that is strictly dedicated to the preservation and

conservation of the natural habitat that exists in the northern wetlands of Singapore. Whereas the Labrador Nature Reserve that may have been preserved at one time, is now the residence of a large bulkhead and is being used as extra storage space for the nearby ports. The Southern Islands Nature Reserve houses the offices and laboratories of the Tropical Marine Science Institute (TMSI) and Agri-Food and Veterinary Authority (AVA) of Singapore's Marine Aquaculture Center. This nature reserve is far from preserving or conserving any part of the marine environment in this area due to the large amounts of human activity in the area. It is evident that Singapore could improve their efforts in protecting, preserving, and conserving their marine environment.

Clearly, there are many challenges that exist in the creation and maintenance of MPAs. There is potential for other forms of management that can be practiced to help conserve coral reefs. I have developed a plan for the creation of an artificial coral reef. This project would help the research and development aspects of coral reef conservation by implementing innovative techniques of regeneration and remediation. Coral reefs in Southeast Asia are being destroyed by sedimentation and burial at land reclamation sites. The goal of this project is to find a solution to some of these problems, while regenerating some of the lost coral reefs and contributing to the natural heritage that they embrace.

For the purposes of this plan I've chosen to develop the reef off the coast of Pulau Semakau, Singapore. This site was chosen because of its potential for coral growth, accessibility, and social priorities. Singapore was once surrounded by coral reefs that had some of the highest biodiversity in the world (Bellwood, et. al., 2004), but since the 1960's Singapore's land reclamation projects and port activity has buried or destroyed most of these reefs. One coral reef remains on Pulau Semakau near the project site which shows potential for

the biological growth of a new coral reef. This location was chosen because of the accessibility as a tourist attraction. Singapore as a nation has goals of increasing their tourism sector and has plans of developing Pulau Semakau into an island for leisure tourism. Finally, this project was based in Singapore because of their financial stability, affluence, and emerging interests in environment and environmental education, and desire to be global innovative leaders.

Over 60 islands and patch reefs once surrounded Singapore (REST, 2008). Since the 1980s, Singapore has lost close to half of the coral reef cover due to land reclamation projects to expand the city (Figure 1) (Dikou and Woesik, 2006). According to Glaser et. al.(1991), “Currently 10%, 5%, and 33% of the total land surfaces of Singapore, Hong Kong and Macau respectively comprise land reclaimed from the sea and these proportions will continue to rise.” Singapore will continue to destroy many of the surrounding coral reefs that exist today. Coral reefs once surrounded most of Singapore and Singapore’s reefs hosted some of the most unique species of coral and were important habitats for thousands of other marine species. Because Singapore is located on a very small area of land, the southern coral reefs are among the only natural habitats left. Tourists often come to Singapore only to catch one of the many inexpensive flights to Thailand to visit the coral reefs that reside off the coast of this Asian country (McGirk, 2005). While the tourists are still coming to Singapore, they are also spending their money in other locations due to the appeal of visiting coral reefs in neighboring countries. Singapore should be working to keep those ecotourists in Singapore to enhance their tourism industry; they can do this by protecting their natural coral reefs (Channel News Asia, 2005).

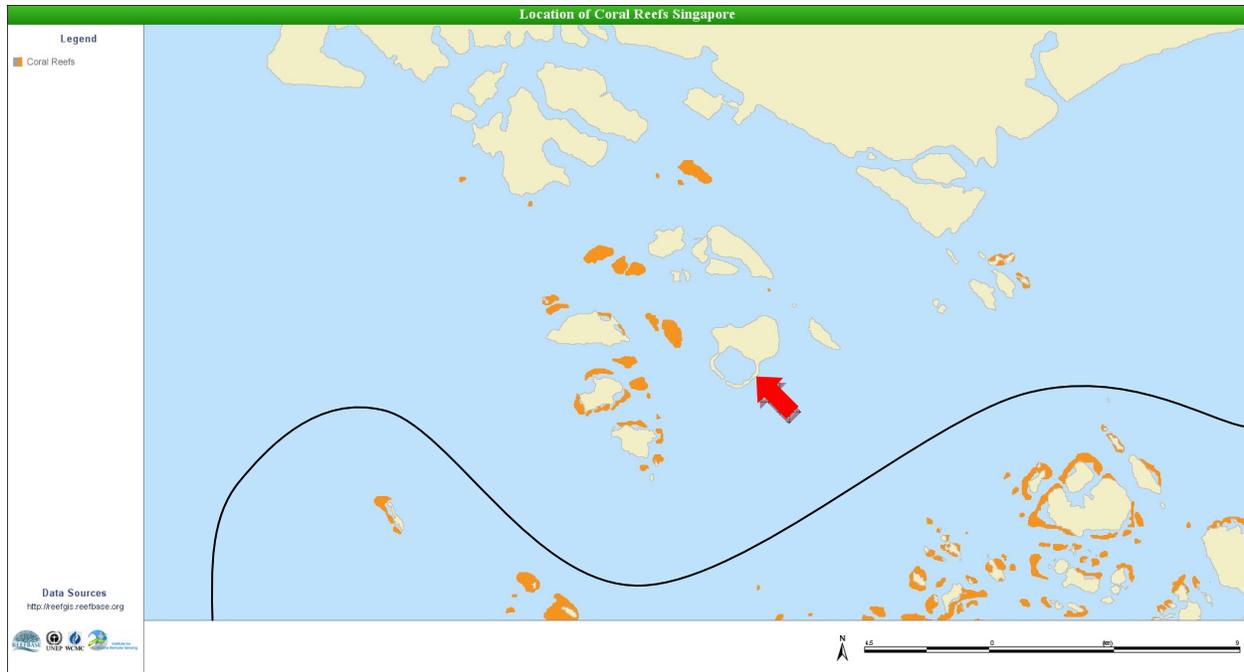


Figure 1. Map of remaining coral reefs to the south of the main island of Singapore. Pulau Semakau is in the middle of the map. The reefs near the bottom are part of Indonesia. (ReefBase, 2008)

Singapore is one of the ten wealthiest nations per capita in the world (CIA, 2008), making projects such as this artificial coral reef park feasible. There is no denying that the start-up costs of this project are high, but are also quite affordable. With contributions from the government of Singapore and private investors the start up costs, as previously quoted, can be met feasibly in Singapore. Singapore's financial success and stability are one of the many reasons why Singapore is a perfect location for this project.

Additionally, the environmental interest shown by the people of Singapore and the dedication to the environment that former Prime Minister Lee Kuan Yew instilled in the public, gives great support both morally and financially by the people of Singapore (Garden City Fund, 2008). Currently, Prime Minister Lee Hsien Loong supports environmental projects such as The Marina Barrage (Prime Minister's Office, 2008). This project consists of the construction of a dam built across the Marina Channel creating a freshwater lake in the middle of the city to act as

a tidal barrier. The Marina Barrage has three main purposes: supply water, flood control, and recreation to encompass a three-in-one project (Marina Barrage, 2008). A project like this is both innovative and unique making it worth the S\$226 million (Marina Barrage, 2008). The artificial coral reef park would also be innovative and unique, while financial manageable for Singapore at an estimated S\$3 million.

This project will include an educational component and self generated funding as well as conserving coral reef ecosystems and boosting tourism. All of these aspects provide for a comprehensive management plan that has some benefits over many of the existing management practices in place today.

Project Proposal

Since Singapore gained their independence in 1965, they have gone from an undeveloped nation to a developed or overdeveloped nation in 2008 (US Embassy, 2008). This rapid development has been very stressful on the environment of Singapore especially the coral reefs. Singapore is renowned for their land reclamation projects that have expanded their small island nation to allow for increased development and to support the growing population. These land reclamation projects have essentially buried all of the coral reefs that existed naturally in the area. The loss of coral reefs has severely depleted habitat for marine organisms and the biodiversity of corals and species that live within coral reefs. Land reclamation also increased the amount of sedimentation in the water which decreases the water quality making it more difficult for corals to survive in the area. In addition to sedimentation, there are often 800 commercial vessels that port in Singapore each day and with that water quality is decreased due to pollution from a variety of ship and port sources. Because most reef habitats have been destroyed, innovative approaches are needed to replace the losses.

Pulau Semakau, the purposed site for this project, is an island that was joined with another island Pulau Sekeng in 1995 to form the larger island that is now considered Pulau Semakau. The islands were joined by the construction of a seawall made of impermeable retainer marine clay. This seawall was then extended to seven Kilometers toward the south in order to house Singapore's only remaining landfill. The island was divided into two sections; the first section was then divided into eleven cells and the second section remains undivided. Incinerated waste from the main island of Singapore is barged to the Semakau Landfill where the ash is then deposited into one of the many cells. Once a cell has been filled the ash is covered with soil and plants begin to generate. There is no artificial plantation that takes place within the cells and only natural regeneration occurs. Once the eleven cells in section one are filled, section two will be divided into cells and those will be filled as well.

The landfill opened in April 1999 and is projected to meet Singapore's landfill space beyond 2040. The goal for Singapore is to reduce their waste and increase their recycling abilities by 2040 to no longer require landfill use. Singaporeans hope that this is the last landfill they will ever need. This island has become an ecotourism destination promoting activities such as intertidal walks, bird watching, sport fishing, star gazing, and educational tours of the landfill facility. These activities will continue to grow in popularity as the landfill continues to fill. Once the landfill is full there are several plans to develop Pulau Semakau into a tourist destination with resorts, casinos and a golf course. This artificial reef will fit nicely into the future plans for Pulau Semakau as it develops into a tourist attraction in the last phase of this project.

Since coral reefs once flourished in this area, and there are still some reefs that exist in Singapore, there is potential for the coral reefs to regenerate. There is evidence on some of the

seawalls of Pulau Semakau, which are approximately 20 years old, that corals will regenerate on an artificial surface, near where they once occurred naturally. Water quality can be expected to improve as reclamation slows and increasing environmental regulations better manage ship pollution. All of these events are favorable for the future growth and health of coral reefs in the area.

The proposed project includes an artificial coral reef recreation park with a strong education element that would be financially self sustaining. The mission of this project is to include conservation, recreation, and education to increase awareness and understanding of coral reef ecosystems and the elements that threaten ecosystem function. The conservation goals will be to augment and preserve a coral reef ecosystem that is indigenous to the shores of Singapore. This park will help Singapore reach the goals they have set for their city in improving the city's living environment and enhance their natural environment (Urban Redevelopment Authority, 2008). Finally, the education element of this project will be applicable to people of all ages to help them learn more about coral reefs and how to better protect their tropical marine heritage.

The project proposal consists of four phases over the course of several years leading to a conservation project that is also an educational facility and a tourist attraction. Phase I includes the construction and the development of an artificial coral reef. Phase II will be the development of the educational elements that this project has to offer. Phase III will be the transitional phase between educational facility and tourist attraction, where the artificial reef becomes a family park. Finally, Phase IV will be the development of an ecotourism attraction that will have benefits for all stakeholders. The remainder of this paper will explain each of the phases and will highlight the major attributes of the project.

1.1 - Creation

Phase I is a three year project in which the main goals are to establish a young coral reef and develop the conservation efforts of the project. In the first year, the construction of the coral reef structure will be completed. This artificial coral reef will be located on the southwestern seawall of Pulau Semakau (Figure 2). The park will consist of flume-like porous concrete structures that visitors will eventually swim or float through (Figure 3). The one side of the flume will be made of porous concrete while the other side will be the seawall that currently exists at Pulau Semakau. This flume-like structure will be approximately two Meters deep at mean low water, twenty Meters wide, and a half Kilometer long. Flume bases will be constructed of cement, floated or barged to the site and placed on a seawall constructed to accommodate it. Once the flume structures are in place it will be seeded with coral rubble from sites being reclaimed. Sponges, soft corals and hard corals will begin to grow on the structure; this will also take place in the first year.



Figure 2. Map of Paula Semakau. (Google Earth, 2007)

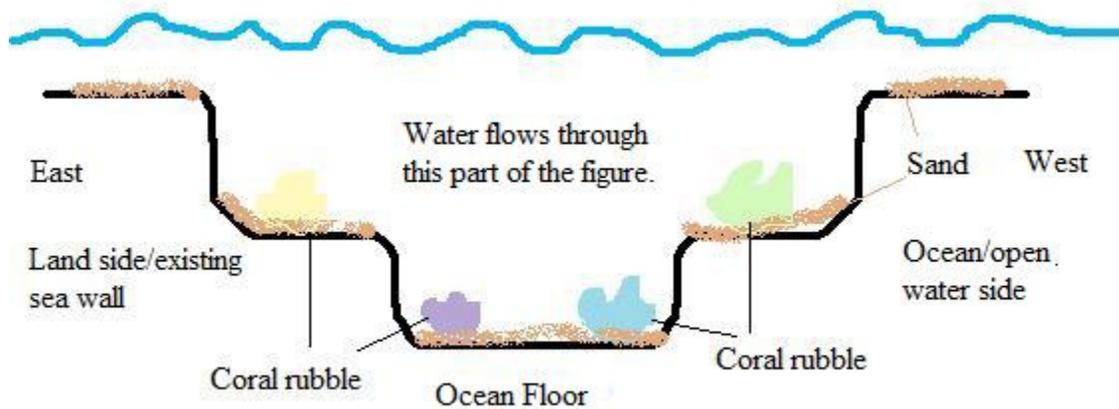


Figure 3. Diagram of flume-like structure of the artificial coral reef. Including sand and coral rubble as partial habitat.

It is important to understand that some of the fastest growing corals species in the world reside in Southeast Asia in the Singapore region. Additionally, there are soft corals and colorful sponges that colonize and grow more quickly than hard corals. It will be necessary to promote the colonization of attractive species, those species that not only grow quickly, but have vibrant colors and interesting shapes or characteristics. This will attract more visitors and government attention essential to the support of this project. The colonization of these species that are attractive and fast growing will provide the proper environment for slower growing corals to establish themselves and grow successfully.

Additionally, it is essential to know that there are currently parts of Pulau Semakau that support healthy coral reef systems and can be a source of propagules. While most of the natural coral reefs in Singapore have been buried, there is a coral reef that lies on the southeastern shore of Pulau Semakau (Figure 2). The plan is to remediate what has been lost while developing a showcase facility as well as an educational facility. Because corals exist near the project site the flow conditions at the site should support another coral reef in the area.

Also during the first year of Phase I, coral rubble will be deposited in the project site to catalyze the growth of corals. These coral rubble pieces will only be extracted from areas in which will be buried or eventually destroyed by some sort of development project to ensure that the development of this project will not jeopardize the health of any existing coral reefs. These coral rubble pieces will also provide the chemical stimulation of coral larvae to colonize in the project site. For the remainder of the first year of Phase I, strict monitoring will be implemented to ensure the growth of corals and high biodiversity. This monitoring will be done by a post doctoral fellow and technician.

If corals do not start to establish themselves during the second year of Phase I transplantation from sites being reclaimed will be attempted. Corals will only be harvested from areas that are planned for development projects in which they would be buried or destroyed inevitably. In no way will this project support the harvest of healthy coral from preserved reefs or support the illegal aquarium trade. The project site will be closely monitored for growth and increased biodiversity.

The third year of Phase I will be dedicated to documenting the growth of the artificial reef. Over years the coral reef should develop into a flourishing ecosystem. While the construction and development of the island of Pulau Semakau continues, the coral reef will have time to develop. Once the island is fully developed and tourists begin to frequent it more often the coral reef will be developed and complete for visitors to come experience this unique habitat.

The following outlines a primary budget for Phase I including the construction and monitoring of the flume structure for three years (Table 1.)

Table 1. Estimated budget for Phase I of the artificial coral reef project. All amounts are calculated in U.S. Dollars.

Description	Computation	Estimated Cost
Construction		
Porous concrete flumes – 0.5 km	(\$2,100/m X 500)	\$1,050,000
Placement of flumes	\$100,000	\$100,000
Tools		
Camera - digital, underwater	\$400*	\$616
Scuba gear	\$2,000*	\$3,080
Boat - borrow from TMSI	(\$320/trip X 12)*	\$5,914
Ferry rides - half day	(\$320/trip X 12)	\$3,840
Additional research equipment	\$1,000*	\$1,540
Transportation of coral rubble		
Barge trip	(\$7,000/trip X 3)	\$21,000
Monitor		
Post doctoral fellow - full time	\$37,000**	\$72,365
Technician - full time	\$15,000**	\$29,337
Management		
Senior scientist - 10% time	\$8,000**	\$15,647
Total		\$1,303,338

* 54% overhead

** 27% fringe and 54% overhead

This park fits nicely into the culture of Singapore, inventive and advanced technology, superior business understanding and stability, historic interest in managed environments, and emerging interest in natural and living environment. This artificial coral reef park will provide innovative elements in conservation, tourism, and education. A conservation project like this has never been created before with the intension of recreating an ecosystem that was once found naturally in an area, but has been destroyed through development and pollution (Raffles Museum of Biodiversity Research, 2008). This project will be at the front lines of the evolution of conservation and ecosystem based management strategies. Creating an artificial reef will not only reinstate the natural environment that once existed in this area, but it will allow

Singaporeans to better understand their marine heritage and insight to their past. The self-sustaining financial structure of this conservation project makes it unique and provides a high probability of successful longevity. This park will have the appearance of a fanciful park much like Disneyland Park (<http://disneyland.disney.go.com/disneyland/>), The Singapore Night Safari (<http://www.nightsafari.com.sg/>), or Sea World (<http://www.seaworld.com/>), but will be managed as a non-profit organization, unlike most large commercialized amusement parks. The goal is to obtain enough funds to maintain and expand the ecological integrity of the artificial coral reef park and to update the education program periodically. Once these techniques and procedures are established and perfected, they can be used to remediate large stretches of seawall in Singapore and other places around the world.

Remediation and conservation are the main elements of this artificial coral reef park; the education program included in this project will be effective in teaching people about the importance of coral reefs, how they live, and how to better protect them. People with all different backgrounds and different levels of education will be able to learn about coral reefs. Children at the elementary level will be engrossed with the colorful underwater park that they enter and will be able to observe nature in one of its most diverse ecosystems. Young adults will be able to visit the park with their secondary school class on a field trip to expand their understanding of nature through biology, chemistry, and earth sciences. These field trips could be coupled with the current tours provided by the Semakau Landfill to provide a multidimensional view. Students in the highest levels of schooling along with scholars will be able to continue to expand their understandings of coral reefs and conservation. Families will be able to visit the park and be enlightened in several different aspects at all levels through a diverse array of media and stimulus. Each person will leave the park with a better understanding of the

coral reef ecosystems and a greater appreciation of how these ecosystems provide for the oceans at large.

Tourism is the last main element that is included in this proposal; it is a quickly growing industry that must also be addressed. While Singapore does not solely depend on the tourism industry, tourism generates a large amount of revenue for the country and has been a growing industry for over 50 years now (World Tourism Organization, 2008). The park would appeal to people all over the world for several reasons including the general interest that tourists have for coral reefs when visiting coastal areas as well as the unique experience they would have at this park. This park would be a different experience than anywhere tourists have been before. Additionally, this park would appeal to the mass tourist who is interested in large group tours and remaining in the tourist bubble as well as the ecotourist who is more interested in experiencing nature and interacting with the culture.

1.2 - Conservation

Climate change, pollution, human contact, and chemical runoff are a few of the many stresses that are threatening the health of coral reefs all over the world. Because coral reefs have such high biodiversity (Reaka-Kudla, 1997) it is important to determine what or who will protect and preserve coral reef habitat through conservation projects. Currently, coral reef conservation is attained by generating Marine Protected Areas (MPAs). MPAs have been established all over the world to help protect and preserve coral reefs and other ocean habitats, critical species, and marine resources. According to ReefBase, a global information system for coral reefs, there are 1,084 MPAs that contain coral reefs throughout the world (2008). There are currently three MPAs in Singapore, but there are several others in neighboring nations (Figure 4).

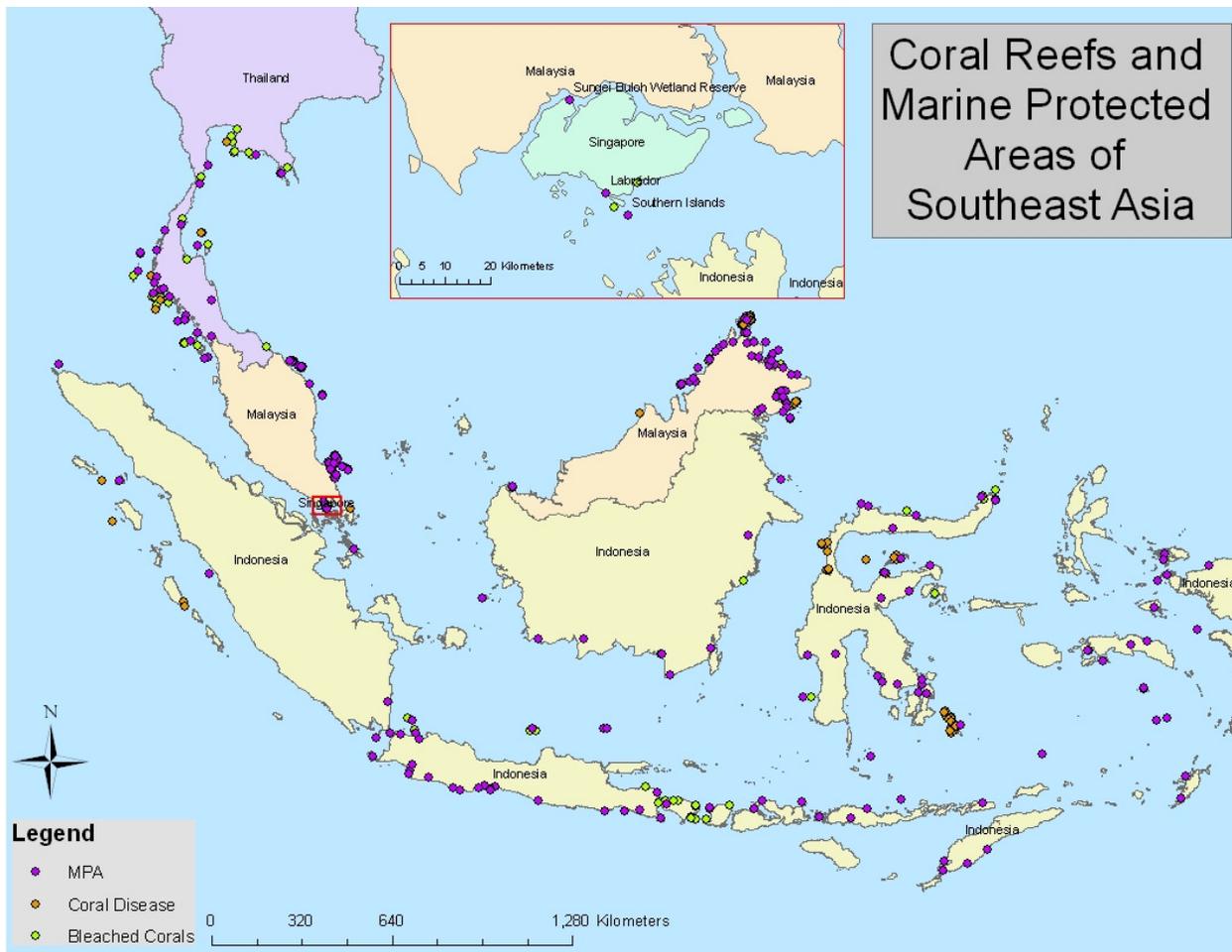


Figure 4. Summary map of MPAs and coral reef disease and bleaching incidence throughout Southeast Asia. Data compiled from ReefBase and GeoCommunity (2008).

MPAs use a variety of regulations including zoning, restriction of activities, limits on visitation, and prevent destructive practices to impose protective measures. Zoning is a common management method and is used in the Great Barrier Reef in Australia. The Australian government has developed a series of levels of protection for each of the different zones which is summarized in Table 2. This is just one example of how MPAs are used as a conservation method.

Table 2. General activities guide to the zoning system in the Great Barrier Reef Marine Park (Australian Government, Great Barrier Reef Marine Park Authority, 2008).

Key: X = not allowed Permit = allowed with permit only Y = allowed	General Use Zone	Habitat Protection Zone	Conservation Park zone	Buffer Zone	Scientific Research Zone	Marine National Park Zone	Preservation Zone
Aquaculture	Permit	Permit	Permit	X	X	X	X
Bait netting	Y	Y	Y	X	X	X	X
Boating, diving, photography	Y	Y	Y	Y	Y	Y	X
Crabbing (trapping)	Y	Y	Y	X	X	X	X
Harvest fishing for aquarium fish, coral and beachworm	Permit	Permit	Permit	X	X	X	X
Harvest fishing for sea cucumber, trochus, tropical rock lobster	Permit	Permit	X	X	X	X	X
Limited collecting	Y	Y	Y	X	X	X	X
Limited spearfishing (snorkel only)	Y	Y	Y	X	X	X	X
Line fishing	Y	Y	Y	X	X	X	X
Netting (other than bait netting)	Y	Y	X	X	X	X	X
Research (other than limited impact research)	Permit	Permit	Permit	Permit	Permit	Permit	Permit
Shipping (other than in designated shipping area)	Y	Permit	Permit	Permit	Permit	Permit	X
Tourism programme	Permit	Permit	Permit	Permit	Permit	Permit	X
Traditional use of marine resources	Y	Y	Y	Y	Y	Y	X
Trawling	Y	X	X	X	X	X	X
Trolling	Y	Y	Y	Y	X	X	X

Even though MPAs are one of the most popular conservation programs, funding these projects to enable enforcement is routinely a limiting factor. Coral reef conservation management is difficult because individual corals and particularly entire ecosystems develop

only over long periods of time. It routinely takes years to observe significant changes. Therefore conservation management is on a time scale of years or decades (Connell, et. al., 1997). Relying on government funding is risky for the livelihood of a conservation project because priorities of national governments depend on local and global politics and can change frequently and suddenly. Often national governments do not have environmental and natural resource conservation as a high priority and do not provide funding for conservation projects.

The artificial coral reef park will be dedicated to education on the remediation, preservation and protection of coral reefs in the context of their biological importance and value to Singapore's natural heritage. The loss of coral reefs, a vital habitat, could have detrimental effects on other aspects of life in Singapore such as fishing and tourism. Natural areas are also important for the well being of Singaporeans. They often need a place to retreat to and remove themselves from the stresses that are associated with big city life. Because of these reasons it is important that the support of conservation projects be maintained for long periods of time and not be determined by political needs and wants.

Recognizing that it is unrealistic to expect long term federal funding, the revenue generated from this proposed artificial coral reef park will be used to maintain the conservation aspect of the park as well as help enhance the project in the future. It is important to find a conservation project such as this that can be self sufficient in order to continue the long term management tools and goals. Singapore, like many other countries, is realizing the importance of conserving natural landscapes and heritage.

This project is also unique in its ability to protect an ecosystem from its origin, which will provide a protected habitat for coral species and the other species that rely on coral reefs. Many of the surrounding natural coral reefs have been destroyed or degraded by the great

amount of development that has occurred in Singapore (Raffles Museum of Biodiversity Research, 2008). This development has included intensive dredging which increases sedimentation in coral reefs which can lead to disease and degradation in corals (Rogers, 1990). Protecting this artificial coral reef will be essential during the development stages in order to allow the coral reef to grow to a healthy state. Once the coral reef is developed protection will be maintained in order to provide a healthy ecosystem and to enhance the aesthetic appeal for visitors. Once this artificial coral reef develops many species of fish and other marine invertebrates will rely on this synthetic ecosystem just as they have relied on natural coral reef in the past (Sale, 1977). Conserving this artificial coral reef will provide habitat for many species that have lost critical habitat in the past due to the degradation of the surrounding natural coral reefs. By providing the area with a healthy coral reef other species such as sea anemones, sponges, small and large fish, and many others, will also flourish (Knowlton, 1998).

The artificial coral reef as a conservation project will also increase the interest and awareness of coral reefs and the conservation issues surrounding coral reefs, making Singapore a global leader in developing remediation technology. In order to be ultimately successful as a conservation project, it is important to increase the awareness of the importance of coral reefs and the activities and practices that threaten these unique ecosystems. This project will capture the attention of local and international scientists, conservation organizations, tourism operators, and many others all over the world. Additionally, the educational component of the artificial coral reef park will educate the general public including local school children and international tourists. A project like this could make Singapore a worldwide leader in coral conservation and protection efforts and has the potential to increase the understanding of coral reefs.

2.1 - Education

One of the fundamental purposes of this project is education of coral reefs and the issues surrounding coral reefs. Education of coral reefs will make Singaporeans more aware of their natural heritage and will encourage them to further protect and preserve their special coral ecosystems. It is important that Singaporeans are educated on the importance of coral reefs and what they can do to help protect them. This is important because Singapore is innovative and a leader in science and technology. The more they know and understand about coral reefs there will be an increased awareness of issues surrounding coral reefs, and there will be an increased effort to conserve these critical habitats. If Singapore makes an effort to conserve coral reefs they can be an example to other countries in Southeast Asia and around the world. It is essential that an education component is incorporated into the artificial coral reef park to educate visitors about what they will see at the park, how to protect the ecosystem they will explore, and why it is important that this ecosystem is protected. Because a large proportion of visitors to this park will be families with young children it is important that the education tools relate to both parent and child.

Once the coral reef has developed some and is stable enough to endure visitors Phase II will begin. This phase will begin by inviting small groups of people to come with trained field guides such as the group that calls themselves The Naked Hermit Crabs (<http://nakedhermitcrabs.blogspot.com/>), to tour the coral reef. On these small tours the guides will point out interesting species and also inform the visitors on what coral reefs are, why they are important to the environment, and why they are an essential habitat that is currently endangered throughout the world. When the site becomes more and more popular a visitor's center will be erected and it will include pictures and bulletins on corals and the issues that

surround coral reefs. Eventually the site would be included in the science curriculum of middle school students in Singapore. And once the artificial reef becomes a tourist attraction the visitors facility will look more like a fanciful aquarium with high technology videos and interactive exercises.

2.2 – The Experience

The education program at the artificial coral reef park will begin as soon as they enter the facility. Once visitors have purchased their tickets they will be invited to watch a short educational video that takes them on a journey under the surface of the ocean to coral reefs. The video will be comprised of segments describing what exactly a coral reef consists of and how the ecosystem functions. Other segments of the video will describe threats to coral reefs and why it is important to protect these highly diverse ecosystems. The final segment of the video will be an instructional presentation of how to act appropriately and properly at the park by refraining from touching any coral while on their tour of the park and things of that nature.

This educational video will present the viewer with the broad understanding of important issues that include coral reefs. Stress will be put on the high biodiversity that coral reefs support and how thousands of species rely on coral reefs. Additionally, the video will help visitors understand the links between fish species that we consume and the coral reef habitat they use for breeding grounds. The video will also explain some of the events and processes that are threatening coral reefs including, climate change, pollution and sedimentation, and direct anthropogenic interaction (touching, breaking, collecting, etc.). The international aquarium trade is also a major issue that will be addressed in this video. Corals are harvested and then sold for aquariums, neighboring Indonesia is the largest exporter of coral and this is a major threat to coral reefs in the region. And the video would finish up with a depiction of what the

consequences would be if coral reefs were to disappear including decrease in commercial fish stocks and decreased biodiversity.

Initially, the park will have small groups of visitors, but will eventually grow as the island of Pulau Semakau grows. In the early phases the artificial reef will have less than 150 visitors a day, as the attraction grows there will be an increase of visitors up to 600 visitors a day. Eventually the management of the artificial reef will have to determine if there is a limit to the number of visitors the reef can endure without compromising the health of the ecosystem. This artificial coral reef park will attract a large audience mostly comprised of Singaporean families, students and eventually international tourists. Because of the broad audience that is predicted to venture into this park it is important that this educational video appeals and applies to people of all ages and backgrounds. This is best accomplished by including material that all age groups can understand and characters that appeal to all age groups, much like the strategy of Underwater World in Singapore (<http://www.underwaterworld.com.sg/>). In order to make sure that some of these complicated topics about biodiversity and environmental threats are understood completely, they must be simplified. Incorporating animated characters into the video will capture the interest of children and help them understand these important issues.

Repeat visitors will have the option to skip this introduction video and explore the aquarium part of the visitor's center at their leisure. A second video will instruct visitors on proper behavior and activities while touring the coral reef. This video will not be optional and all repeat visitors will be required to watch this video. Additionally it is important that tourists from other nations will be able to understand this video. Tourists will be able to take advantage of language headphones where they can choose from a list of the most common languages of the

tourists that visit Singapore along with subtitles, so that they can also understand the video and take away the important messages about conservation and preservation.

After viewing the video, visitors will be invited into a small aquarium where they can explore more closely some of the species and issues discussed in the video. This room will include a small number of aquariums where species of particular interest or importance will be on display so that visitors will be able to get a guaranteed closer look at these organisms. Additionally, a small number of touch tanks will be open to visitors to touch and feel some of the species that they will see in the park. This will allow park employees a chance to describe in more detail some of the species and also satisfy the urge some visitors have for touching organisms and therefore preventing them from touching the coral in the park. Park employees will be available in this room to answer any questions that the visitors might have about coral reefs and how they contribute to ocean ecosystems.

In addition to enhancing the knowledge of the general public that visits the park, this artificial coral reef will be an opportunity for institutional research and observation. On a regimented basis, scientist will be able to research more about coral reefs and the benefits that they have to the world. This project will allow for extensive research on artificial coral reefs and the potential for coral reef recovery. Continued development on artificial coral reefs and the impacts on surrounding ecosystems could be very beneficial science for conservation all over the world. The park could potentially assist Singapore in having some of the leading science on coral reefs and coral reef technology.

The final educational component to the artificial coral reef would be an interactive web site for the park. It is important to keep in mind that this park would be part of an overall conservation project. In order to best describe the purposes and environmental factors a web site

would be used to have interactive features for people of all ages. It would include extensive description of goals and purposes as well as descriptions of species and their interaction with one another to create the coral reef ecosystem. Additional sections would be included with games for kids and activities to fit their age group. This website would be a sophisticated version of some of current websites like <http://www.coralfilm.com/> or web sites for attractions such as the Singapore Night Safari (<http://www.nightsafari.com.sg/>), Jurong Bird Park (<http://www.birdpark.com.sg/>), and Underwater World (<http://www.underwaterworld.com.sg/>).

The three main educational components: the video and aquarium, the institutional research, and the interactive website, are the main educational components to the artificial coral reef park. It is important to inform more people about the uses and importance of coral reefs so that more people will realize the need for protection. These three components are the formal make up of the educational portion of the artificial coral reef park, but the true educational benefits will simply be the visitor's experience of swimming through the coral reef and observing nature for themselves. Once the visitor can experience this coral reef they will have a much greater interest in the protection and conservation of this unique ecosystem.

3.1 – Family Park

In order to develop this artificial coral reef into a self-sustaining conservation park, it will have to generate some form of revenue. This phase could also be incorporated to a joint tour of the Semakau Landfill and the artificial coral reefs. The best way for a park like this to generate revenue is to charge an entrance fee. Once Phase I and Phase II of this park are complete, a healthy coral reef will be established and the parks popularity will be anticipated based on the number of visitors during Phase II. Once the artificial coral reef has become a site of interest by many it will develop into a family park during Phase III by charging a small entrance fee to enter

the visitor center and explore the coral reef. This will allow this project to generate revenue to help support the maintenance and future development of the site.

While the start-up costs of the artificial coral reef park are demanding, the maintenance costs for investors will be minimal. The revenue generated by the artificial coral reef park will be directly deposited back into the project to continue the conservation efforts. These funds will be used to maintain and upgrade the coral reef structure and habitat as well as the education and tourism marketing sectors of the project. One of the main purposes of this project is to develop a self-sustaining conservation program in order to protect, preserve, and learn about coral reefs on a long-term scale. Many conservation projects are terminated or scaled back significantly because long-term funding is abandoned (Focused Performance, 2008). Conservation projects rely on longevity to be successful because many ecological responses take years or decades to observe significant changes. Without continued funding many of these projects are simply wasted amounts of time and resources because no significant changes can be observed or managed.

4.1 - Tourism

There are three main purposes for the creation of an artificial coral reef park: conservation, tourism and education. In this section I will focus on a description of the tourism contributions and challenges that will be included in this project. Tourism is a global industry that has been growing significantly since the 1950s (World Tourism Organization, 2008). In 2003, the tourism sector contributed 5% of Singapore's gross domestic product and is considered one of the largest service industries in the island nation (Reuters). Because Singapore is such a small country and has few natural resources or land for agriculture and textiles, it is important that they continue to add and improve the tourist industry in their country. Because of

Singapore's many unique characteristics there are many ways that this proposed recreational park will contribute to tourism in Singapore, despite the challenges that may occur.

While this artificial coral reef park may have the feel of a fanciful play area it is actually an ecotourism site where people will learn about the importance of coral reefs, mitigating reef destruction, and the environmental factors that are threatening corals all over the world. The visitors will get to experience coral reefs through video, touch tanks and aquariums, and finally, actively snorkeling or boating through the coral reefs. Additionally, the 'ecotourist' will be able to experience the culture of Singapore by interacting with the employees of the park and gaining an understanding of the interest that the people of Singapore have for nature and technology. Dr. Yaacob Ibrahim, Minister for the Environment and Water Resources, in a speech at the Committee of Supply Debate, describes the environmental interest of the community of Singapore, "Besides collective community efforts, we want people to feel that they have a personal stake in keeping the environment clean and beautiful. To this end, we will create more opportunities for the community to enjoy and appreciate our environment and water resources" (2005).

Singapore has several current initiatives to make their nation more environmentally friendly including The Singapore Green Plan 2012; Active, Beautiful, Clean Waterways for All (ABC); and Gardens of the Sea. The Ministry of the Environment and Water Resources in Singapore with the Singapore Green Plan 2012 hope to go "Beyond Clean and Green Towards Environmental Sustainability" (2008). While the PUB's ABC initiative hopes to "beautify Singapore's waterways" and is considered Singapore's blue initiative (2006). And Gardens of the Sea is a grant received by the Tropical Marine Science Institute (TMSI) which is part of the National University of Singapore (NUS). Gardens of the Sea is inspired by the idea of Singapore

being the Garden City; they wanted to extend this idea into the ocean by revitalizing marine habitats such as coral reefs. This project proposal accentuates many of the ideas in these plans that are currently being implemented in Singapore.

This family oriented nature park will help increase the tourism industry in Singapore and will enhance the existing plans of tourism development. Singapore is currently planning to develop the island of Pulau Semakau, which is where this artificial coral reef would be constructed. The artificial coral reef park would be a nice side trip from the bustling of the city for many locals and tourists. This park would be one of the first of its kind and would easily be listed as one of the “20 Unique Things to do in Singapore” or “Top 10 Family Experiences” on www.visitsingapore.com.

The tourism sector in Singapore has been greatly increasing over the past ten years, from 7.1 million visitors in 1997 to 9.7 million visitors in 2006; with more visitors comes more revenue (Singapore Tourism Board, 2008). The Singapore Tourism Board hopes to continue these trends of increased visitors and increased revenue generated. The artificial coral reef park would help attract more visitors to Singapore and provide another unique and interesting tourist attraction. However, to maintain the integrity of the coral reef there may need to be a limit on the number of visitors that can explore the coral reef each day. This number would have to be determined by the management of the artificial coral reef.

Despite the benefits this artificial coral reef park will have on the tourist industry in Singapore, there will be some challenges to overcome. One of those challenges would be ensuring the safety of all the visitors to the park. All visitors will be required to wear lifejackets while in the water; to provide everyone with the necessary equipment to be safe and feel comfortable in the water. Additionally, lifeguards will be posted alongside each of the coral reef

flumes to help any distressed swimmer. Another challenge will be to ensure that everyone that visits the park will be able to enjoy all the park has to offer including the elderly, those with disabilities, those that do not feel comfortable in the water, or those that are simply unable to swim. For these visitors we will provide the option to view the artificial coral reefs while onboard glass bottom row boats. This tour will provide all visitors the opportunity to experience the artificial coral reef and to observe the natural system within the park.

Conclusion

The future of coral reefs near Singapore is bleak. Conservation and remediation of the few remaining natural coral reefs is needed. The conservation project proposed here incorporates several elements that coordinate well with the goals that Singapore has as a nation as well as initiatives that are already in place. Singapore very literally is a growing country and they are going to continue to develop outwards as much as they possibly can and these land reclamation projects will continue to destroy the coral reefs of Singapore unless something is done to prevent it.

This project incorporates the ideas of conservation, education, and tourism in a realistic view. This exact project may not be realistic for all nations, but it is for a wealthy nation like Singapore and can be used as a demonstration and example for coastal nations all over the world. This artificial coral reef park would be the first of its kind and would mark Singapore as the leaders in coral reef remediation and conservation technology. It will be an example where a conservation project can appear as a fanciful tourist attraction by allowing people to explore this ecosystem and generate revenue, but also protect the natural environment simultaneously. This concept is the future of conservation; scientists and conservationist must start being more realistic in terms of society and economy.

Acknowledgements

I would like to give special thanks to my advisor Dr. Dan Rittschof, who helped me through my entire master's curriculum as well as this master's project. He was able to show me Singapore from several different angles as he led our class through the small country and he supported my ideas when others rejected them. I would also like to thank conservationist Ria Tan who provided me with thousands of pictures of corals and the marine environment of Singapore as well as led us through the coral rubble of Pulau Semakau not once, but twice. Thanks to N. Sivasothi, my first introduction to Singapore and an inspiration with his conservation work at Chek Jawa. Thanks to scientists Serena Teo and Tsai Mun Sin who helped me understand the realities of Singaporean politics and have given me the opportunity to help them with the Gardens of the Sea grant.

And of course I wouldn't have been able to complete this project without the love and support from my friends and family, especially – my parents, my grandparents, Joe Bari, Lisa White, and Tony Rafferty.

Sources

Australian Government, Great Barrier Reef Marine Park Authority. Zoning Maps. Site last visited Feb 28, 2008. http://www.gbrmpa.gov.au/corp_site/management/zoning/zoning_maps.html

Bellwood, D.R., Hughes, T.P., Folke, C. and Nystrom, M. Confronting the coral reef crisis. *Nature*. Jun 24, 2004. Vol 429, P 827-833.

Central Intelligence Agency. The World Factbook. Site last visited Feb 18, 2008. <https://www.cia.gov/library/publications/the-world-factbook/rankorder/2004rank.html>

Channel News Asia. Innovative Singapore turns Semakau island into eco-tourism attraction. Aug 29, 2005. Site last visited Apr 24, 2008. Article viewed at <http://www.wildsingapore.com/news/20050708/050829-1.htm>

Connell, J.H., Hughes, T.P., and Wallace, C.C. A 30-year study of coral abundance, recruitment, and disturbance at several scales in space and time. *Ecological Monographs*. Nov, 1997. Vol 67, No 4, P 461-488.

Dikou, Angela and Van Woelik, Robert. Survival under chronic stress from sediment load: special patterns of hard coral communities in the southern islands of Singapore. *Marine Pollution Bulletin*. Nov 2006. Vol 52, Is 11, P 1340-1354.

Focused Performance. Top 10 Sources of Project Failure. Site last visited Feb 18, 2008. <http://www.focusedperformance.com/toptenpm.html>

Garden City Fund. Site last visited Feb 18, 2008. <http://www.gardencityfund.com.sg/>

GeoCommunity: The premier portal for geospatial technology professionals. Site last visited Apr 20, 2008. <http://www.geocomm.com/>

Glaser, R., Haberzettl, P., and Walsh, R.P.D. Land reclamation in Singapore, Hong Kong and Macau. *GeoJournal*. Aug 1991. Vol 24, No 4, P 365-373.

Google Earth. 2007. Site last visited Apr 20, 2008. <http://earth.google.com/>

Hughes, T.P., Baird, A.H., Bellwood, D.R., Card, M., Connolly, S.R., Folke, C., Grosberg, R., Hoegh-Guldberg, O., Jackson, J.B.C., Kleypas, J., Lough, J.M., Marshall, P., Nystrom, M., Palumbi, S.R., Pandolfi, J.M., Rosen, B., Roughgarden, J. Climate change, human impacts, and the resilience of coral reefs. *Science*. Aug 15, 2003. Vol 301, No 5635, P 929-933.

Ibrahim, Yaacob. Committee of Supply Debate. Mar 8, 2005.

Knowlton, Nancy. The future of coral reefs. *Proceedings of the National Academy of Sciences USA*. May 8, 1998. Vol 10, P 5419-5425.

Male, Timothy D. and Bean, Michael J. Measuring progress in US endangered species conservation. *Ecology Letters*. Sep, 2005. Vol 8, Is 9, P 986-992.

Marina Barrage. Creating a reservoir in the city. Site last visited Feb 18, 2008.
<http://www.pub.gov.sg/Marina/about.htm>

McGirk, J. Tourism, scuba diving destroying Phuket's coral reefs. Cyber Diver News Network. Apr 21, 2005. Site last visited Mar 3, 2008. <http://www.cdn.info/news/eco/e050421.html>

Ministry of the Environment and Water Resources. Site last visited Apr 16, 2008.
<http://app.mewr.gov.sg/sgp.asp?cid=114&nid=114&id=SAS434>

Moberg, Fredrik and Folke, Carl. Ecological goods and services of coral reef ecosystems. Ecological Economics. May, 1999. Vol 29, Is 2, P 215-233.

Prime Minister's Office. Prime Minister's New Year Message 2008. Site last visited Feb 18, 2008.
<http://www.pmo.gov.sg/News/New+Year+Message+2008.htm>

PUB. Waternet. Apr/May 2006.

Raffles Museum of Biodiversity Research. National University of Singapore. Marine Diversity. Site last visited Feb 28, 2008. <http://rmbn.nus.edu.sg/research/marine/marine%20diversity.htm>

Reaka-Kudla, Marjorie L. A Global Biodiversity of Coral Reefs: A Comparison with Rain Forests. Chapter 7 of Biodiversity II: Understanding and protecting our biological Resources by Wilson, Don E. 1997. Joseph Henry Press,

Reef Ecology Study Team (REST), National University of Singapore. Coral Reefs of Singapore. Site last visited Mar 3, 2008. <http://coralreef.nus.edu.sg/index.html>

ReefBase: A Global Information System for Coral Reefs. Site last visited Apr 20, 2008.
<http://www.reefbase.org/main.aspx>

Reuters on CNN.com. Singapore: Tourism hit by war, virus. Mar 25, 2003. Site last visited Jan 23, 2008. <http://www.cnn.com/2003/TRAVEL/03/25/leisure.singapore.tourism.reut/index.html>

Roberts, Callum M. and Hawkins, Julie P. Extinction risk in the sea. Trends in Ecology and Evolution. Jun 1, 1999. Vol 14, Is 6, P 241-246.

Rogers, Caroline S. Responses of coral reefs and reef organisms to sedimentation. Marine Ecology Progress Series. April 5, 1990. Vol 62, P 185-202.

Sale, Peter F. Maintenance of high diversity in coral reef fish communities. The American Naturalist. Mar-Apr, 1977. Vol 111, No 978, P 337-359.

Singapore Tourism Board. Site last visited Jan 23, 2008. <http://app.stb.gov.sg/asp/tou/tou01.asp>

Urban Redevelopment Authority. URA unveils another new waterfront proposal. Jan 28, 2008.

US Embassy. Meeting with Economics Official on March 31, 2008.

Wilkinson, Clive R. Global and local threats to coral reef functioning and existence: review and predictions. Marine and Freshwater Research. 1999. Vol 50, No 8, P 867-878.

C. Knoell

World Tourism Organization. Historical perspectives of world tourism. Site last visited Jan 23, 2008.
<http://www.unwto.org/facts/menu.html>