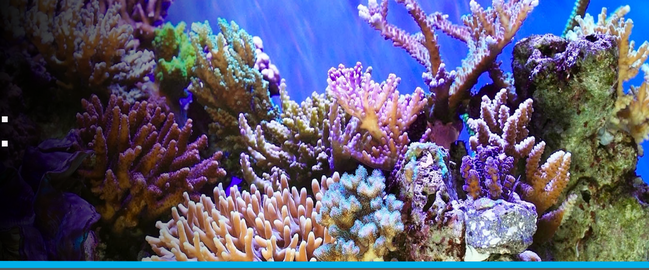
2017

Dredging Land Reclamation Causing Mucus Development in Massive Spherical Corals in the Spratly Islands, South China Sea: The Effects on China's Fishing Industry

Tiffany K. Ho
Virginia Commonwealth University

Dredging Land Reclamation Causing Mucus Development in Massive Spherical Corals in the Spratly Islands, South China Sea: The Effects on China's Fishing Industry



Tiffany Ho | Virginia Commonwealth University Honors College | Mary Boyes | Jacqueline Smith-Mason, Ph.D. | Herbert H. Hill, M.A. | HONR 200: Rhetoric

Introduction

Land reclamation is the process in which bodies of water are converted into artificial land. Over the past 50 years, Southeast Asia has experienced rapid industrialization and population growth, creating a higher demand for construction. With overcrowding in developed areas, countries, such as China and Singapore, began extending their borders through land reclamation in order to compensate for the increasing human population. Between December 2013 and June 2015, China reclaimed more than 2,900 acres, in which about 95% were located in the Spratly Islands (United States Department of Defense, 2015, p.17).

Southeast Asia contains 34% of the world's coral reefs, covering nearly 100,000 square kilometers. Coral reefs play an important role in the marine ecosystem by protecting coastlines from threatening waves, providing shelter for other organisms, assisting in carbon and nitrogen fixing, and playing the role of a consumer in the food chain.

Images from Asia Maritime Transparency Initiative at the Center for Strategic and International Studies depicted huge masses of white coral mucus secreted from coral reefs in the Spratly Islands, in particular Mischief Reef, after construction began. In *Reefs at Risk in Southeast Asia*, Burke, Selig, and Spalding (2002) declared that human activities, including dredging, landfilling, and coastal construction, threaten almost 90% of Southeast Asia's coral reefs (p.8)

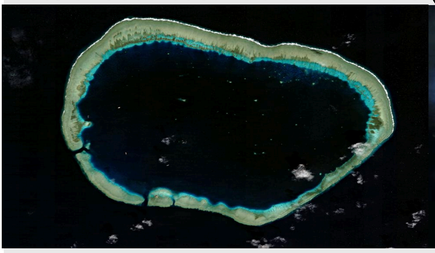


Figure 1. Mischief Reef before land reclamation taken on January 24, 2012. Adapted from Asia Maritime Transparency Initiative (n.d.). *Mischief Reef Tracker*. Retrieved from http://amti.csis.org/

Figure 2. Mischief Reef undergoing land reclamation on June 10, 2015. Adapted from Asia Maritime Transparency Initiative (n.d.). *Mischief Reef Tracker*. Retrieved from http://amti.csis.org/

Methods

Journal articles focusing on the biology of coral mucus, bacterial communities associated with coral tissue, mucus, and seawater, coral mortality from different environment impacts, coral coverage of reefs in Spratly Islands, and symbiotic relationships between reef fishes and corals were studied for this research.

Land Reclamation Methods Increase Sedimentation and Turbidity in Seawater

Comparison between accumulated pollution of water explosions and silt dredging.

Diffusion area of suspended sediment	Water Explosions	Silt Dredging
10-100 mg/l	66.80 km^2	4.350 km^2
100-150 mg/l	17.36 km^2	0.089 km^2
>150 mg/l	20.99 km^2	0.045 km^2
Total	105.15 km^2	4.484 km^2

Note. The table is adapted from "Comparing effects of land reclamation techniques on water pollution and fishery loss for a large-scale offshore airport island in Jinzhou Bay, Bohai|Sea, China" by Yan, H., Wang, N., Yu, T., Fu, Q., & Liang, C., 2013, *Marine Pollution Bulletin, 71*, pp. 29-40.

During land reclamation, very fine, silty clay and colloidal material are freshly broken from the seabed surface. The dredged sediment is readily mobile and creates milky, white clouds that remain suspended in water over prolonged periods (Erftemeijer et al., 2012, p. 1740). Weber et al. stated that "sedimentation events after terrestrial runoff or wave resuspension expose corals to fine nutrient-rich sediment, that when settled on reef-building corals, can bleach or kill exposed tissues" (p. E1558).

Increased Turbidity and Reduced Oxygen Cause Coral Bleaching

As heterotrophic organisms, corals have a symbiotic relationship with photosynthesis algae that live inside the tissues for protection. In return, the zooxanthellae produce oxygen and nutrients. Increased sedimentation from coastal construction results in high turbidity. Weber et al. measured that sediment depths of 0.5 mm, 1 mm, and 1.5 mm exponentially decreased the amount of light reaching the coral surface by 43%, 9% and less than 1%, respectively (p. E1559). Fine particles reduce the quality and quantity of incident light levels, inhibiting photosynthesis that causes anoxia and the expulsion of the algae.

Fast-growing branching coral species are affected more by coral bleaching than slow-growing massive coral species. Because branching corals are the most prevalent in Zhubi and Maiji Reef, comprising 50% of the total coral cover, the coral reefs in the Spratly Islands are highly susceptible to bleaching events (Zhao et al., 2013, p. 7384).

Corals Produce Mucus to Actively Reject Sedimentation on Surface

Corals actively reject sedimentation through polyp inflation, mucus production, and ciliary and tentacular action, but require energy at the coral's expense (Erftemeijer et al., 2012, p. 1746). Compared to branching, encrusting, and hemispherical corals, massive corals have a greater surface area and continuously produce excessive mucus in order to prevent burial by heavy sedimentation.

Coral Polysaccharide Concentration in Response to Pollutants.

Pollutant	Amount of Pollutant Added (ppm)	Coral Polysaccharide Concentration
Control / No Pollutants	0 ppm	25 µg/10 mL
Crude Oil	100 ppm	500 µg/10 mL
Phosphate	100 ppm	150 µg/10 mL
Copper Sulfate	100 ppm	1200 µg/10 mL
Organic Matter Dextrose	1000 ppm	500 µg/10 mL

Note. The table is adapted from "Bacterial attack of corals in polluted seawater" by Mitchell, R., & Chet, I., 1975, *Microbial Ecology, 2*(3), pp. 227-233.

Corals produce mucus as a protective mechanism, particularly against pollutants. After prolonged exposure, the epithelial mucocytes are exhausted and can no longer perform active rejection, which ultimately leads to coral mortality.

Dissolved Organic Carbon in Coral Mucus Acts as a Food Source

Of the total carbon in mucus secreted by coral, only 20-30% were mucus-polysaccharides, while the rest was composed of dissolved organic carbon-lipids, which more than 90% were wax esters and a small fraction was phospholipids (Crossland, 1987, p.35). Wax esters in coral mucus as polyunsaturated fatty alcohols and polyunsaturated fatty acids that have similar properties to triglycerides. Wax esters are an important energy source in the marine environment because copepods deplete triglycerides first before slowly metabolizing wax ester reserves.

Coral Mortality Induced by Bacteria

Because of its high content in polysaccharides and wax esters, the mucus secreted from the coral surface layer attracts highly active microbial communities. Bacterial communities that consist of primarily heterotrophic bacteria, such as those in the Gammaproteobacteria class, have high aerobic respiration rates that consume the oxygen rapidly and create an anoxic environment surrounding the coral head. Alternatively, certain species of bacteria, such as *Desulfovibrio*, perform anaerobic respiration and produce the byproduct hydrogen sulfide, which is generally toxic to eukaryotic organisms, including corals.

Mutualistic, Symbiotic Relationship Between Coral and Fish

Comparison between fishery resource loss water explosions and silt dredging.

Fishery resource loss	Water Explosions	Silt Dredging
Fish egg	3.91 x 10^8 numbers	5.33 x 10^6 numbers
Fishery larvae	1.52 x 10^8 individuals	2.07 x 10^6 individuals
Nekton	1.42 x 10^5 kg	1.81 x 10^3 kg
Total	US$2.15 million	US$1.1 million

Note. The table is adapted from "Comparing effects of land reclamation techniques on water pollution and fishery loss for a large-scale offshore airport island in Jinzhou Bay, Bohai Sea, China" by Yan, H., Wang, N., Yu, T., Fu, Q., & Liang, C., 2013, *Marine Pollution Bulletin, 71*, pp. 29-40.

Corals provide shelter for fish and larvae and even food, in return for protection against seaweed predation. Overfishing and destructive fishing are two major threats to coral reefs in the South China Sea, but the effects of sedimentation and loss of corals together can result in fishery loss. Fish species are strongly associated with live coral cover because their habitat are usually determined from their place of birth, where fishes use the coral's structure for protection and sometimes feed on coral tissue (Yahya et al., 2011, p. 17).

Yahya et al. discovered that there were lower abundances of all the trophic groups in the eroded coral plots, suggesting that fish eventually migrate to other healthy and live coral reefs (p.19). Specifically, triggerfish were significantly more likely to choose colored stimuli over grey distractors.

Conclusion

The South China Sea is the main resource that supports the fishing industry in China. Recent surveys showed that fish species, including coral groupers and humphead wrasses, have declined by 80% within the past eight years. In order to allow for rehabilitation of marine resources, China has been placing annual fishing bans that last between May 16 and August 1 since 1999. Despite China's two-month annual ban on fishery in the South China Sea, populations of fish will continue to decline as more land reclamation projects are implemented in the Spratly Islands.

Massive corals produce excess mucus to counteract the high sedimentation levels. Highly active heterotrophic microbial communities are then attracted to the mucus's dissolved organic carbon and perform respiration that rapidly consumes the oxygen and causes the coral to be stressed. Because corals are important in the reef ecosystem, coral death would affect fish higher in the food chain.

In order to prevent disruption of corals and fishes, the Hong Kong International Master Plan 2030 proposed two alternative methods: drained reclamation and deep cement mixing. Eik and Liew (2014) proposed the concept of Very Large Floating Structures (p. 235). There are four strategies for maximizing environmental cautious: direct protection of specific areas, legal regulation and policy, economic incentives, and education and awareness (Burke et al., 2002, p.57).

References

Asia Maritime Transparency Initiative (n.d.). *Mischief Reef Tracker*. Retrieved from http://amti.csis.org/

Burke, L., Selig, E., & Spalding, M. (2002). *Reefs at risk in Southeast Asia*. Washington, D. C.: World Resources Institute.

Crossland, C. J. (1987). In situ release of mucus and DOC-lipid from the corals Acropora variabilis and Stylophora pistillata in different light regimes. *Coral Reefs, 6*(1), 35-42. doi:10.1007/BF00302210

Eik, L. H. & Liew, S. (2014). A conceptual floating alternative to land reclamation for application in congested island states and coastal cities of Malaysia. *2014 International Symposium on Technology Management and Emerging Technologies, 1*, 235-239. doi:10.1109/ISTMET.2014.6936512

Erftemeijer, P., Riegl, B, Hoeksema, B. W., & Todd, P. A. (2012). Environmental impacts of dredging and other sediment disturbances on corals: A review. *Marine Pollution Bulletin, 64*(9), 1737-1765. doi:10.1016/j.marpolbul.2012.05.008

United States Department of Defense. (2015). *The Asia-Pacific maritime security strategy* (RefID. F-79748EF). Retrieved from http://www.defense.gov/

Weber, M., Beer, D., Lott, C., Polerecky, L., Kohls, K., Abed, R. M. M., . . . Fabricius, K. E. (2012). Mechanisms of damage to corals exposed to sedimentation. *Proceedings of the National Academy of Sciences, 109*(24), 1558-1567. doi:10.1073/pnas.1100715109

Zhao, M. X., Yu, K. F., Shi, Q., Chen, T. R., Zhang, H. L., & Chen, T. G. (2013). Coral communities of the remote atoll reefs in the Nansha Islands, southern South China Sea. *Environmental Monitoring and Assessment, 185*, 7381-7392. doi:10.1007/s10661-013-3107-5

Acknowledgements

I would like to thank Mary Boyes, Jacqueline Smith-Mason, Herbert Hill, Virginia Commonwealth University Honors College, and the teaching assistants of HONR 200: Rhetoric, who contributed to the success and implementation of the project.