Climate Change Impacts on Southeast Asia's Marine Biodiversity

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Abstract

Southeast Asia's status as a global marine biodiversity hotspot is challenged by heavy anthropogenic pressure from rapid economic expansion and a fast-growing population. Increasing attention to the erosion of marine ecosystem integrity is evident in the last three decades but management response continues to lag. Climate change is expected to exacerbate biodiversity loss particularly when ecosystem resiliency has already been largely compromised by human pressure. Equatorial biodiversity, functioning within the higher extreme of the temperature range will shift towards higher latitudes in the most simplistic sense as temperature elevates, but since species exhibit differential behavioural and physiological responses, habitat community structure will inevitably change through trophic disruptions, disorders in ecosystem processes and species-specific differences in temporal and distance migratory shifts. Apart from temperature elevation, other climate change impacts such as increased frequency of extreme weather, sea-level rise, and ocean acidification will also affect marine biodiversity. Some of these impacts can be seen from present conditions depicting climate change. A suitable response is to reduce present anthropogenic pressures and restore ecosystem health so that ecosystem resiliency can improve and strengthen against the impacts of climate change.

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INTRODUCTION

Southeast Asia straddles the equator between latitudes 210N to 120S and longitudes 930E to 1410E. The combined marine area of 9 million km2 represents 2.5% of earth's ocean surface but holds almost 30% of the world's coral reef ecosystem (Burke et al., 2011), one third of the world's mangrove ecosystem (FAO, 2007) and 17% of the world's seagrass ecosystem (Green & Short, 2003). The region also has a great variety and extent of coastal and marine ecosystems, known throughout the world for their high species richness (Chou, 1996). Filled with numerous islands of varying size, the seas form a link between the Pacific and Indian Oceans while separating the continents of Asia and Australia. The seas are characterised by the extensive shallow continental shelves of the Sunda and Sahul as well as deep basins, trenches, troughs and continental slopes.

The world's two largest archipelagos, Indonesia and the Philippines, have about 25,000 islands and almost all the region's countries along the Asian continent possess extensive coastlines and numerous offshore islands, most of which are coral or volcanic. The combined coastline length of 92,451km amounts to 15.8% of the world's total and the extensive coastline supports a wide variety of coastal and marine ecosystems. Coastal features such as cliffs, coves, beaches (rocky, sandy, muddy), deltas, spits, dunes and lagoons provide the potential of harbouring high species richness. The high diversity marine habitats are favoured by the tropical climate and heavy precipitation that transports nutrients from land to sea.

The high nutrient content of Southeast Asian seas is facilitated by the scattering of numerous islands, each contributing terrestrial inputs to the marine system. Some of the larger seas remain remote from this direct nutrient source. The warm tropical climate further contributes to boosting primary productivity, enabling mangrove forests to reach their maximum development and greatest luxuriance in parts of the region (Rao, 1986). A comparative review of mangrove ecosystem productivity based on different parameters such as phytoplankton production, primary production, benthic primary production and total litter production showed that the region's mangrove forests maintained the highest values than elsewhere in the world (Singh et al., 1994)

Rapid industrialisation and strong economic development combined with the fast expanding human population exerted high pressure on marine biodiversity through habitat loss and degradation, pollution and overexploitation. Economic growth generated mainly by industrialisation and international trade remained high during the 1980s and early 1990s (JEC, 2000). Evidently, economic development remained the clear focus of Southeast Asian states with the pace intensifying from the 1960s (UNEP/COBSEA, 2010). The link between biodiversity and climate change is clear (IPCC, 2007). While climate change will affect biodiversity, the latter has a role in mitigating climate change influences (Djoghlaf & Ganapin Jr., 2010). The region's marine biodiversity is already under high threat from anthropogenic impacts that compromise its ability to provide ecosystem services that can mitigate climate change impacts.

GLOBAL MARINE BIODIVERSITY HOTSPOT

The region's geomorphologic and oceanographic features together with the tropical weather make the seas highly productive and supportive of rich and extensive marine habitats. Recognised as the faunistic centre of the entire Indo-Pacific (IUCN/UNEP, 1985), species richness of corals and other reef-associated flora and fauna is the highest throughout the world making the region a global hotspot for coral reefs (Kelleher et al., 1995). It has about 80% of the world's hard coral species (Spalding et al., 2001), 60% of mangrove species (FAO, 2007) and 50% of seagrass species (Green & Short, 2003).

A major significance is that many taxa are present only in the region and their loss means a global extinction. This species uniqueness has to be guarded against further loss. Investigations into population genetics of reef organisms such as corals (Knittweis et al., 2009), fish (Lourie & Vincent, 2004; Timm & Kochzius, 2008), crustaceans (Barber et al., 2006), molluscs (Kochzius & Nuryanto, 2008) and echinoderms (Kochzius et al., 2009) indicate high levels of genetic structuring with distinct signatures from the Indo-Pacific.

A high proportion of coral, fish, gastropod and lobster species have restricted geographic ranges (Roberts et al., 2002) and remain at high risk of extinction from localized reef degradation. Bellwood & Meyer (2009) demonstrated that the recognized (but arbitrarily defined) hotspots of the Indo-Australian Archipelago do not necessarily support high numbers of endemics or serve as a speciation source, and suggested that conservation of areas beyond these hotspots is also important. Weeks et al. (2010) also recognised from their assessment of community-based Marine Protected Areas (MPAs) in the Philippines that these small protected areas should be supplemented by larger no-take reserves for biodiversity conservation targets to be more effectively met.

ANTHROPOGENIC IMPACTS

Marine biodiversity of the region has suffered significant loss and degradation (UNEP/COBSEA, 2010). Anthropogenic impacts are significant and increasingly depressing delivery of ecosystem services essential to the well-being of human society and national economies (UNEP, 2001; MEA, 2005; ASEAN, 2006; UNEP/COBSEA, 2010). Signs of decline in the rate of mangrove loss have emerged for the rest of the world but not in Asia, which has the greater proportion of the ecosystem (SCDB, 2010). Long-term decline of Indo-Pacific reefs is evident with the proportion of reefs having at least 50% live coral cover falling from 66% in 1980 to 4% in 2004 (SCBD, 2010).

CLIMATE CHANGE IMPACTS

There is increasing evidence that climate change can cause significant impacts to biodiversity (IPCC, 2007). Climate change exposes marine biodiversity to a wide range of impacts that include sea level rise, elevated sea temperature, and increased frequency of extreme weather and intensification of water column stratification (Chou 1994). These impacts generate accompanying environmental effects on coastal and marine systems through coastal erosion, sudden salinity fluctuation, increased sedimentation, nutrient loading, salt water intrusion, coastal inundation, and changes in coastal geomorphology and circulation patterns (Chou, 1992). While it is not easy to isolate climate change impacts on natural systems from adaptation and other drivers not directly related to climate change, it is possible to get some idea of climate change impacts from existing scenarios that simulate climate change conditions (Chou, 2010).

Impacts on biodiversity can occur at the species and community levels. At the species level, physiological constraints limit the individual's tolerance to environmental changes. At the community level, changes in the community structure alter the ecosystem functioning of the habitats. A review of the implications of expected climate change impacts on natural coastal ecosystems in the region has been made by Yap (1994). Climate change impacts on species will vary. Some species can move to new areas with more suitable conditions, while sessile and sedentary ones will have to cope or perish. Many are not expected to adapt to the rate and intensity of projected climate change scenarios and risk extinction (SCBD, 2010). In the most simplistic sense, a shift to the higher latitudes is expected of fish and other pelagic species resulting in a possible decrease in equatorial biodiversity. However, large changes in community structure will take place as intact communities fragment from the departure of some species resulting in trophic cascade modification and ecological imbalance. The same effect will be seen at sites receiving the immigrating species.

Rising sea levels inundating low-lying coastal plains can overwhelm adaptation response of coastal biomes and temperature elevation is expected to elicit physiological and behavioural responses from species that could be detrimental to entire biological communities and ecosystem integrity. Further warming of estuarine and near-shore habitats may make them inhospitable to species that already live close to the upper temperature tolerance limit. Increased precipitation will also test the tolerance limits of these species.

Ocean acidification from increased dissolved carbon dioxide is detrimental to many marine species such as corals, shellfish and plankton. Coral reefs in particular are highly vulnerable to lowered ocean pH and the region, with its high proportion of the world's reefs will suffer a greater loss. Should atmospheric CO2 concentrations reach 500ppm after 2050 as projected by Rogeli et al. (2009), coral growth will be arrested as dissolution takes place (Silverman et al., 2009). The loss of coral reefs will be significant to the region where millions of people depend on it for subsistence.

Elevated sea temperature and increased precipitation are two impacts that have occurred in the recent past, the former at a global scale and the latter at a local scale. They give a fair warning of what can be expected and both impacts are examined further.

Elevated sea surface temperature

The 1998 El Niño event provided a good opportunity to observe the effects of global warming. Elevated sea surface temperature occurred from mid-1997 to late 1998 and coral reefs displayed the most dramatic effect. Mass bleaching of corals took place worldwide at an unprecedented scale and highlighted the urgency of protecting reef resiliency. Management is thus needed to prevent compromise of reef system integrity. Mortality of shallow water corals was as high as 95% in some parts of the world while no mortality was observed in other places (Wilkinson & Hodgson, 1999).

Moderate to extensive bleaching was reported throughout Southeast Asia and all countries noted the extent of this event, which was unprecedented (Chou et al., 2002). In Indonesia, bleaching started in early 1998 in West Sumatra resulting in over 90% mortality. It then spread to other reefs throughout the country causing decreases in live coral cover ranging from 30 to 90%. Recovery was variable after a few years with some reefs retaining depressed live coral cover of less than 10%, while for others it reached 40%. In the Philippines, mean live coral cover decreased by 19% after the 1998 bleaching in Tubbataha with no further loss or recovery after two years. At Danjugan Island in Negros Occidental where coral mortality from the bleaching was high, recovery was observed over the next two years. The species Pavona clavus recovered better in medium depths of 12m compared to shallow waters of 6m.

Widespread bleaching of shallow reefs in the Gulf of Thailand affected also the coral recruits. Corals on pinnacles in deeper water (10-15m) escaped the bleaching. Local extinctions of some Acropora species were recorded while Goniopora showed complete recovery. Recovery in the inner Gulf of Thailand took a longer time because of low coral recruitment, but the east and west coasts of the Gulf had large numbers of coral recruits that facilitated recovery. In Vietnam's Con Dao islands, 37% of coral colonies bleached. Recovery was reported to be slow over the next two years. In Singapore, widespread mass bleaching occurred as sea surface temperature remained unusually high from January 1998, reaching 34.30C in June. All hard coral species bleached, together with some species of soft corals and colonial sea anemones. However, sea surface temperature returned to normal (29.5 to 31.50C) after June, allowing the bleached corals to recover and limit mortality to 20%.

Wilkinson & Hodgson (1999) noted that the 1997/98 bleaching event was the most severe ever observed and raised the question of whether this was just an isolated event or that similar events will follow at greater frequency as global warming continues. In the early part of 2010, the seas warmed up to temperatures higher than in 1997/98 and triggered widespread bleaching once again. Investigations revealed that species that were severely impacted in the 1997/98 bleaching appeared to be less impacted this time, while those that showed little effect to the earlier event were heavily bleached. The differences in species response and mortality patterns suggested some adaptive ability to thermal stress by coral species (Guest et al, 2012).

Sudden salinity depression

Increased frequency of extreme weather events is expected from global warming. Periods of drought interspersed by intense precipitation will cause wide salinity fluctuations in shallow waters and affect intertidal life. The impact of sudden lowering of salinity on intertidal biological communities was observed at a location in Singapore after unusually heavy rainfall over many decades occurred at the end of 2006 and early 2007 (Chou, 2010).

Excessive discharge from Malaysia's Johor River northeast of Singapore caused a sustained decline of salinity in that part of the Johor Strait. Chek Jawa, a protected intertidal habitat on the island of Pulau Ubin was fully exposed to the freshwater outflow for weeks. Mass mortality of sessile and sedentary osmotic-conforming species was observed and many species such as carpet anemones, sea stars and sea cucumbers, unable to regulate the osmotic concentration of their body fluids against the lowered salinity, literally burst open as the less saline water infused their body cavities. The intertidal flat was scattered with the fragmented remains of these species.

Investigations showed that recovery was good within a year after the event. Many species that suffered the mass kill had reappeared in abundance. At the same time, some species, which were not common before, became more abundant. These findings indicated that biodiversity can generally recover as environmental conditions revert to normal but long-term changes in the community structure are inevitable as indicated by the new appearance of the invasive Asian mussel, Musculista senhousia, a native of northern Southeast Asia that has spread to Singapore, Australia, New Zealand, the United States and the Mediterranean. In Singapore, Musculista senhousia established only in degraded habitats and its opportunistic colonization of Chek Jawa after the excessive rainfall in December 2007 demonstrated the potential of an invasive species to dominate a biodiversity-rich natural habitat following an abrupt environmental change and disrupt full recovery to the original community structure.

DISCUSSION

Climate change together with elevated sea surface temperature and ocean acidification are looming threats to the region's marine biodiversity. It will test the resilience of marine ecosystems, which are already compromised by intense anthropogenic pressure. The capacity of marine ecosystems to adapt to climate change impacts is severely undermined by present human demands that lead to excessive overexploitation, degradation, fragmentation and pollution. These pressures erode ecological integrity and depress ecosystem services.

Ecosystem resilience needs to be strengthened to minimise damage from climate change impacts (SCBD, 2010) and the immediate focus is the reduction of anthropogenic pressure and more efficient management of marine biodiversity. This is one of the great challenges facing the region, which has relied heavily on the services of marine ecosystems but not doing enough to maintain sustainability.

A sensible investment is to improve efforts at increasing the resiliency of ecosystems. This can be done through better management that includes more effective protection and restoration of degraded habitats such as seagrass, mangroves and coral reefs. There is much scope for research into reef restoration (Edwards & Gomez 2007) and many reef restoration techniques have been initiated (Chou et al., 2009). They include low cost approaches to hasten reef recovery from blast fishing where rubble stabilization and rock piles were found to encourage better coral recruitment and growth compared to scattered rubble. (Fox et al., 2005; Raymundo et al., 2007).

Against the gloomy outlook of habitat destruction are successful protection and rehabilitation measures at local levels (Tun et al., 2008) and demonstration sites on reversing degradation trends have been established under different regional projects such as the UNEP/GEF South China Sea project (UNEP 2004).

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