The Seagrass-Mangrove Connection as a Climate Change Mitigation and Adaptation Factor in East Asian Coasts

Miguel D. Fortes
Marine Science Institute CS, University of the Philippines, Diliman, QC Philippines
fortesm@upmsi.ph, migueldfortes@gmail.com

The Seas of East Asia encompass ecosystems, which are globally significant for their biodiversity e.g. 30% of the world’s coral reefs, 33% of the world’s mangroves, at least 20% of the world’s seagrasses. Hence, the coastal area of the region provides a continuous supply of goods and services from its ecosystems. But because coastal areas are preferred sites for human settlements and urbanization, severe conflicts result from multiple use and competition for the limited land and sea resources by various stakeholders. Hence, the region’s coastal ecosystems are severely damaged: over 80% of coral reefs are at risk, mangroves have lost 70% of their cover in the last 70 years, while loss of seagrass beds range from 20-60%. Unless managed, reefs will face collapse within 20 years, all mangroves will be lost by 2030, and seagrass beds will follow suit. With the above, fish production in the region has fallen dramatically. The major challenge facing East Asian coasts today is managing the use of the coastal zone, so that future generations can also enjoy the visual, cultural, and usable products that it provides. Actions should be undertaken in the context of climate change impacts. This is where sustainable development and science interact most intensely.

DRIVERS OF COASTAL ECOSYSTEM CHANGE

Changes in the ecosystems of the East Asia Seas are driven by demographic, economic, sociopolitical, scientific-technological, cultural-religious, biophysical-chemical factors, and the interactions among them. These variables are critical drivers of the demand for ecosystem services and the capacity of the ecosystems to provide them. The demographic drivers that have implications for the ecological systems in the region include population size and rate of change over time, age and gender structure of the population, household and spatial distribution, migration patterns, and level of educational attainment. The economic drivers are manifested by global economic growth and its distribution by country, sector and individual. How growth is distributed determines the character of demand of ecosystem services. The sociopolitical drivers are seen in the general role of the public in decision-making, which appears to be expanding while governance across the developing world is improving, the voices that are heard and how they are expressed has changed (e.g. changing role of women and the rise of civil society, decentralization trends in power and authority, increasing involvement of NGOs and grassroots organizations). The scientific and technological drivers can have significant implications for ecological systems and human well being. Parts of investment in research and development, rates of adoption of new technologies, changes in the productivity and extractive capabilities of new technologies, and access to and dissemination of information through new technologies all have profound implications to the integrity of ecosystems.
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Drivers determined by cultural and religious values include those perceptions shared by a group of people. A substantial body of literature provides lessons on how policies and programs can most effectively produce cultural change around environmental behavior. Religious precepts that prescribe acceptable and unacceptable consumption patterns might have a significant impact on the demand for ecosystem services as population grows. The physical, biological and chemical drivers include solar radiation, climate variability and extreme weather events, fires, volcanic eruptions, earthquakes, pest and disease outbreaks and natural biological evolution. The primary human-induced drivers include land-use changes, climate change, air and water pollution, acid deposition, soil erosion, soil salinization and fertility changes, irrigation, fertilizer use, harvesting, the use of persistent organic chemicals, and the introduction of nonnative species. Key physical and biological characteristics included the living and non-living components of the earth system that sustain ecosystems and human lives. Changes in ecosystem services are always caused by multiple, interacting drivers originating from different levels of organization of the coupled social-ecological systems. A large part of climate change impacts belongs to this category. Moreover, the changes in ecosystem services lead to feedbacks on the drivers of change. For example, changes in ecosystems create new opportunities and constraints for land use, induce institutional changes from local to global levels in response to perceived and anticipated resource degradation, and give rise to social changes in the form of income differentiation.

**SEAGRASS, MANGROVES AND CLIMATE CHANGE**

Seagrass and mangroves profoundly influence the physical, chemical and biological environments of coastal waters. They provide critical habitats for aquatic life, alter water flow and help mitigate the impact of nutrient and sediment pollution. They play a significant role in protecting the earth from the increasing buildup of carbon dioxide, acting as carbon sink, sequestering (absorbing) carbon dioxide from the atmosphere. Trapped for long periods in the sediments, this carbon helps to slow down global warming. Seagrass beds sequester between 0.012 to 1.33 metric tons of carbon per hectare per year (tC ha\(^{-1}\) yr\(^{-1}\)).

In relation to climate change, seagrasses are known to mitigate and adapt themselves to its impacts. In the context of this paper, these impacts (and how seagrasses mitigate their effects) are:

**Sea level rise** – seagrasses at sloping underwater terrains ‘adjust’ their range of colonization, occupying additional area shoreward, but losing a corresponding area at the other end of its distribution. At gently sloping terrains which are often exposed to sun and air at low tide, however, the beds lose their above ground parts (leaves), but retain their rhizomes (underground growing parts), to grow again when conditions become favorable.

**Seawater temperature rise** – Since seagrasses are photosynthetic plants, they take up carbon dioxide (and heat) in the water and give off oxygen and water in the process of food production. These products aerate the water medium. In addition, their thick collective foliage and mats of sloughed off plant parts shield the substrate from the direct heat of the sun, cooling it in the process.

**Strong waves** (generated by windiness or storminess) – Seagrasses are very effective in holding or stabilizing sediments. This is particularly true in the case of deep-rooted species like *Enhalus acoroides* and *Thalassia hemprichii*. The other smaller species, while shallow rooted, aid in this function by forming thick mats through their interlocking rhizomes and roots. In the process of succession, these smaller fast-growing (pioneer) species create conditions favorable for the colonization of the bigger slow growing (climax) species like *E. acoroides* and *T. hemprichii*. 

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Loss of mangroves and coral reefs (and reduction in biodiversity) – As ecotones or transition zones between mangroves and coral reefs, seagrasses are known to protect these adjacent systems by dampening wave energy otherwise detrimental to mangroves and, on the other hand, reducing siltation or sedimentation harmful to coral reefs. They also provide permanent or temporary refugia for species of the neighboring habitats. This impact causes disruption in food web dynamics because different species of seagrass support different organisms.

In addition, as nurseries and substrates of the young stages of economically important species of fish, invertebrates and seaweeds, and as energy source (feeding grounds) for the fauna, seagrasses sustain the rich biodiversity that resides in its system and those of reefs and mangroves. This function of seagrasses in mitigating the adverse impacts of habitat and biodiversity loss from strong waves is facilitated and ensured by the ability of the plants to effectively hold and retain the sediments.

Loss of livelihood and source of income – This is a direct consequence primarily of the potential loss of the habitats (coral reefs, mangroves, mudflats) and their resources (fish, invertebrates, seaweeds, sand) upon which coastal communities depend for basic goods and services in order to survive.

Mangroves are affected by climate change principally through increasing temperature, which will tend to shift the distribution of the plants to higher latitudes and increase diversity within many existing mangrove areas. Climate change may cause potential problems through changes in rainfall pattern, increased frequency of storms, altered CO$_2$ levels and possibly the impact of ultra-violet radiation, which are known to affect mangrove growth and distribution. On the other hand, mangrove forests serve as carbon sink, which may reduce global warming. The above ground parts of mangroves (Indonesia) yielded 84.6 to 218.2 tC ha$^{-1}$, while their below ground parts, 220 tC ha$^{-1}$ (Iriomote, Japan) to 1,300 tC ha$^{-1}$ (Ponape, Micronesia). These values are generally higher than those obtained from other productive terrestrial vegetation. Interestingly, the World Conservation Union (IUCN) compared the death toll from two villages in Sri Lanka that were hit by the devastating giant waves. Two people died in the settlement with dense mangrove and scrub forest, while up to 6,000 people died in the village without similar vegetation.

Mangroves have very similar functions as seagrasses in relation to their responses to the impacts of climate change mentioned above. Some differences, however, may be pointed out:

Sea level rise - Threat comes from sea level rise (and associated changes in sediment dynamics and salinity), which will inundate the mangroves and erode their substratum. If sea-level rise accelerates, some additional sites would also begin to slowly deteriorate and submerge. In some areas, the sinking or subsidence of the marsh system, coupled with human development, is the major cause of wetland loss. In the United States, computer model simulations of the combined influence of sea-level rise, storms, and floods suggest that large areas in its southeastern parts could be converted from coastal marsh to open water and from forest to marsh.

Temperature increase – Globally, major impacts on mangroves come principally through increasing temperature, which will tend to shift mangroves to higher latitudes and increase diversity within many existing mangrove areas.

Carbon availability – Carbon is as readily given up by seagrasses as it is taken in in photosynthesis. This is where the productivity and ecological role of seagrasses resides – in its rapid growth rate, exceeding all other green plants without energy subsidy - making carbon its produces readily available to the ecosystem.
In Bolinao (Philippines), a shoot of *E. acoroides* turns over in just 28-31 days. On the other hand, the productivity of mangroves resides in its exceptional ability to store the carbon it produces in its bulk (roots, branches, litter). This is not as readily available to the ecosystem. In *Rhizophora*, it takes about a year to completely degrade a leaf.

**THE SEAGRASS-MANGROVE CONNECTION AND CLIMATE CHANGE**

Seagrass and mangrove, together with coral reef, are connected to each other through the nutrient cycles, physical processes, plant and animal migration and human impact. The result is an interconnected web of habitats where nutrients, sediment, and even pollution are transferred from habitat to habitat, changing them along the way. One important implication is that ‘you destroy one habitat, you destroy the other’. Protecting coastal ecosystems must be an integral component to a comprehensive approach to climate change adaptation program. These ecosystems provide natural protection against rising seawater temperature and sea level, to storms and strong waves. There is a need to protect them so that other interventions can be more effective and less costly. With these impacts, they would be exposed to greater risks with the interplay of traditional causes of coastal zone destruction e.g., dynamite fishing, poison/cyanide fishing and siltation. Elimination of stresses that decimate seagrasses and mangroves must be addressed; otherwise the debilitated state of coastal habitats will have low chance of surviving the ill effects of climate change. Strict implementation of fishery laws is needed to increase the survival rate of climate change acting in isolation with the other factors. Current efforts to mitigate and adapt to the impacts of climate change should be directed to offering coastal communities four options: avoidance, accommodation, relocation, and use of soft and hard engineering approaches. Developing countries in the East Asian seas region should be encouraged to invest on mitigation and adaptation measures which are attuned to their economic status and community capability, since the engineering approaches are costly.

**CONCLUSION**

Seagrass beds and mangroves are highly vulnerable to climate change. The ability of management to adapt to the impacts of such change will be critical to the future of the ecosystems and for the social and economic services they provide. With science providing important insights, effective management strategies in a changing climate are only just emerging. There is now a need to test and refine these ideas, and to accelerate learning through sharing management experiences–successes and failures–in responding to the challenges of climate change. Management needs to be bold and adaptive if it is to be effective in averting the crisis that is currently confronting the East Asian coasts. It is critical that marine protected area managers focus on opportunities for improving the prognosis of these exceptionally important ecosystems. The outcome of this conference will provide a useful basis for such prognosis.
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