SERVICES OF MANGROVE FOREST TO ECOSYSTEM AND ENVIRONMENT: A REVIEW

Dr. Surya Shekhar Das
Assistant Professor of Botany,
Bolpur College, Bolpur, Birbhum, West Bengal, India.

ABSTRACT

Mangrove plants have great economical and medicinal values and most importantly they offer unique ecological services. Three very important ecological services include: (a) nursery for fish, crabs, prawns and other fauna; (b) protection of erosion of shoreline; (c) carbon dynamics including fixation, storage and export. This review critically evaluates these roles based on modern research work performed in different corners of the globe. It is undisputed that mangrove forests do offer many ecological services. But the extent and magnitude of such ecosystem performances vary depending on many factors. Some of which are its bio geographical location, degree of disturbance due to urbanization, aquaculture, tourism, diversity and richness of flora and fauna, hydrological regimes, climatic parameters (temperature, rainfall, tropical storm etc.), and even the nature of adjoining habitats etc. It is also evident that habitat destruction due to urbanization, excessive aquaculture, tourism is the major threat to mangrove ecosystem itself and thereby to the ecological services they provide. The focus of such ecological evaluation must include recent impacts of global warming and climate change on mangrove ecosystem and the services it provide.

Keywords: *Mangrove, Ecological services, Climate change, Global warming*.

INTRODUCTION

Mangroves are one of the most unique ecosystems on this planet. They occur in the intertidal zones along the coastline of tropical and subtropical regions. Mangrove plants grow in such a habitat that would likely kill most of the other plants. Such habitat puts continuous stress on plant life in the form of high salt concentration, submergence, low oxygen, high UV to name a few. But mangrove plants are fighters and survivors. They are equipped with a series of adaptive features to cope up with all these stress conditions and grow, flower and reproduce. Moreover, they have great economical and medicinal values and most importantly they offer unique ecological services.

In recent years research on mangrove has increased significantly. The theme of such research has also undergone a shift from biodiversity studies to ecological services. Moreover the span of area of mangrove ecosystem under study has been widened from local to regional, then to global scale. The major focus of such ecological evaluation included the following parameters: (a) nursery for fish, crabs, prawns and other fauna; (b) protection of erosion of shoreline; (c) carbon dynamics including fixation, storage and export/sequestration (Alongi, 2012).

MANGROVE FORESTS AS NURSERY FOR FISH, CRABS, PRAWNS AND OTHER FAUNA

Mangrove ecosystem is a habitat for vertebrates like many different fishes, reptiles and even many mammals along with a variety of many invertebrates. It serves as a nursery for fishes and crustaceans as it supports a greater value of average number of individuals per unit area than to other ecosystems inhabited by the juveniles. The reasons behind such higher conversion rate are attributed to unique root structures of mangrove plants, profuse amount of available food and reduced predation due to high turbidity, low visibility and low depth microhabitats (Nagelkerken, 2009). Complex network of root system of mangrove inhibits predation of smaller shrimps and fishes by larger organisms to a significant extent. Thick vegetation and turbidity cut down the frequency of prey-predator encounters to a low level. A good amount of protection is also provided during the ecdysis phase of shelled fauna (Manson *et al*., 2005). The positive role of mangrove in nursing fish and crustaceans is not free of criticism. But those data mostly represent high catch rate of fish and shrimps in juvenile stage rather than casualties during juvenile to mature transition phase (Faunce & Serafy, 2006). Barbier *et al.* (2011) proved a significant role of mangroves for reef fishes unequivocally in the coast of Tanzania. Similar result was obtained in Caribbean. On the other hand a less significant role has been revealed in the western Atlantic (Faunce & Layman, 2009) and Virgin Islands of Caribbean. So the nursery value of mangrove varies with different locations.

This variation is due to differences in many parameters prevailing in two distinct mangrove habitats. These parameters includes composition of flora and fauna, difference in hydrology, tidal amplitude etc. Species dwelling in areas which get exposed during low tide move to nearby ecosystem for survival. So mangrove solely does not constitute the nursery, rather is a subunit of a larger habitat. Presence of such adjacent habitat component and their physico-chemical properties play a significant role and the hosts are benefitted due to 'trophic relay'. Such habitat connectivity is also necessary in permanently inundated mangroves, as a stock of resources which supplement continuously and complement in hard times like food scarcity (Drew & Eggleston, 2008). With the increase in number and diversity of adjacent habitats the survival and yield of fish and shrimps also increases, which ultimately enhances the nursery value of mangrove (Sheaves, 2005). So the overall landscape also is one of the determinants of nursery values of mangroves. Such habitat shifts reduce intra specific competition leading to high survival rate and better growth of the juveniles remaining in the mangrove habitat component. Relatively mature individuals which are less prone to predation moves to open waters leaving the nursery habitat (Mumby *et al*., 2004). Organisms with smaller size and shorter life spans do not have such stringent need for multiple component habitats.

Recent research involves use of stable isotope tracer, micro tags by which a number of parameters like juvenile densities, growth, survival and movements can be monitored. Another powerful tool to assess the role of mangroves as nursery is otolith microchemistry (Kimirei *et al*., 2013). Jones *et al*. (2010) conclusively proved the "Habitat Mosaic Hypothesis" using these innovative approaches. Molecular studies reveal that host species can detect mangrove habitats through olfactory cues (Huijbers *et al*., 2012). Lowering of pH due to sea acidification has been shown to interfere negatively in such olfactory detection (Munday *et al*., 2009). More studies using modern tools and techniques are to be done to reveal the role of habitat connectivity more accurately **(**Meynecke *et al*., 2007).

MANGROVES FOR COASTAL PROTECTION

For decades, based on circumstantial evidence and empirical data, mangroves have been thought to have a positive role in coastal protection. Some models have been proposed showing the ability of mangroves to offer coastal protection against moderately violent tropical storms (Zhang *et al*., 2012). Both the speed of a storm and the wave energy created by it are significantly reduced by fully grown mangrove vegetation. Many researchers have portrayed mangrove forest as a buffer between sea and the adjoining coastal land (McIvor *et al*., 2012a). The degree of protection is determined by different factors distributed over three hierarchical levels namely species, community and landscape. Many variations exist in root structure of mangrove trees and thus different degree of protection is offered. Although all models regarding resistance to storm surges consider mangrove trees as cylinders, it is far from reality. Such things lead to less accurate conclusions (Iimura & Tanaka, 2012). Anatomy of the vegetation community, species composition, density, maturation level play significant role in determining the degree of protection (Ohira *et al*., 2013). Mangrove forest type, geomorphologic settings and overall landscape also have prominent role in this regard (Dahdouh-Guebas & Jayatissa, 2009).

A lot of research works regarding coastal protection ability of mangrove were published after the 2004 Indian Ocean tsunami. Multiple factors came out to be crucial while assessing the extent of damage and protection. Forest structure especially the formation of barren patches due to grazing or cutting of trees reduce the protective potential. The presence, ecological status and integrity of connected ecosystems of the mangrove forest also play a critical role. So to maintain the coastal protection function of mangroves, the adjoining ecosystems must be protected and left undisturbed from human activities like construction of harbour. Settlements located behind the mangrove forest were less affected. Mangroves failed to offer sufficient protection against high energy events like tsunami. Hostile events with moderate energy were handled more efficiently by such forests. A better protection is offered against cyclonic storms and El Nino generated heavy rainfall which occurs at the interval of months or years. But against daily tidal events, mangroves cannot prevent erosion due to low level of sediment accretion occurring through these tides. The floating materials may serve as a barrier or even sometimes source of erosion (Bayas *et al*., 2011).

Due to increasing anthropogenic pressure mangrove forests are continuing to be destroyed rapidly (Duke *et al*., 2007). It is clear from remote sensing data that the continuity of forest has been disrupted. Such fragmented forests are less capable in performing protective roles. Mangroves are good source of timbers, fuel and medicine. For this reasons they are often overused without any accompanying sustainable management strategies. In the process of serving these economical roles, the ecological roles like coastal protection of such forests are being compromised. Human interference not only destroys the forest cover but also negatively affect health status and regeneration ability of mangroves leading to reduction in their protective services (Wever *et al*., 2012). Another important factor is 'cryptic ecological degradation' in which there is no change in forest cover but the composition of species has been altered. Such things mostly remain unnoticed as they are not detected by remote sensing. Unscientific plantation principles have suffered detrimental consequences along with loss of money, time and effort (Lewis, 2005).

Some ecological models are suggesting that climate change may lead to habitat range shifts of mangrove plants (Quisthoudt *et al*., 2013). Then the abundance of mangroves may be increased along the coastline and colonization of mangrove free coastline may occur. If such things happen in reality an enhancement in coastal protection may be observed.

CARBON DYNAMICS: FIXATION, STORAGE AND EXPORT

Mangrove forests are one the most productive ecosystems on this planet, in spite of low species diversity. They photosynthetically fix atmospheric carbon in such an amount which is more than sufficient for their growth and development. This creates opportunity for storage and export. Mangrove ecologists often consider mangroves as net exporters of carbon, a phenomenon called 'outwelling'. Although there is some loss of fixed carbon due to herbivory, the estimates of lost amount never exceed 3% of total fixed carbon (Sousa & Dangremond, 2011). But, there is one hidden problem in these data as they are based on above-ground production and biomass and ignores below-ground counterpart.

Some authors like Bouillon *et al*., propose that there is significant amount of 'inwelling' resulting from trapping of organic material and sediment which in turn is promoted by slowing of water current due to complex ground structure of mangrove ecosystem. It seems that most of the fixed carbon of mangrove flora is processed through the detritus food chain. The amount of conversion of mangrove detritus to faunal biomass is less significant and there is also the factor of rapid mineralization (Kristensen et al., 2008).

Carbon storage of mangroves depends mostly on two factors: (a) utilization of mangrove detritus by microbes and macro consumers; (b) variation in tidal amplitude affecting storage and export. Leaf litter is the major form of carbon available for utilization by macro consumers. But this proposal has a major drawback and that is the low nitrogen content (< 1% N, high C/N ratio) and high refractory nature of mangrove leaf litter. The proposal also lacks evidence from tracer isotope experiments. Macro consumers do consume leaf litter but they cannot survive solely on this high carbon low nitrogen food. Presence of cellulase enzyme in detritivore and herbivore crab species supports the consumption theory (Adachi *et al*., 2012) Predation of animal may be an alternative to meet the nitrogen demand (Lee, 2008).

The amount of detritus carbon stock is largely dependent on two factors: consumption by gastropods, grapsid crabs etc. and presence or occurrence of factors facilitating export of detritus. The magnitude of export is influenced by river flows and tidal amplitude. Higher rainfall also promotes export over storage of leaf litter. The present export pattern is being modified by increased frequency and severity of cyclones supposed to be a by product of global warming and climate change.

CONCLUSION

So, in a nutshell, it is undisputed that mangrove forests do offer many ecological services. But the extent and magnitude of such ecosystem performances vary depending on many factors. Some of which are the size and remoteness of the forest, its bio geographical location, degree of urbanization, aquaculture, tourism, diversity and richness of flora and fauna, hydrological regimes, climatic parameters (temperature, rainfall, tropical storm etc.), synergistic relationship with adjoining habitats etc. It is also evident that habitat destruction due to urbanization, excessive aquaculture, tourism is the major threat to mangrove ecosystem itself and thereby to the ecological services they provide. Complex interaction occurs due to discharge of domestic, agricultural and aquaculture wastes which get mixed to mangrove detritus.

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