The Effects of Climate Change on Mangrove Ecosystem Services and Their Dependent Communities

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Writer's Comment: I am keenly aware that I am part of the climate change generation who will spend the rest of our lives paying the price for human mistreatment of the planet. As such, it is necessary for us to understand how the ecosystems we depend on to survive will be impacted. Mangroves in particular play a fascinating role in the natural world, and offer humans both a living and potential solution to the snowballing effects of climate change. My goal for this paper was to describe the complex interactions between mangrove systems and climate change, but present it in a light that would prompt even someone who knows nothing of the subject to care. Not everyone believes in the intrinsic value of ecosystems, but many can be persuaded of their worth when considering how ecosystem services benefit people. Papers like this are one of many ways I want to contribute to saving our planet.

Instructor's Comment: Taking an upper division writing course over the summer, virtually, during a global pandemic is a challenge. Full stop. In the summer of 2021 Adrienne was a student in my course and her exemplary work shows that even during times of great difficulty, the need for clear, concise and compelling science communication persists. In this Literature Review, Adrienne tells us about the significant ecosystem services coastal mangrove forests provide. We learn about their contributions to coastal communities, how they mitigate impacts from a changing climate and what is being done to help protect them

from loss. Her writing is accessible to general audiences, and provides them with insight gleaned from her careful study of the current research in this field. She also does the important work of situating the urgent need for this research by helping us understand what is at stake if these, and other keystone species continue to decline.

—Russ Carpenter, University Writing Program

Abstract

Mangroves are a saline-tolerant species of tree that grow in coastal regions of the world, primarily between the Tropics of Cancer and Capricorn. Their attributes make them a critical habitat for many species and an indispensable source of ecosystem services, including defense against hurricanes and floods, prevention of eroding shorelines, a source of food and raw materials, water filtration, and carbon storage. However, climate change and land development have been major perpetrators of their decline, especially driven by violent storms, rising sea levels, pollution, deforestation, and intensive aquaculture. Mangroves are struggling to survive under these poor conditions, and even if left to regenerate on their own, will still need human support to make a full comeback. Restoration attempts thus far have seen mixed results, with manual plantings finding little success and mound plantation programs achieving more promising results. Management will require an interdisciplinary approach spanning all aspects of life from government bodies to average people. Local governments will need to push policies protecting mangrove forests while making sure local communities understand why they are so important, assessing location, ecosystem services, and economic aspects before any decisions are made. More research, outreach, and management experimentation must be undertaken to fully understand how humans can better care for these ecosystems. Sourced from a variety of studies chosen for their analyses of management, valuation, and ecology, this review will illustrate

how climate change is affecting the ecosystem services that mangroves impart and how these effects impact human communities.

Keywords: Mangroves, Ecosystem Services, Climate Change

Introduction

Life on the tropical coasts depends on mangroves for survival. For thousands of years, they have provided humans with services that sustain our populations, including hurricane and flood protection, fishing nurseries, water filtration, and recently more important, carbon storage (Akbar et al. 2021). Despite their importance, they are a prime target of unsustainable deforestation, agriculture, and pollution, currently resulting in a 35 percent loss of mangrove coverage across the globe (Mehvar 2018). Climate change exacerbates these problems even further, resulting in a global decline of mangrove forests and, by extension, their ecosystem services. If humans wish to save mangroves and the boons they provide, a global restoration effort must be undertaken to reverse the aforementioned predicaments.

At the moment, there is no particular consensus on how to manage mangrove forests. Using current restoration strategies, the mortality of planted seedlings is still quite high (Akbar et al. 2021). There have been several theories suggesting interdisciplinary approaches involving collaboration between local communities, various stakeholders, and the government; but according to Carrasco De La Cruz (2021), ecosystem services must be appraised for their monetary values before proper management practices can be carried out. This review describes the current state of mangrove management, how their ecosystem services are affected by climate change, and elucidates the next steps that need to be taken to improve present circumstances.

Mangroves and Ecosystem Services

The exact definition of an ecosystem service is disputed, but the general consensus states that the services must benefit

people, be a specific part of the ecosystem outside of its natural processes, be measured discreetly, and have no human role in the service's existence (Carrasco De La Cruz 2021). There is immense variety in what this encompasses, but in the case of mangroves, their ecosystem services include protection from hurricanes and rising sea levels, sediment stabilization, erosion protection, marine fishing nurseries, carbon storage, water filtration, and biodiversity (Powell et al. 2019).

The ability of mangrove forests to simultaneously perform all these feats comes from their species characteristics: by growing in thick, dense forests, they trap water and sediment that can cause floods and erosion (Rahman et al. 2019). This not only filters the water from contaminants, but also creates a defensive barrier to storms that would otherwise buffet or destroy communities on the shoreline (Mehvar 2018). Because of their chaotic growth, the trees generate significant biomass, making them five times as effective at absorbing atmospheric carbon than other trees (Akbar et al. 2021). Due to all these factors, mangroves are the ideal habitat for many species, making them a biodiversity hotspot and critical nurseries for fish (Powell et al. 2019).

How much an ecosystem service is valued is typically calculated in monetary terms and varies by country. In India, ecosystem services provided by mangroves ranged around 200 dollars per hectare not accounting for inflation after the early 2000s, paling in comparison to the staggering 10,000-12,000 dollars per hectare in Thailand (Mehvar 2018). One must take into account which ecosystem services are being valued; in this case, India is only valuing storm protection and nutrient retention, while Thailand is valuing general coastal protection, wood from logging, and habitats for fisheries. It was also noted in this study that fisheries and storm protection were the most valued services overall. Thus, it is safe to assume that the more ecosystem services a community utilizes, the greater the monetary value of the mangroves in that region. Though not an ecosystem service, mangroves also provide a source of income for local communities through tourism. Together with

coral reefs, they reign in an estimated value of 150-196 million dollars every year in the Caribbean Islands alone (Mehvar 2018).

Climate Change and Other Threats

Mangroves are fragile ecosystems that are considerably threatened by climate change (Win et al. 2020). Climate change affects them in a variety of ways by driving increasingly intense hurricanes, storms, and floods that cause rising sea levels, the intrusion of saltwater into freshwater, and fluctuating erosion and accretion of sediment in coastal zones (Rahman et al. 2019). While mangroves serve as strong protection in storms, they are not indestructible—in Myanmar in 2008, 80 percent of mangroves in the Ayeyarwaddy Delta were seriously damaged by cyclone Nargis (Win et al. 2020). Storms like this wreak havoc on human communities, as their increasing frequency and intensity leads to less and less mangroves, which causes higher human mortality rates and loss of livelihood (Rahman et al. 2019). Though mangrove forests are able to bounce back and somewhat regenerate on their own in the right circumstances, protection and restoration efforts may not be enough to save them if climate change driven storms continue to devastate global populations on a yearly basis. Combined with rising sea levels and erosion-accretion avulsion, mangroves have been on a declining trend and consistently pressed to the limits of their adaptive capacity (Win et al. 2020).

There is still very limited information as to how climate change specifically affects the value of ecosystem services. As a baseline, it is obvious to state that if climate change negatively affects mangroves and contributes to their decline, there is a high probability that it also causes ecosystem services to function less effectively, or not at all, when their ecosystem vanishes entirely. Biodiversity and carbon storage in particular are extremely threatened. While mangroves are fragile ecosystems, islands are even more so, putting island mangrove ecosystems in an exceptionally precarious position with all of their biodiversity hotspots following

suit (Mishra 2020). Currently, climate change's positive feedback loop is spiraling too quickly for species to adapt and survive (Watson et al. 2020). With between 22-50 percent of all ecosystem services in, or going to be in, a climate class transition, it is highly likely that the systems people have depended on for generations are going to change significantly in the coming years (Watson et al. 2020). It is possible that in some ways climate change can actually benefit mangroves by increasing global temperatures and allowing them to expand their range, but we do not have enough information to know how much of a difference this will make when considering human interference, decreases in water quality, and frequent, harmful hurricanes (Powell et al. 2019). Though current studies have not yet conjectured on the financial effects of changes to ecosystem services, by looking at the avoided damage costs in the data from Mehvar (2018), one can surmise that losing these services is going to potentially cost millions for both local communities and the rest of the world depending on them.

On top of climate change, human interference with mangrove forests is another major contributor to their global decline. Land development and pollution are typically the main drivers for loss, including logging, mining, aquaculture, and tourism for the former; and industry, agriculture, and oil spills for the latter (Akbar et al. 2021). Shrimp aquaculture in particular is highly damaging in relation to pollution, making up 80 percent of the total (Akbar et al. 2021), but it is also valued at 6.12 million international dollars, making the industry a tempting, lucrative one (Watson et al. 2020). Overfishing does not directly affect the forests but it contributes to the deterioration of marine nurseries as an ecosystem service they would provide (Mishra 2020). These forests are vital to coastal populations for food and raw materials, even supporting entire economies, but a sustainable balance of give and take has yet to be reached (Akbar et al. 2021).

Management and Restoration

Many management ideas such as criminalizing deforestation or mass planting young mangroves have been thrown around, but few plans or new techniques have been successful. Managing forests is already difficult while trying to stamp out unsustainable development and illegal activities within them, but restoring them is even more challenging. Mangroves have a very low rate of recruitment, meaning that most of the time, only 25-30 percent of seedlings will reach adulthood (Rahman et al. 2019). This makes afforestation difficult and slow, and though manual planting has such a high risk of failure, it is currently still the most used method to restore mangrove forests (Akbar et al. 2021). Bangladesh is opting to create mangrove mound plantations instead as a way to simultaneously protect and restore forests while creating alternative livelihoods for vulnerable communities. Their plan calls for bestowing families with an acre of land for mangrove plantation and rice cultivation; allowing these families to make decent money, have a backup plan if the rice crop fails, and increase their own knowledge and interest in the subject of mangrove restoration (Rahman et al. 2019). Conversely, in Myanmar, plantations are established in agricultural zones where the previous owner dies or leaves, which resulted in a 26.75 percent increase in mangrove area in the seven year period after cyclone Nargis (Win et al. 2020). Despite this seemingly large increase, the authors of this study have reason to believe that natural regeneration is the main source of the 2,265.6 hectare per year upswing, signifying that improving living conditions for mangroves is actually more beneficial to their recovery process than human intervention.

Given the fact that mangrove forests are difficult to restore in less-than-ideal conditions caused by pollution and climate change, management must be thoroughly researched and planned. Carrasco De La Cruz (2021) affirms that it is absolutely imperative for four main pathways to be carried out in order for management to be successful: continue publishing research, facilitating outreach

to communities, writing policy based on these foundations, and producing results from all three together. In theory, an integrated approach with interplay between local governments, communities, and stakeholders would be the most effective at promoting interest, knowledge, and overall willingness to comply (Akbar et al. 2021). Powell et al. (2019) have stated that using mangroves as coastal infrastructure could offer an effective compromise between ecological and socioeconomic stability. Christened as natural infrastructure, research is still lacking in determining to what extent mangroves can provide ecosystem services, or where they would be more effective than gray infrastructure such as seawalls, dikes, and levees. However, according to this study, mangroves require relatively little investment and have the potential to provide any or all of their profitable ecosystem services. Alternately, using mangroves in conjunction with some gray infrastructure as a hybrid approach can double their success while remaining cost-effective. The main limitations of mangrove infrastructure are related to a lack of outreach and research, which could be alleviated by following the aforementioned four pathways and subsequently implementing the integrated approach.

Conclusion

Mangroves are vital to human life for their ecosystem services that support coastal communities by acting as storm barriers, sources of food and raw materials, and hubs of biodiversity. Economically, the location of a mangrove forest and the number of ecosystem services it provides dictates how much of a direct monetary value it has for humans. As climate change progressively gets worse, mangroves' capacity for carbon storage becomes more and more invaluable, yet, ironically, they are declining from anthropogenic activities. More intense and frequent hurricanes, as well as rising sea levels, are putting a great strain on mangrove forests, reducing their numbers and ability to regenerate. Changes in climatic conditions and unsustainable human development are

reducing them even further before we have refined an action plan to tackle management or restoration. There are different ways to address the question of management, but so far there is a distinct lack of examples carried out at a large scale, with most being left to theoretical conjecture. More research must be conducted to discover the fiscal impacts of climate change on ecosystem services, more outreach must be done to educate communities on the importance of mangrove restoration, and more management experiments must be undertaken to find the best way forward. With this in mind, action should be taken wherever relevant to mitigate current mangrove loss and incorporate all parties in the endeavor.

(1,944 words + 243 abstract)

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