Module 3: Blue Forests Superpowers

Preface

Blue forests, such as mangroves, saltmarshes, seagrass, and kelp, are teeming with life and are some of the most diverse habitats on Earth. The value they provide for life above and below water is immense. Their natural abilities to provide a wide range of benefits are considered their superpowers. Blue forests use these superpowers to prevent climate change and protect coastal communities from its harmful impacts, such as rising seas, flooding and cyclone winds. In this module, we will learn about the importance of these ecosystems for supporting fisheries, sequestering carbon, and their applications for human use. Despite their paramount role and dimensions, sadly, humans continually overlook the benefits of these incredible ecosystems and are destroying them at an alarming rate, though recent trends in ecosystem conservation and restoration show promise for the improvement of blue forests.

1. Introduction to Ecosystem Benefits

Human well-being and quality of life depend broadly on natural capital, defined as the world's stock of natural resources, which includes geology, soils, air, water and all living organisms. Some natural capital assets provide people with free goods and services, called ecosystem services or ecosystem benefits. All of these underpin our economy and society and thus make human life possible.

Ecosystem benefits are the direct and indirect benefits of a healthy ecosystem that contribute to human welfare. The vast number of ecosystem services can be categorised into provisioning, regulating, supporting and cultural services. The ecosystem service concept is very anthropocentric, or human-centred, which is in contrast to eco/ bio-centric where humans are just one of the many species that rely on habitats. There are several frameworks used to assess the types of ecosystem benefits that exist. The three most common are the Millennium Ecosystem Assessment (MA), a UN-sponsored effort to analyse the impact of human actions on ecosystems and human well-being; the Economics of Ecosystem Services and Biodiversity (TEEB); and the Common International Classification of Ecosystem Services (CICES). For the purposes of this module, we will be focusing on the TEEB framework of ecosystem services and benefits. Within the TEEB and MA frameworks, the "outputs" of ecosystem benefits fall into the following categories:

Supporting services maintain fundamental ecosystem functions. These processes are considered the foundation for all other ecosystem services through nutrient cycling, soil formation, habitat provision and primary production.

Regulating services seek to establish balance within an ecosystem through disturbance regulation. Regulating services are the most basic natural cycles that nature needs to function, including the water cycle, carbon cycle, photosynthesis, climate regulation, and the cycling of nutrients between organisms and the soil.

Provisioning services represent the most direct and tangible benefits to humans. These services include providing food, raw materials such as building materials, energy and fuel, and medicinal and ornamental resources (i.e., fashion, crafts and decoration).

Cultural services are the sociocultural, non-material benefits ecosystems provide, which are often involved in identity formation. These benefits cover a spectrum of services, including aesthetics, recreation and tourism, education and historical or spiritual value. This can come in the form of heritage and identity, a sense of place or belonging, traditional knowledge, as well as tourism and recreation opportunities. Cultural services are rarely included in national, regional or global ecosystem accounts, as their quantification is more complex than other services.

One common way to think through how the biophysical structures of ecosystems can ultimately produce benefits of value for humans within our socioeconomic system is through the Ecosystem Service Cascade Model.[1] All blue forests ecosystems have biophysical capacities that make them useful to people (i.e., their canopy height, below-ground biomass), which is considered their ecosystem function. The outputs of these ecosystem functions are what we would call ecosystem services, which by definition contribute to human wellbeing (i.e., health, safety, increased happiness) and ultimately produce value and income (i.e., harvestable products, livelihoods) as well as non-monetary enjoyment.

2. Overview of Key Ecosystem Benefits

While blue forests provide numerous important ecosystem benefits, let's dive deeper into four key superpowers: carbon sequestration, support of biodiversity and fisheries, coastal protection, and water purification.

2.1 Carbon sequestration

While terrestrial forests typically receive most of the attention regarding carbon storage, they are not the only ecosystems with a natural ability to fight climate change. Pound for pound, blue forests can be ten times more effective at sequestering carbon dioxide on a per area basis per year than boreal, temperate, or tropical forests.[2,3] This is because terrestrial forests store most of their carbon in their biomass (branches, roots and leaves), while blue carbon ecosystems store most of their carbon in their soils.

There is an increasing global recognition of the potential of mangroves, seagrasses, and saltmarshes as nature-based solutions in the fight against climate change as these habitats alone can store an estimated 10% of all organic carbon sequestered in the ocean annually[3] within their biomass and soils. Blue carbon ecosystems help fight climate change by removing carbon from the atmosphere. However, carbon sequestration and storage aren't the only climate benefits conferred by protecting and restoring coastal wetlands, nor the sole motivation for many countries looking to harness these habitats' potential in the fight against climate change.

2.2. Support of biodiversity and fisheries

Blue forests provide critical habitats for all different kinds of marine and coastal wildlife. For example, mangrove trees are also home to oysters, barnacles, sponges, and anemones which cling to the submerged roots.[4] While pelicans build their nests at the top of mangrove trees, crabs burrow down in their deep muddy soil. Many small creatures can also be found hiding among swaying seagrass beds and thick saltmarshes. Blue carbon ecosystems are a crucial food source for animals above and below the sea and play a key role in several food webs.

Biodiversity occupies different niches along the three dimensions of blue forest habitats' seascapes and landscapes. For example, an adult dugong, or a sea cow, can eat up to 40 kg of seagrass daily.[5] Birds like herons, egrets, and geese are frequent visitors to saltmarshes as they come to forage for insects, crabs, and fish. Raccoons, mink, and hares can also be spotted visiting the wetlands for a bite to eat. As seagrass and kelp decompose, the organic matter provides nutrients for organisms like worms, sea cucumbers, and various filter feeders.

Healthy blue forests play a critical part in maintaining fish stocks. The commercial fisheries that feed the world also rely on the productivity of these coastal ecosystems. Most fish we eat spend their early days swimming among mangrove roots and seagrass shoots. Nearly 95%[6] of commercial fish species depend on coastal habitats at some point during their life. If these ecosystems are destroyed, fish won't have a safe place to raise their young, and their populations will decline.

2.3 Coastal protection

As climate change causes tropical storms to become more powerful and sea levels to rise, coastal flooding and destruction are more likely to occur. The vegetation that fringes shorelines acts as natural barriers, defending communities against these damaging impacts. Mangrove roots stand firm against crashing waves and storm surges when seawater is pushed ashore during a significant tropical storm. A 100-meter stretch of mangroves can reduce the height of waves by up to 66%.[7] Mangroves are estimated to protect 15 million people from flooding yearly and minimize property damage by more than $65 billion.[8] These numbers will only grow as climate conditions worsen. Wave dampening and, therefore, coastal protection has also been attributed to other blue forest habitats. Saltmarsh plants are highly effective at reducing the power of smaller waves. Their peat soils also help prevent flooding by absorbing water like a giant sponge. Mangrove roots, seagrass, and marsh plants also help to hold sediment in place and stabilize shorelines, thus preventing beach erosion. By trapping sediments and filtering out pollutants before they reach the ocean, blue carbon ecosystems protect other habitats, such as coral reefs and underwater life.

2.4 Water purification

The physical structure of seagrasses slows the flow of water as it moves across the seagrass bed. Suspended particles within the water column can then drop out and settle on the seagrass bed floor. This sediment trapping can improve water clarity by settling particles that make the water murkier. Contamination levels, including nutrients, microplastics and other pollutants from wastewater, can be reduced in habitats such as mangrove forests, seagrass meadows and saltmarshes.[9] Blue carbon habitats or salt-tolerant plants might assimilate wastewater contaminants (mainly via root uptake) and transport oxygen to the vicinity, enabling microorganisms to take up pollutants. Oxygen, a photosynthesis by-product, also enables purification and reduction of pathogenicity within a blue forest. Although kelp's carbon sequestration received most of the attention, kelp may appear better at mitigating excessive amounts of nitrogen. Nitrogen pollution is caused in coastal areas by urban sewage, domestic water runoff or fisheries waste disposal. It can lead to potential threats in marine environments, including toxic algae blooms, higher bacterial activity and depleted oxygen levels. Kelp grown in polluted waters could still be a promising tool for cleaning such areas.[10] Kelp and wider seaweeds absorb nitrogen and phosphorous as fertilizers and contribute to water purification.

3. Many Superpowers of Many Ecosystems

Let's take a deeper dive and explore the superpowers of each blue forests habitat.

3.1 Mangrove forests

Mangrove forests are highly productive and biologically rich habitats that play a prominent role in providing valuable ecosystem goods and services for human well-being. The dense, intertwining roots of mangroves act as sheltered breeding and nursery grounds, protecting fish and shrimp species from larger predators. Mangroves are some of the most carbon-rich ecosystems on the planet, storing on average 1,000 tons of carbon per hectare in their biomass and underlying soils.[11] Mangrove forests occupy 2% of the world's coastline and are responsible for approximately 30% of carbon burial in tropical and sub-tropical continental borders.[12] In addition to their carbon storage benefits and their role in reducing the risks and impacts of climate change, these ecosystems support healthy fisheries, improve water quality, and provide coastal protection against floods and storms. Mangroves can be worth at least US$1.6 billion per year in ecosystem services, worth US$ $33,000-57,000 per hectare per year.[13] Provisioning services from mangrove forests also include timber, fish, thatching materials, fuel wood, crabs, honey and wax. Considering 100 million people are estimated to live within 10 km of significant mangrove areas, fisheries provision is vital for subsistence, livelihoods and commercial practices in coastal communities worldwide.[14,15]

3.2 Seagrass meadows

More than 1 billion people are estimated to be within 100 km of a seagrass meadow worldwide. Seagrasses are believed to be one of the most valuable and vital coastal marine ecosystems. While they cover just 0.1% of the ocean floor, seagrasses provide valuable nursery habitats to one-fifth of the world's largest fisheries and store up to 18% of the world's oceanic carbon.[16] Indeed, the average fisheries nursery function of seagrasses is estimated at $618,505 per hectare per year.[17] Seagrasses also protect shorelines from storm surges, rising sea levels, and floods, which exacerbate coastal erosion. Additionally, they are considered natural biofilters for coastal waters as they purify water from nutrients, contaminants and other particles through their leaves and roots, such as nitrates, phosphates and ammonium. Seagrass meadows, such as species of Halodule and Halophila, can also be food sources for the endangered and charismatic dugongs, manatees, sea turtles and sea horses.

3.3 Synergistic ecosystems: Mangroves and seagrasses

Mangroves are sometimes interconnected with seagrass beds (and coral reefs), which results in functional linkages.[18] The biodiversity of flora and fauna in seagrass meadows and forested mangrove sites may include – depending on habitat – a variety of mammals, reptiles, amphibians, insects, birds, plants, macroalgae and fungi. This is combined with the additional species diversity of vertebrates and invertebrates, of which some are rare and endangered animals. Juvenile fish, prawns and crabs also benefit from the calm physical environment with low current speeds and reduced wave action within mangroves and seagrass meadows. They also access the food supply and can grow to a size where they can go back into coral reefs, offshore sites, and upstream into rivers.

3.4 Saltmarshes

Saltmarshes are tidal wetlands comprised of salt-tolerant grasses, herbs, and shrubs that flourish between land and open salt water. Saltmarshes protect shorelines from erosion by buffering wave action and trapping sediments. They reduce flooding by slowing and absorbing rainwater, protecting water quality by filtering runoff, and metabolizing excess nutrients. Marshes can reduce erosion, stabilize shorelines, protect against storm surges, and support species crucial to recreational and commercial fishing, hunting, birding, and other activities. Saltmarshes are one type of estuarine habitat that acts like an enormous filter, removing pollutants such as pesticides and heavy metals from the water flowing through it. The ability of these coastal wetlands to store significant amounts of carbon, mainly in the soil, spearheaded climate action that guides countries to implement carbon sequestration global climate strategies known as Nationally Determined Contributions (NDCs). Saltmarshes store between 65 and 95% of their carbon in their belowground soils.[19,20] Wet coastal soils have much lower oxygen levels than those on the forest floor, which causes dead plant matter to take longer to decay. As a result, the carbon stored in coastal soils can remain trapped there for thousands of years. Regarding cultural benefits, saltmarshes provide a ground for recreational fishing, nature tourism, education, research opportunities and sometimes hunting.[21]

3.5 Kelp forests

Kelp forests occur in temperate waters and may occur sporadically in warmer deep waters. The role of kelp forests acting as a carbon sink is an active area of research. However, kelps are essential contributors to the carbon cycle by converting inorganic carbon into organic biomass, which stores carbon in the short term. Kelp biomass that is not grazed can be buried in the seafloor or transported to depths beyond 1,000 meters for long-term carbon storage.[16] Beyond carbon, kelp forests support biodiversity and habitats for many species within their extensive vertical canopies. In Norway, for example, a single L. hyperborea kelp individual was shown to support around 80,000 organisms of more than 70 species.[22] Healthy kelp forests can also play an essential role in mitigating the impacts of storm surges on vulnerable coastal areas by dampening the intensity of the waveforms generated before they reach land.

Kelp generate direct use value through the kelp harvesting, commercial and recreational fishing, and tourism activities they support. Kelp cultivation is a fast-growing industry for edible human and animal feed products. Alginate is also extracted from brown seaweed and is used as a stabilizer for food items such as ice cream and other dairy products and also a thickener and emulsifier for salad, pudding, jam, tomato juice, and canned products.

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