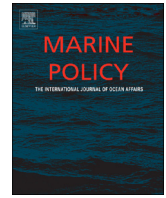




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Keys to successful blue carbon projects: Lessons learned from global case studies



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ABSTRACT

Ecosystem services such as protection from storms and erosion, tourism benefits, and climate adaptation and mitigation have been increasingly recognized as important considerations for environmental policymaking. Recent research has shown that coastal ecosystems such as seagrasses, salt marshes, and mangroves provide climate mitigation services because they are particularly effective at sequestering and storing carbon dioxide, referred to as “coastal blue carbon”. Unfortunately, degradation of blue carbon ecosystems due to anthropogenic impacts contributes to anthropogenic carbon emissions from land use impacts and prevents these ecosystems from continuing to sequester and store carbon. Given the impressive carbon sequestration and storage in coastal ecosystems, many countries with blue carbon resources are beginning to implement blue carbon restoration projects using carbon financing mechanisms. This study analyzed four case studies of projects in Kenya, India, Vietnam, and Madagascar, evaluating the individual carbon financing mechanisms, the project outcomes, and the policy implications of each. Strengths and challenges of implementing blue carbon projects are discussed and considerations that all projects should address are examined in order to develop long-term sustainable climate mitigation or adaptation policies. This analysis can help to inform future project design considerations as well as policy opportunities.

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1. Introduction

As anthropogenic climate change presents an ever-growing problem to the international community, policymakers have increasingly sought creative ways to reduce the human carbon footprint, including addressing land-use changes. Changes in land use, including deforestation and farming activities, comprise up to 20% of total global carbon emissions, and more so for many countries with uniquely high rates of deforestation [1]. In order to respond to this significant contributing factor of anthropogenic climate change, the United Nations Framework Convention on Climate Change (UNFCCC) has adopted policies to allow countries to account for gained and lost carbon emissions through land use change, both by including these emissions in national assessments and by providing mechanisms to fund and incentivize conservation projects [2].

Several recent studies have focused on the importance that coastal

ecosystems such as salt marshes, seagrasses, and mangroves have in mitigating climate change by acting as carbon sinks [3–8]. While these ecosystems only make up two percent of global area, studies have shown that these coastal ecosystems are both ten times more effective at sequestering carbon dioxide on a per area basis per year than boreal, temperate, or tropical forests [9] and about twice as effective at storing carbon in their soil and biomass [10]. The “blue carbon” service is only one of the important benefits these ecosystems provide along with shoreline protection, water quality improvements, building materials, and seafood [11].

Unfortunately, coastal blue carbon ecosystems have been lost at an alarming rate—an estimated one third of the global total lost over the past several decades [12]. This degradation is primarily caused by direct and indirect anthropogenic factors such as deforestation, increasing coastal population size and coastal development, agriculture and aquaculture, sedimentation and siltation, and effects of climate change such as sea level rise and extreme weather events [9]. When these ecosystems are degraded, they not only fail to act as carbon sinks, but also contribute to carbon emissions by releasing stored carbon into the atmosphere. With a global annual loss of blue carbon ecosystems between 0.7 and 7%

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annually, it is projected that these ecosystems are releasing between 0.15 and 1.02 billion tons of carbon into the atmosphere each year [12], contributing significantly to anthropogenic climate change.

In response to the significant negative effects of blue carbon ecosystem degradation, there is an opportunity to develop coastal wetland projects with the goal of mitigating climate change [13] and many groups are in the process of planning or implementing blue carbon conservation projects. In addition, the international community has begun to evaluate how these ecosystems can be more effectively included within existing policy frameworks, including carbon financing mechanisms such as Reducing Emissions from Deforestation and Forest Degradation (REDD+) and other UNFCCC mechanisms [2]. The goal of this study was to develop a database of many of the blue carbon projects around the world and examine in more depth which financing mechanisms appear to be working to support these coastal conservation and climate mitigation projects. Four case study projects were selected in Kenya, India, Vietnam, and Madagascar, exploring financing methods, outcomes, and policy implications of each project. Conclusions based on these case studies address the current best opportunities to facilitate future coastal conservation and climate mitigation projects to inform the broader international climate policy discussions and negotiations in order to make it simpler for countries with rich blue carbon resources to conserve and restore coastal wetlands while reducing carbon emissions.

2. Methods

The first step was to develop a larger list of projects that had a focus on blue carbon ecosystems and conservation (see Table S1, Supplemental online information). These four case studies were chosen based on availability of information as well as the type of financing mechanism the project is using or has attempted to use (in order to include a diversity of funding mechanisms) (see Table 1). Projects that were included are using or attempted to use carbon markets, and more specifically are using UNFCCC mechanisms such as REDD+ and the Clean Development Mechanism (CDM) or voluntary carbon markets, all of which are based on carbon offsets and credits. In developing each case study, a number of resources were used including personal interviews, project status reports and evaluations, and peer-reviewed studies.

Carbon markets for natural carbon sinks are based on the idea that carbon stored in these ecosystems can be quantified using scientific methods and can be sold as credits, which the buyer will then use to offset emissions. This method is also known as emissions trading. Carbon credits are verified by a certain “standard”, which includes accounting, monitoring, verification, and certification standards, and registration and enforcement systems. The credits are then sold either on the compliance market, in which parties such as national governments or industry members are required to reduce their emissions under a treaty (such as the Kyoto Protocol or the European Union Emissions Trading Scheme), or on the voluntary market, in which buyers voluntarily buy credits in an effort to be more sustainable [14]. It is important to note that credits verified under the compliance market can be sold on the voluntary market, but not vice versa [14].

UNFCCC mechanisms that utilize the carbon market, such as REDD+ or CDM, fall under the compliance market. CDM is a mechanism in which Annex I, or developed, countries under the Kyoto Protocol can implement development projects in non-Annex I, or developing, countries, and receive carbon offset credits for those projects. REDD+ is a mechanism that works similarly to CDM, but expands upon the land use sector in an effort to more effectively implement projects focused on reducing emissions from land use change. Alternatively, a blue carbon project could be financed by

Table 1
Descriptions of the four blue carbon mangrove case studies.

Project	Location	Lead organizations	Funding organizations	Size	Is project including Soil Carbon?	Financing mechanism	Stage
Mikoko Pamoja	Gazi Bay, Kenya	Association for Coastal Ecosystem Services (ACES), Kenya Marine Fisheries Institute, Earthwatch Institute, Napier Edinburgh University, Plan Vivo	Kenya Marine Fisheries Institute, Earthwatch Institute, Napier Edinburgh University, Plan Vivo	117+ ha	No	Voluntary Carbon Credits – Plan Vivo	Implemented
Markets and Mangroves	Mekong Delta, Vietnam	SNV Netherlands, International Union for Conservation of Nature (IUCN)	International Climate Initiative, German Federal Ministry for the Environment, Building and Nuclear Safety (BMU), Minh Phu Livelihoods, Danone Fund for Nature	1715 ha	No	Natural Organic Shrimp Certification	Implemented
India Sundarbans Mangrove Restoration Project	Sundarbans, India/Bangladesh	Livelihoods, NEWS, Institute of Environmental Studies and Wetland Management		6000 ha	Yes	Voluntary Carbon Credits – VCS	Implemented
Blue Forests Madagascar	Ambanja Bay and Ambaro Bays, Madagascar	Blue Ventures	Blue Ventures	26,000 ha	Yes	REDD+ or Plan Vivo	Planning



Fig. 1. (a) Mangrove seedling planting in the Mikoko Pamoja project; (b) Woman measures a mangrove sapling on project site. Photos used with permission from Mark Huxham, <http://www.aces-org.co.uk/>.

carbon credits sold on the voluntary carbon market, using methodologies such as Plan Vivo² or the Verified Carbon Standard (VCS)³. These methodologies have proven significantly easier to implement due to the diversity and flexibility of different voluntary standards as well as lower costs of the required carbon accounting, verification, and certification, associated with submitting a voluntary carbon project versus complying with one of the UNFCCC mechanisms, which require working directly with and through national governments' processes in developing countries as well as within the UNFCCC [15]. Additionally, UNFCCC projects may have a minimum threshold that is difficult for coastal projects to reach due to the more rigorous requirements to achieve a compliance standard, thus making it difficult for small projects to profit using these mechanisms [15]. For example, a project under CDM using the compliance market must sell about 5000 metric tons of carbon in order to justify transaction costs [14] and the successful blue carbon Mikoko Pamoja project (see Section 3.1 below) only sells 2215 credits (each equal to one metric ton of carbon) per year. The projects discussed in this paper all chose to utilize voluntary standards if participating in the carbon market, even if they had explored UNFCCC mechanisms. Here we explore each project and financing decisions in order to inform current and future climate mitigation strategies and carbon market opportunities for blue carbon ecosystems.

3. Case studies

3.1. Mikoko Pamoja, Kenya

3.1.1. Background

Mikoko Pamoja is a mangrove restoration and reforestation

project currently being implemented in Gazi Bay, Kenya (Fig. 1a) [13]. The project includes 117 ha of nationally-owned mangroves, with the potential to grow. The Gazi Bay community depends on the mangroves for their livelihoods, with eighty percent of the community making their living off of fishing-related activities [16]. The Gazi Bay mangroves also provide building materials, tourism, and coastal protection [16]. Degradation of this ecosystem has occurred due to mangrove deforestation undertaken by individuals seeking to use the wood for building materials.

Mikoko Pamoja is a community-led project financed by voluntary carbon credits. Objectives of the project are to facilitate development in the area, restore mangrove ecosystems, enhance ecosystem services (including carbon sequestration), promote sustainable mangrove related income, and act as a model for future projects [13]. The Gazi Bay community has entered into a Payment for Ecosystem Services (PES) agreement with Plan Vivo, who manages the credits, and research on carbon storage potential was conducted over five years [17]. The project has been successfully implemented and completed its first crediting period. Revenues collected from the sale of credits have gone to project implementation (one full time staff member, mangrove planting and conservation) and to community development projects [13].

3.1.2. Financing mechanism

Credits are managed by the Edinburgh organization Plan Vivo through a Payment for Ecosystem Services (PES) agreement with the community [16]. Each year, 2215 credits are issued to be sold, and the project is reaccredited every 5 years [16]. These credits are not connected to any UNFCCC mechanisms, but the project has been modeled after these mechanisms [18]. The price of these credits ranged from 6.50 USD and 10.00 USD for 2013–2014 [13]. It is important to note that these carbon credits do not account for soil carbon, only carbon stored in the mangroves themselves. The credits can be bought by any public or private entity, as well as

² See (<http://www.planvivo.org/foradditionalinformation>).

³ See (<http://www.v-c-s.org/foradditionalinformation>).

Plan Vivo resellers. So far, buyers of Mikoko Pamoja credits have included individuals, NGOs, and companies, which have been recruited both through personal contacts and through the marketplace [17]. The annual sale of carbon credits to date after factoring in a risk buffer of 30% has been \$12,500 USD (for the community to use to implement the project [19]. The Mikoko Pamoja team hopes to gradually increase the area of mangroves protected [17]. It is important to note that the project has many benefits beyond carbon including carbon sequestration, offshore fishery, biodiversity conservation, and coastal protection. However, these benefits primarily benefit people outside the local community. It would be worthwhile for the international community to explore a payment scheme for these other ecosystem services that could benefit local communities, as well as developing alternative livelihoods [20].

3.1.3. Outcomes

The Mikoko Pamoja project has met its target for 2014 through mangrove planting and conservation. The local community has benefitted from diversifying sources of mangrove-related income, such as beekeeping and ecotourism related to the “Gazi Bay Boardwalk”. The profits have also funded school construction projects, purchase of books, and the installation of water pumps. In addition, alternate sources of wood from terrestrial forests have been cultivated near the project site, which provide a replacement form of building materials for the local community. These projects are managed by Gazi women, who have particularly benefitted from this project through their participation in alternative sources of livelihood which are often not available for women in this area (Fig. 1b) [16]. Driven by the success of Mikoko Pamoja, Association for Coastal Ecosystem Services (ACES) is working to launch a similar project down the coast at Vanga and has been assisting another NGO at Mtwapa [17].

As a pilot project, Mikoko Pamoja faces some challenges. The price of credits tends to fluctuate due to an uncertain market [17]. The small size of the project makes it difficult to attain economies of scale and to sell at global carbon market prices, therefore making it difficult to find buyers for the carbon [18]. Additional challenges of this project include: (1) difficulties receiving funds for a watchtower to help prevent the illegal cutting of mangroves by locals; (2) changing rainfall patterns and unprecedented sedimentation that have stalled the planting process and led to mortality of some mangrove seedlings; and (3) turnover in the project coordinator position [17]. Despite these challenges, the project is meeting its goals to date and has been quite successful [16].

The Mikoko Pamoja project's success likely stems from several key aspects. First and foremost, the local community has actively supported and participated in the project, which has been implemented through a transparent process [13]. There has been a significant amount of published scientific research on mangroves and carbon sequestration in the region, laying a sound scientific foundation for the project. In addition, Dr. James Kairo, from the Kenyan government, has been invaluable in bringing the local community, the science community, and the government of Kenya together to make this project effective [21]. Dr. Kairo has extensive institutional knowledge as he has lived with the community for 20 years and has facilitated science programs in the area. Thanks to the collaboration facilitated by Dr. Kairo, the community has been able to build strong scientific, administrative, and governmental capacity for the project [21].

3.1.4. Policy implications

The success of the Mikoko Pamoja demonstrates that a voluntary carbon market can both successfully fund a small-scale community-based blue carbon mangrove restoration project and benefit local communities in a developing country. This project

does not make use of UNFCCC mechanisms, likely at least partly because there is uncertainty in how a small community-based project could benefit from REDD+, as the funding has to be channeled through the government which poses difficulties for many developing countries [18]. Furthermore, international climate finance mechanisms might not always recognize the direct needs of the communities involved [16].

One important limitation of this project is the lack of inclusion of soil carbon leaves much of the climate mitigation potential of these ecosystems untapped but requires a significant amount of additional scientific work to measure and account for soil carbon. Additionally, this project did not take into account the effects of sea level rise and climate change in its planning stages, which may be important considerations as these effects become more severe in the future. In spite of these limitations, the success of Mikoko Pamoja has encouraged the East African Forum for Payments for Ecosystem Services (EAFPPES) networking body to help promote similar projects throughout east Africa, working with Tanzania, Madagascar, Mozambique, and Kenya [18].

3.2. Markets and Mangroves, Vietnam

3.2.1. Background

Vietnam's seafood and aquaculture markets comprise a six billion dollar industry, of which shrimp farming makes up about a third (Fig. 2a), contributing significantly to the livelihoods of the coastal communities [22]. However, the environmental impact of this industry is severe, and as the shrimp industry has grown, mangrove ecosystems have been lost at an alarming rate-over half



Fig. 2. (a) Vietnamese man harvests shrimp in the Mekong Delta, Copyright: Aiden Dockery; (b) Farmers participate in the organic shrimp industry as a part of the Markets and Mangroves Project. Photos used with permission and copyright: SNV Netherlands Development Organization.

of Vietnam's mangroves have been lost in the last 30 years [22]. The Mekong Delta in particular is home to half of the mangroves in Vietnam and about three-quarters of the country's aquaculture. While national law in Vietnam currently requires 60% mangrove cover, in practice mangrove cover is much less and is rapidly declining in this area [22].

The Markets and Mangroves (MAM) project, initiated in 2012, is located in Ca Mau, which is one of the 12 provinces in the Mekong Delta. The project site encompasses 3371 ha of land, which currently includes 1715 ha of mangroves. Markets and Mangroves, seeks to conserve mangrove ecosystems in this area by helping shrimp farmers get organic certification for their shrimp farming activities, giving farmers a premium price for their shrimp (Fig. 2b). At the same time, the certification does not allow any more mangrove destruction for the construction of shrimp ponds (thereby stopping ~23.5 ha of mangrove loss per year in the project area) and mandates that each farmer maintain or achieve 50% mangrove coverage, leading to either conservation or planting of mangrove forests [23]. This means that for the first five years of the project, an average 12.5 ha of mangroves will need to be re-forested for a total of 63 ha after five years in order for the entire project area to meet the 50% mangrove cover required for certification.

3.2.2. Financing

While carbon financing initially was expected to play an important role in the MAM project, organic certification turned out to be a more lucrative and expedient financial alternative. This project works with Minh Phu, a global seafood export company, which buys the organic shrimp and sells it for the premium price. The shrimp market in Europe, the United States, and Canada pays 10% more for organic shrimp as demand for organic and sustainable seafood is growing worldwide [24]. Increased mangrove cover has also been linked to increased shrimp production, giving farmers another incentive to certify their farms [22]. As a result, the local economy has expanded and farmers are able to see the direct economic benefit of conserving their mangroves [24]. Estimates vary widely, but for integrated shrimp-mangrove farmers the average profit has been found to be ~US\$900/ha/yr, in years without major disease; this does not include the labor costs (assuming two workers who are usually from the owner household) of \$600/ha/yr [24]. But farmers may be able to harvest other species, such as crab and fish, from their farms as well, so total revenue might be a little higher.

3.2.3. Outcomes

Thus far, 1150 farmers in Ca Mau have been certified with Naturland – a recognized international organic aquaculture and agriculture standard [23]. Due to the project's success, MAM seeks to expand the number of participating farming households to 6000 [24]. While this project does not incorporate a UNFCCC carbon financing mechanism, it achieves the same emissions reduction goals through alternative means, while boosting the profitability of the shrimp industry in Vietnam [24]. IUCN calls the organic certification plan a “form of international PES,” albeit an indirect form [24]. By ensuring 50% mangrove cover in the project site, MAM both prevents deforestation and conserves existing forests, improving the area's potential to create more carbon sinks. The diversity of stakeholders involved in MAM has also likely contributed to the success of the project.

3.2.4. Policy implications

The amount of carbon in this area was assessed before the project was implemented [23] with the intention to inform a carbon financing mechanism in the future and the feasibility of carbon financing for this project was evaluated in an SNV study

[22]. The SNV study estimated carbon stocks in the region and examined potential funding mechanisms, ultimately recommending linking MAM to the UN-REDD program, VCS, or Plan Vivo standards, or potentially submitting this project for NAMA funding. However, project developers maintain that they have no intention of linking this project to UN-REDD, and have avoided this program due to the lengthy amount of time it took to fulfill the UN-REDD requirements [23]. Despite the challenges of applying carbon financing, the project has already succeeded in capitalizing on the economic needs of local communities, linking conservation, climate mitigation, and economic growth through the organic shrimp market. In the future, this type of project could be linked to a carbon financing mechanism, but for the moment the sustainable shrimp certification is achieving similar conservation goals without dealing with carbon financing.

3.3. India sundarbans mangrove restoration project

3.3.1. Background

The Sundarbans, a group of islands extending between West Bengal in India and Southern Bangladesh, are home to the largest estuarine mangrove forest on Earth. More than 28% of its land has been lost in the past 40 years from the effects of sea level rise due to climate change, rapidly degrading its mangrove ecosystem [25]. Anthropogenic factors such as population growth and subsequent ecosystem disturbance, and prawn harvesting have also contributed to the degradation of mangroves in this area [26]. These mangroves provide important ecosystem services for the local communities of approximately five million people, acting as



Fig. 3. (a) Embankment construction in the Sundarbans; (b) Local woman waters mangrove seedlings in the Sundarbans. Photos used with permission from Ajanta Dey.

natural barriers protecting a man-made embankment (Fig. 3a) that was constructed for flood and storm protection following cyclonic storm Aila, which devastated the local community in 2009 [25]. In addition, the mangroves protect the community from 20 foot daily tidal variations [27].

The India Sundarbans Mangrove Restoration project seeks to plant 6000 ha of mangroves over three years that will store a projected 700,000 t of carbon over 20 years in their biomass and soil. The principal objectives of this project are carbon emission reduction, climate adaptation, and biodiversity conservation [26]. A study on the applicability of carbon standards was completed for this project and found that carbon financing was a viable option. [27]. The new mangrove plantations will also potentially provide timber and opportunities for aquaculture in the local communities. The project has been implemented as a VCS grouped project, covering four zones in the Sundarbans. Most of the financing is distributed to communities as payment for work, with the remaining finances covering the technical survey and scientific monitoring required for carbon offset certification [25] (see more details in Section 3.3.2). Local women were trained for the mangrove planting process and are paid for their work, providing them with small alternative sources of livelihood (Fig. 3b) [27].

3.3.2. Financing

The India Sundarbans Mangrove Restoration project is part of VCS' sectoral scope 14, which refers to "agriculture, forestry, and other land use" (AFOLU) projects. Within AFOLU, this project is grouped under the Afforestation, Reforestation, and Restoration (ARR) category for mangroves. Since soil carbon is included within the scope of this project, it also must comply with the Wetlands Restoration and Conservation (WRC) requirements. Initially, the project planners sought to apply the Clean Development Mechanism (CDM) on small scale bundled projects. However, when large scale mangrove restoration became available with the VCS, the project switched to the validation process for a grouped VCS project [26]. As of September 2015, the project is validated and emissions reductions credits were issued by the UNFCCC to Livelihoods [27]. Livelihoods currently is not planning to sell the credits but are instead using the credits as part of a socially and environmentally valuable emissions reduction offset strategy for the company and for company branding [27]. The project costs have been covered by Livelihoods to date and these costs include supporting the local community restoration activities. Those considered "forest friends" who initially were helping to protect the mangroves from threats like grazing have been making a small amount mostly to offset travel costs which equated to roughly \$45 USD per month. The project is now transitioning to a voluntary monitoring system with Mangrove Stewardship taken on by the community to care for their mangroves. Those doing the planting can usually work for about 4 hours a day during low tide and can make roughly \$2.54 USD a day, or around \$50–56 USD per month. Project managers on the project have been making about \$120 USD per month and field officers making \$225 USD per month [27]. Those raising seedlings are paid per sapling. Prices to date have ranged from 0.015 to 0.0375 USD per saplings, depending on the species (i.e., *Avicennia*, *Ceriops*, *Rhizophora*, *Hereteira*, *Excoecaria*) with a total of 0.8 million saplings already planted as part of this project [27].

3.3.3. Outcomes

The project has so far been successful, as mangrove planting and restoration combined have reached the goal of 5600 ha and the financial targets of the projects have also been met [27]. Additionally, reports show that the amount of carbon sequestered is almost three times the expected amount [27]. The project has provided some additional ecological benefits such as shellfish

habitat, and the communities' economies are benefiting slowly from the mangrove restoration [27]. In addition, the project has social benefits by empowering local women with meaningful work in an area where much of the population lives below the poverty line [28]. The community has been informed of progress throughout the project's planning and implementation [26].

Challenges faced by this project include illegal deforestation, livestock grazing, and aquaculture or fishing occurring in the newly planted mangroves. Because mangrove ecosystems provide abundant nurseries for shrimp and other fish, physical disturbance from fishing activities can cause degradation of mangrove health [29]. A mangrove guarding system has been implemented in order to prevent these activities [27]. Support has also been provided to some communities that must rely on grazing for their livelihoods, such as fodder grasses that can be grown on small plots of land for livestock to eat [25]. Furthermore, increasing salinity due to climate change has changed the adaptability of certain mangrove species in the area, but future mangrove seedlings were chosen based on salinity tolerance [28]. Natural disasters such as hail storms and cyclones continue to threaten newly planted mangroves in some plantation sites. These anthropogenic and natural factors have been noted and many mangroves have been replanted [28]. Despite these challenges, many sites are thriving [28].

3.3.4. Policy implications

The India Sundarbans Mangrove restoration project is thus far a successful example of a large-scale VCS project. It demonstrates the viability of the VCS AFOLU methodology for financing blue carbon projects, especially since soil carbon has been included in the carbon accounting for this project. One potential difficulty this project faces includes planning for the long-term; this project did not account for sea level rise caused by climate change, which could present problems in the future if mangrove seedlings are unable to survive [21]. To deal with the issue of degradation of the mangroves due to fishing and aquaculture, another potential future option would be to explore a policy that includes a sustainable business model for mangrove fisheries [27], similar to the Markets and Mangroves in Vietnam. Such a policy could further support local livelihoods and prevent the degradation of mangrove seedlings from fishing activities [28].

3.4. Blue Forests, Madagascar

3.4.1. Overview

Madagascar is home to 2% of the world's mangrove forests, which support its coastal communities by providing fisheries, timber, and other ecosystem services such as protection against storms and erosion. The Blue Forests initiative, undertaken by Blue Ventures, works with local communities to implement carbon financing projects seeking to conserve mangrove forests to support sustainable communities. In Madagascar, this Blue Forests effort aims to integrate mangrove conservation and restoration projects into the country's national REDD+ strategy [30] and implement mangrove conservation projects using voluntary carbon market standards across several project sites.

Research undertaken by Blue Ventures focused on quantifying greenhouse gas emissions that can be achieved by mangrove conservation and restoration, including an analysis of the drivers of wetland loss and modeling to predict future wetland changes. Additionally, Blue Forests seeks to understand the socioeconomic impact of its activities, which includes identifying alternative sources of livelihood and analyzing user rights of mangrove forests. These goals aim to fulfill the VCS, the Plan Vivo Standard, and the standards laid out by the Climate Community and Biodiversity Alliance [30]. A recent study established the feasibility of conducting a blue carbon project in Ambanja and Ambaro Bays, which

have lost almost 24% of their mangroves in the past 20 years mostly due to exploitation for harvesting for charcoal [31].

3.4.2. Financing

Blue Forests seeks to eventually incorporate blue carbon projects within Madagascar's national REDD+ strategy. Madagascar's national definition of forests limits forests to trees taller than five meters, however, which does not include the majority of mangrove forests. Blue Ventures is currently focused on working with Madagascar's government to change its national definition of forests to include all trees taller than three meters, which would encompass up to 98% of mangroves in the project [32]. If these negotiations are successful, the Blue Forests project will be able to move forward with a REDD+ carbon offsetting strategy in Madagascar. In the meantime, Blue Forests is assessing the feasibility of a large-scale VCS mangrove conservation project in Ambanja and Ambaro Bays and a smaller scale Plan Vivo project in Assasin's Bay [33].

3.4.3. Outcomes

While this project has not yet been implemented, Blue Forests has made strides in building community capacity for a REDD+ mangrove project in Ambanja and Ambaro Bays. In particular, the organization has overcome challenges negotiating user rights to the mangrove forests, enabling the communities that depend on these mangroves to gain equitable benefits and become legal users of these forests [30]. Additionally, Blue Forests has engaged the local communities through distribution of educational materials and ensuring that there are sustainable alternatives for the communities to use as natural resources for building materials [30], similar to the methods used in Mikoko Pamoja in Kenya.

3.4.4. Policy implications

Blue Ventures' blue carbon assessment and planning in Madagascar has made great strides towards setting the stage for both voluntary carbon crediting projects and eventually implementing REDD+ for mangrove projects. The blue carbon assessment that was conducted in Madagascar includes soil carbon in mangrove forests, a positive step towards capitalizing on these ecosystems' full climate mitigation potential. Further, this project has thus far successfully engaged the local communities throughout the REDD+ process. If the national definition of forests in Madagascar can be changed to trees taller than 3 m and this project begins receiving carbon credits, then the success of REDD+ for mangroves can be more comprehensively evaluated and would serve as an example for other countries. This project highlights that in some instances, national governments must be involved in order to change or create the policies necessary to implement blue carbon projects with regards to REDD+ or other UNFCCC mechanisms, since blue carbon projects may require additional action not needed for terrestrial "green" carbon projects under these same mechanisms.

4. Discussion

4.1. Suggestions to achieve successful blue carbon projects

While the case studies discussed in this paper vary widely in scope, stage, and methodology, some common themes emerge that can lead to successful projects. All of these case studies show the benefits of incorporating livelihood aspects as part of the restoration project design and of the importance of involving members of the local community in all stages of planning and implementation. For the case study projects, communities had a reason to be engaged in these projects from the beginning because

they understood that they would reap direct benefits.

Considering the needs of local communities during project development also ensures that leakage does not occur, i.e. that protecting a mangrove forest in one place does not lead to deforestation of mangroves elsewhere. For the Mikoko Pamoja project in Kenya, for example, the community has worked to avoid leakage by planting pine trees outside of the mangrove project site, providing the community with an alternative source of wood to help prevent mangrove deforestation. In the Sundarbans, newly planted or protected mangroves are sometimes degraded due to aquaculture and fishing activities which suggests that the project managers may want to consider additional sustainable livelihood options, such as sustainable shrimp farming, to help ensure the long-term sustainability of the mangrove carbon project. The Sundarbans project could potentially benefit from considering the sustainable shrimp farming method being used in the Markets and Mangroves project in Vietnam, which could enable the local community to gain revenue from shrimp farming while also protecting their mangroves. Unless local communities are able to look to other opportunities for income, blue carbon projects may be unable to overcome the threats that will likely occur due to local use of the mangroves.

All of the projects cited climate mitigation as one of their main objectives and yet none are currently being implemented using UNFCCC mechanisms. The two projects that are currently using carbon finance (Mikoko Pamoja in Kenya and the Sundarbans Mangrove Restoration project in India) both generate voluntary carbon credits because voluntary credits have so far proved to be more feasible for these smaller projects than UNFCCC mechanisms. There are higher transaction costs and more stringent standards under the UNFCCC. Additionally, for UNFCCC mechanisms to be available to individual projects, national governments must implement compliant laws and regulations. Therefore, a feasible carbon funding mechanism for these blue carbon projects has been the voluntary market. That said, two projects are in the planning stages for UNFCCC mechanisms with the hope of participating in the compliance market in the future, which demonstrates that blue carbon projects have the potential to be included within the UNFCCC system with proper planning and capacity-building. But non-carbon finance is likely to continue to be a better alternative for projects in some cases.

4.2. Benefits and challenges of the voluntary market for blue carbon projects

Based on the case studies, the voluntary market is more accessible for small, community-based projects. Participants in the voluntary market have a choice among standards (e.g., Plan Vivo, VCS) and projects can be completed while potentially avoiding some of the high costs and administrative burden associated with meeting CDM standards [14] or the detailed process needed to get a REDD+ project approved. In Vietnam and Madagascar, the length of time and planning required for a REDD+ project has been challenging such that MAM in Vietnam went forward with an alternative financing mechanism (sustainable shrimp) [34] and Madagascar has yet to implement their REDD+ project. For some projects, it will be more time-efficient and cost-effective to utilize another standard until the UNFCCC process becomes more streamlined. But it is important to recognize that credits in the voluntary market tend to be worth less than in the compliance market due to lower demand, differing quality standards, and lack of transferability to the compliance market [14]. Thus, there is a tradeoff to using voluntary carbon mechanisms. Additionally, as more coastal voluntary carbon market projects are implemented, additional supply in the voluntary market may drive the price of the credits down and make it more difficult to find buyers [21];

this has already been observed in Kenya [18].

4.3. Additional limitations and science needs for blue carbon projects

One of the most important considerations when accounting for the maximum amount of carbon in coastal ecosystems is including carbon stored within the soil, which is “by far the biggest carbon pool for all the focal coastal habitats” [12]. Only one of the four cases reviewed (Sundarbans) included soil carbon in their carbon accounting which means that much of the carbon in these ecosystems remains unaccounted for, preventing projects from attaining their full financial potential. In order to incorporate soil carbon, soil carbon measurements are needed, which may require capacity building to do these measurements locally or partnering with others who can provide the necessary technical expertise but would greatly enhance the climate mitigation value of blue carbon projects.

Accounting for sea level rise and the effects of climate change are also important considerations for long-term success of blue carbon projects. The Sundarbans mangrove project does not take into account the effects of sea level rise over time, despite 20 foot tidal changes [21,25]. It is possible that newly planted mangroves may drown under future sea level conditions if this project does not account for these changes [21], giving the project a finite life. Blue carbon project managers must account for future climate change impacts to the best of their ability, considering impacts perhaps 100 years into the future instead of only 20 or 50 years. Scientific capacity to do sea level rise projections or to interpret existing data will be needed, so communities may need help developing this expertise or leveraging resources elsewhere in order to better take future environmental and climate changes into account that may have important impacts on the long-term success of blue carbon projects.

4.4. Potential steps to support additional blue carbon projects

All of the projects discussed in this paper are specific to mangrove ecosystems. This study was unable to identify projects that include the other blue carbon ecosystems to date, most likely because most of the countries working to develop offsets are in tropical areas where mangroves are abundant, and because some of the UNFCCC mechanisms, notably REDD+ and CDM, only include mangrove ecosystems. Nevertheless, salt marshes and seagrasses are also effective coastal blue carbon ecosystems, sequestering and storing carbon at a greater rate than terrestrial forests [12]. Salt marsh and seagrass projects can also be included in voluntary market projects (see, for example, the tidal wetland and seagrass restoration methodology under review at the VCS⁴) or in future compliance market opportunities if the regulations for compliance markets are written broadly enough to include non-forested systems. We recommend that all three blue carbon ecosystems be included in future projects to capitalize on the carbon storage services they offer.

Other funding mechanisms for blue carbon projects should be considered as well. For example, NAMAs are another UNFCCC mechanism that are just beginning to be explored as a way to support blue carbon projects. NAMAs allow for individual countries to propose their own mitigation actions, allowing for greater flexibility in the types of projects proposed as well as the types of funding mechanisms for projects, which could be ideal for blue carbon projects. The Dominican Republic currently has one mangrove restoration NAMA (Table S1) project in the planning stages

which is likely to serve as a global model of how blue carbon NAMA projects can be developed (Table S1).

Another option for financing might come from the Green Climate Fund (GCF), a UNFCCC funding mechanism that became active in 2015 and is available for use in both adaptation and mitigation projects. The UNFCCC requires the approval of the country's national authorities in order to implement the fund, requiring countries to prioritize blue carbon projects [33]. This mechanism may be useful for projects seeking to capitalize on both climate mitigation and adaptation benefits of blue carbon ecosystems, especially since blue carbon ecosystems are known to provide adaptation benefits, such as storm and erosion risk reduction [21,35]. Additionally, some countries might benefit from using alternative financing mechanisms not based on carbon, as we saw in the MAM project in Vietnam.

It is also important to note that while the projects discussed here are all located within the developing world, coastal blue carbon projects can be implemented in any country where these ecosystems are present. Abu Dhabi is one notable example of a developed country with a blue carbon project underway, though this project did not use carbon financing mechanisms (Table S1) [36]. More research is needed on methods of implementing these projects in the developed world.

Finally, while these case studies analyze a variety of coastal blue carbon project types, there are many more projects in development around the world (Table S1). Many of these projects are either early in the development stages or do not have recently updated information publicly available. In order to facilitate more blue carbon projects, it is recommended that a global agency such as UNEP or a non-profit develop and maintain an up-to-date online database of existing, completed projects as well as those that are currently in the planning and implementation stages. The strategies that lead to successful projects will need to be investigated as more successful projects are completed.

5. Conclusions

Coastal blue carbon projects worldwide currently act as a testing ground for new ideas, methodologies, and financing mechanisms. These results suggest that small-scale blue carbon projects using either the voluntary carbon market or alternative financing mechanisms have been the most successful to date, largely due to simpler requirements for project development. This suggests that there are other viable alternatives to UNFCCC mechanisms that are currently more cost-effective and easier to implement. And despite the fact that the voluntary market is relatively small and makes up a small part of the global contributions to total greenhouse gas reduction, [14], the voluntary market does serve as an important “testing field for new procedures, methodologies and technologies that may later be included in regulatory schemes” [14]. As more countries and institutions seek to respond and adapt to climate change impacts by reducing their carbon footprint, the compliance market is likely to grow and more blue carbon projects will hopefully be included within this market. Projects developed within the voluntary market testing ground can help inform larger discussions about global climate mitigation policy. The international community is still learning best practices for implementing REDD+, CDM, and NAMA projects, but will hopefully be able to facilitate the inclusion of more blue carbon projects in the future.

With coastal blue carbon becoming an emerging issue in the UNFCCC and in countries worldwide, it is important for countries to learn from these case studies in order to make the process for implementing coastal blue carbon projects more streamlined and effective. It is hoped that more blue carbon projects will be

⁴ See: (<http://www.v-c-s.org/methodologies/methodology-tidal-wetland-and-seagrass-restoration>).

implemented around the world as awareness of the services that these ecosystems provide grows and different alternative methodologies for supporting projects are developed.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at <http://dx.doi.org/10.1016/j.marpol.2015.12.020>.

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