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Mangrove blue carbon in the Verde Island Passage

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MANGROVE BLUE CARBON
IN THE VERDE ISLAND PASSAGE

FOREWORD

Shyla Raghav (signature)

Shyla Raghav

Climate Change Lead
Conservation International

If we don't address climate change, little else will matter. Nature is an overlooked, irreplaceable asset in combating climate change. Protecting and restoring natural ecosystems would account for at least 30% of global action needed to avoid the worst climate scenarios – and these ecosystems, when conserved, help communities adapt to the effects of climate change that are already happening. Yet, natural climate solutions only receive 2% of global climate finance. Maximizing nature's role in combatting climate change will require efforts across sectors that relate to all forms of land use.

A significant part of realizing nature's potential as a climate solution requires conservation of particularly carbon-dense ecosystems, such as peatlands, old growth primary forests, and mangroves. These ecosystems store so much carbon that it cannot be restored on any human-relevant time scale. Mangroves, along with other coastal ecosystems, store four to five times the carbon (called 'blue carbon') in an equivalent area of terrestrial forest. Evidence also suggests that human settlements surrounded by mangroves are more resilient to the extreme impacts of climate change such as storm surges and therefore suffer less losses. Therefore, conserving mangroves and coastal ecosystems for the long-term is an indispensable part of any credible global and local strategy to avoid the most dangerous impacts of climate change.

Until recent times, mangroves were thought of as swampy, muddy, and tangled coastal forests that were an impediment to coastal development. Recent understanding of their value, however, has created incredible motivation to consider mangroves as critical for addressing climate change. The findings in **Mangrove Blue Carbon in the Verde Island Passage** show that, through cutting edge science, we can quantify the carbon storage and sequestration benefits of these critical ecosystems. Analyses like those in this research can help increase credibility in the carbon accounting of mangrove forests, in order to integrate them into funding mechanisms and policy approaches.

All these topics and more are featured here, with a focus on the Verde Island Passage in the Philippines. I, and Conservation International, are honored to have been part of this important work.

FOREWORD

Enrique A. Nuñez, Jr
Country Executive Director
Conservation International Philippines

Coastal communities are deeply dependent on coastal ecosystems while being especially vulnerable to climate change. Intense typhoons, storm surge, and habitat loss due to coral bleaching are among the impacts that threaten their lives and livelihoods. These will only become more severe if carbon dioxide emissions continue to increase unabated.

Blue carbon is a natural innovation to reduce carbon dioxide emissions. Among the first steps in harnessing blue carbon for climate change mitigation is quantifying potential carbon storage in respective coastal habitats, and understanding the factors that influence such capacity.

Conservation International Philippines has initiated pioneering research in the Verde Island Passage, systematically assessing the carbon storage efficiency of representative mangroves in four provinces. This publication **Mangrove Blue Carbon in the Verde Island Passage** presents key results that may pave the way for further research, and enhance mangrove conservation and management.

Conservation International Philippines and its partners are implementing the 10-year **Highlands to Oceans Strategy**, an integrated plan to "improve and sustain natural capital and productions in target sites under climate change" by 2027. In the Verde Island Passage, Conservation International Philippines is working with local government and communities, and stakeholders to establish a mangrove greenbelt. Various strategies such as the protection and rehabilitation of existing stands, reversion of abandoned, undeveloped, and underutilized (AUU) fishponds, and use of best planting practices are being urged to realize the benefits of a true greenbelt.

As part of this larger framework towards resilience, blue carbon is recognized as both a catalyst and incentive for stronger mangrove conservation and management. The Verde Island Passage is poised to become a compelling model for blue carbon in the Philippines.

Mangrove Blue Carbon in the Verde Island Passage serves to further emphasize the inimitable role of nature in our lives. Conservation International Philippines, through its efforts on blue carbon, continues to strive towards its ultimate goal of improving human well-being.

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PLATE

ACRONYMS

AUU	Abandoned, undeveloped, and underutilized (fishponds)
GHG	Greenhouse gas emissions
NCCAP	National Climate Change Adaptation Plan
NDC	Nationally Determined Contributions
REDD+	Reducing Emissions from Deforestation and Forest Degradation
UNFCCC	United Nations Framework Convention on Climate Change

UNITS

Mg	megagram (1 megagram = 1,000 kilograms)
Mg C/ha	megagram(s) of carbon per hectare
Tg	teragram (1 teragram = 1,000,000 megagrams)
Tg C	teragram(s) of carbon
Tg CO$_2$	teragram(s) of carbon dioxide

I.
MANGROVES AS BLUE CARBON

Coastal wetlands including mangrove forests, seagrass meadows and tidal saltmarshes are known as "blue carbon" ecosystems because they are able to trap ("sequester") and store large amounts of carbon (1). These blue carbon ecosystems use carbon dioxide from the atmosphere during photosynthesis. Some carbon is returned to the atmosphere through respiration but most of it ends up in the plants and in the soil (2; Figure 1). Blue carbon ecosystems can sequester four to five times more carbon dioxide per hectare than tropical upland forests (3).

Carbon in living plant parts is stored for relatively short time scales (years to decades), but blue carbon in the soil is stored in massive amounts over longer periods (centuries to millennia; 4). In mangroves, organic litter and detritus are trapped by their complex root systems. These continuously accumulate in the waterlogged, oxygen-poor sediment where decomposition is very slow. These conditions enable carbon storage in the mangrove soil for hundreds to thousands of years (5).

The ability of mangroves to sequester carbon is affected by ecosystem health and intertidal position. Mangroves are effective carbon sinks when they are healthy, but can potentially become carbon emitters when they are disturbed or damaged (6, 7). Every year, a little more than 1 billion tons of carbon dioxide are released by degraded coastal ecosystems (8). On the other hand, mangroves nearer to land can accumulate more carbon than those in the coastal fringe, which are more exposed to waves and currents.

By sequestering carbon, mangroves provide a natural solution to reducing carbon dioxide emissions. International policies such as the United Nations Framework Convention on Climate Change (UNFCC), Reducing Emissions from Deforestation and Forest Degradation (REDD+), among others, have already considered blue carbon for its role in climate change adaptation and mitigation (9; see 10 for REDD+). However, the specific contribution of mangroves must be quantified. Such value is the imperative for their conservation and restoration towards climate resilience (see 11).

Carbon Sequestration/Capture
Carbon dioxide in the atmosphere is used by trees during photosynthesis.

Carbon is stored in the leaves, branches, and roots of the plants. Some is returned to the atmosphere through respiration.

Carbon Storage
Dead leaves, branches, and roots containing carbon are buried in the soil, which is typically submerged in tidal waters. In this oxygen-poor environment, plant parts decompose very slowly, resulting in substantial carbon storage over depths.
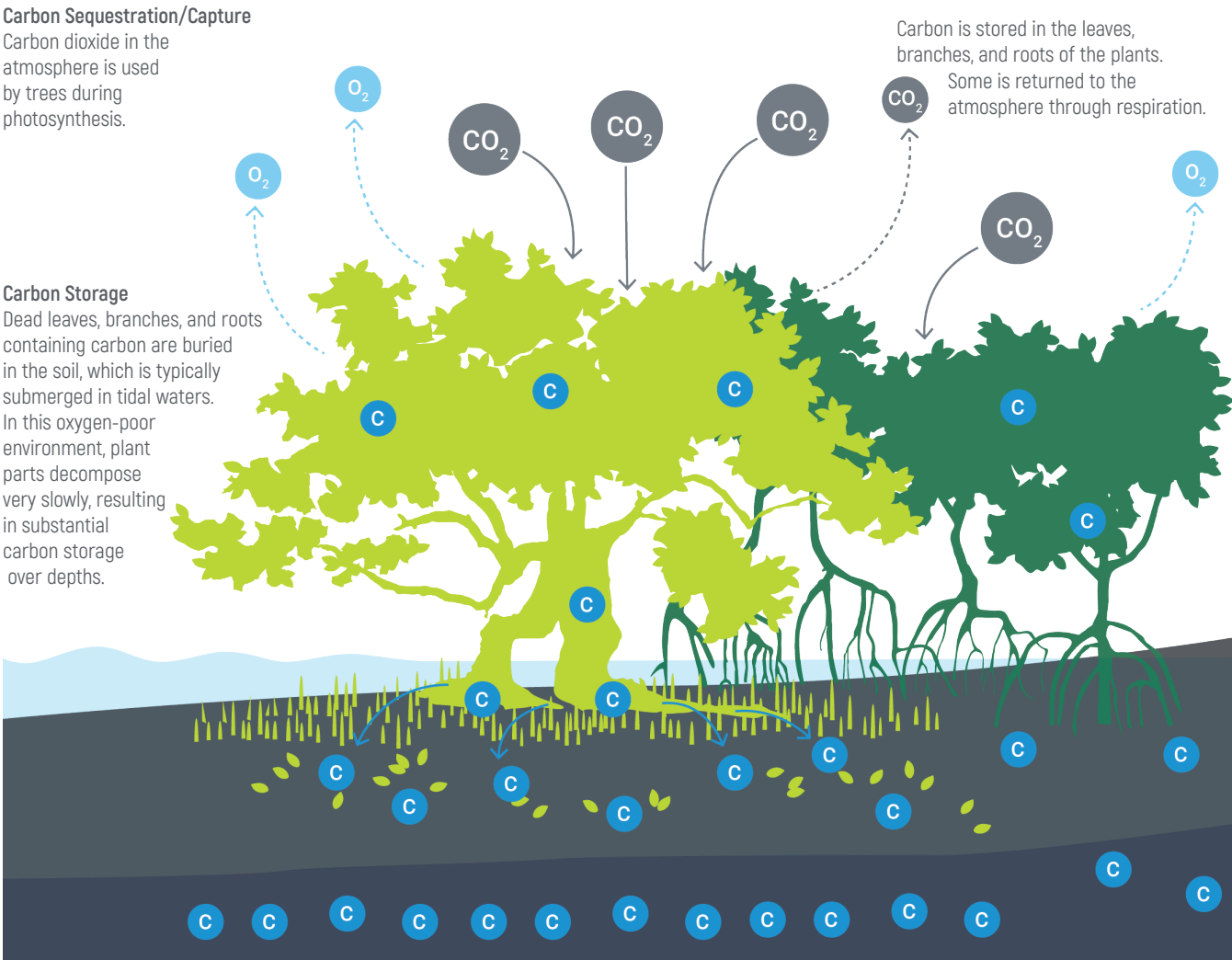
Figure 1: Carbon sequestration in mangroves

While carbon stocks have been measured in other parts of Asia and the Pacific, information is still limited in the Philippines. Most recent estimates are from only three studies, highly varied, and not geographically representative (12). Better estimates of carbon stocks and sequestration rates across different mangrove settings are needed to establish a representative value for the Philippines.

The Verde Island Passage is the center of shorefish biodiversity and one of the most productive ecosystems in the world (13). Since 2005, Conservation International Philippines, working with the local government and communities, has supported various research on biodiversity and climate change adaptation. Information from these have been used to formulate scalable conservation and management plans.

The mangroves in the Verde Island Passage have recently been assessed for their function as carbon sinks. Carbon stocks were measured in selected sampling sites, and used to calculate for total carbon stock. Carbon stocks were comparable across mangrove sites, but patterns of accumulation and storage varied. These were affected by ecosystem health, extent, and structural complexity.

Total carbon stock in the Verde Island Passage was slightly higher than other known values in the Philippines. These measurements, as well as those from other sites in the Philippines, are important in accounting for the country's Nationally Determined Contributions (NDC) in reducing greenhouse gas (GHG) emissions.

In the Verde Island Passage, strong coastal management, driven by local governments and communities and non-government organizations like Conservation International Philippines, provides numerous opportunities for blue carbon research and application. Carbon sequestration as an added ecosystem service provides further incentive to strengthen efforts in both mangrove conservation and restoration (see 14-16 for national legislation on mangrove conservation; 17-19 for mangrove conservation efforts and challenges in the Philippines and in the region).

Better restoration practices, which are being urged in the Verde Island Passage, are needed to enhance blue carbon management. Particularly, the reversion of abandoned, undeveloped, and underutilized (AUU) fishponds to their original state as mangroves ensures better survival of seedlings. These restored mangroves would eventually help reduce GHG emissions.

Overall, there is great potential for the mangroves in the Verde Island Passage to be harnessed as blue carbon for climate change adaptation and mitigation. Further, the area is an ideal demonstration site for relevant research and management because of the existing governance structure, meaningful involvement of local governments and communities, and long experience in marine conservation.

II.
MEASURING CARBON STOCKS IN THE VERDE ISLAND PASSAGE

The mangroves in the Verde Island Passage have recently been assessed for their function as carbon sinks. Researchers conducted field studies to determine carbon stocks in representative sampling sites, then used these to estimate carbon stocks for the entire area. Total carbon stock in the Verde Island Passage was found to be slightly higher than other known values in the Philippines. With further research and sustained management, the mangroves in the Verde Island Passage may be harnessed as blue carbon for climate change adaptation and mitigation.

Field measurements

Five representative mangrove sites across four provinces in the Verde Island Passage were selected for field measurements of carbon stocks. These were Calatagan in Batangas, Calapan and Naujan in Oriental Mindoro, Looc in Romblon, and Sta. Cruz in Marinduque. All of the sites have healthy mangroves and are potential models for blue carbon, each representing a different habitat condition and management regime (Table 1).

Table 1: Characteristics of the mangrove sampling sites

Site	Features	Management	Extent (m)	Number of species	Dominant species	Density (trees/ha)	Height (m)	Diameter (cm)	Basal area (sq m/ha)
Sta. Cruz, Marinduque	Natural, intact	Informal marine protected area	> 1,500	14-20	*Ceriops decandra, Rhizophora stylosa*	1,528 ± 107	6.52 ± 0.85	9.19 ± 1.12	19.69 ± 1.57
Naujan, Oriental Mindoro	Natural, uplifted	Fishponds, plantation	1,200	16	*Avicennia marina, Rhizophora stylosa, Sonneratia alba*	1,963 ± 408	4.34 ± 1.10	7.17 ± 1.95	24.79 ± 18.72
Calapan, Oriental Mindoro	Natural, uplifted, residential	Marine protected area, eco-tourism	700	4	*Sonneratia alba*	1,878 ± 109	5.57 ± 0.52	9.22 ± 0.95	37.01 ± 8.71
Calatagan, Batangas	Natural	Marine protected area, eco-tourism	150	5	*Avicennia marina*	2,165 ± 305	2.86 ± 0.16	4.35 ± 0.56	9.80 ± 5.22
Looc, Romblon	Natural, residential	None	< 80	5	*Sonneratia alba, Rhizophora stylosa*	883 ± 121	5.60 ± 0.42	16.62 ± 3.32	62.97 ± 22.51

*Mangrove distribution (20); provincial mangrove information (21); for marine protected areas in the Verde Island Passage, see 22.

Of the five sites, Sta. Cruz has the greatest width at more than 1.5 km from shore to land. Along with Looc, it also has the most species, having more than 16 of the 40 mangrove species known to occur in the Philippines. In Sta. Cruz, the species *Ceriops decandra* ("baras-baras") makes up about 40% of the vegetation, though in the rest of the sites, *Sonneratia alba* ("pagatpat"), *Avicennia marina* ("apiapi" or "bungalon"), and *Rhizophora stylosa* ("bakhaw bato") are dominant. Looc has the fewest trees, though these were the largest measured.

Calapan and Naujan in Oriental Mindoro were uplifted from an earthquake in 1994. In Calapan, mangrove cover shows damage from recent typhoons while in Naujan, the trees have colonized abandoned fishponds. All of the sites, except Looc, are managed by either local government or communities at varying degrees. Calapan and Calatagan, in particular, are ecotourism sites managed by people's organizations (PO). The sites in Calapan and Looc are near coastal residential areas.

The researchers measured carbon stocks in the biomass and the sediment. For the carbon in the biomass, they used tree diameter to compute for above- and belowground biomass (cf. 23). It is assumed that 45-50% of the biomass is carbon. For carbon in the sediment, the researchers analyzed core samples in the lab for bulk density (weight per unit volume) and organic carbon at different soil depths for 100 cm. Bulk density and organic carbon were then used to calculate for carbon stocks in the sediment. Carbon stock in the sediment was the sum of carbon in the entire 100-cm sample. (The methods to assess carbon stocks are after those described in 24.)

To account for possible variation in carbon storage, measurements were taken in the mangrove landward, middle, and seaward zones.

The researchers also surveyed the vegetation, including identifying the tree species present, measuring trunk diameter-at-breast-height, counting tree saplings and seedlings, and estimating height and canopy cover (24). Carbon burial and long-term storage in mangroves is most effective with diverse and healthy vegetation, and oxygen-poor ("anoxic") sediment conditions. The presence of large mangrove trees, of different species, sustains primary production and creates a complex network of vegetation that effectively traps and stabilizes organic debris. Further, dense or contiguous forests, being relatively protected, accumulate and store carbon more efficiently than narrow or sparse stands that are more exposed. Specifically, the latter are more vulnerable to sediment loss from shoreline erosion by waves and currents, and are therefore more likely to lose carbon (see also 25).

Measuring carbon stocks

Assessing vegetation
Species ID; measurements for diameter-at-breast-height, tree height, canopy cover; and seedling/sapling count
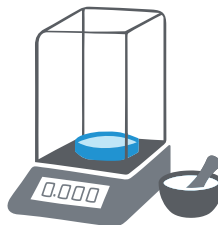
Assessing sediment
Core sample collection up to 100 cm; measurements for water quality

Lab analyses
Analyses for organic matter and bulk density to calculate sediment carbon

Calculating carbon stocks
Carbon in above- and belowground biomass, and sediment
Total carbon stock = aboveground carbon + belowground carbon + sediment carbon

Carbon stocks in the mangrove sampling sites

The average total carbon stock across sites was 626.70 megagrams per ha (Mg C/ha; 1 megagram = 1,000 kilograms), slightly higher than the Philippine average (624 Mg C/ha). The highest total carbon stock was in Sta. Cruz (689.57 Mg C/ha) and lowest in Calapan (579.73 Mg C/ha; Table 2). Of all the sites, the mangrove in Sta. Cruz has relatively better vegetation and sediment conditions, and is the widest and most contiguous. On the other hand, the forest in Calapan is relatively small and patchy, which makes it more vulnerable to soil erosion and, ultimately, carbon loss.

At least 80% of the total carbon stock was found in the sediment, though the proportion varied with sites (Figure 2). For example, nearly 95% of the total carbon in Calatagan was from the sediment while only 60% was derived from that in Looc. In Looc, more carbon is stored in the vegetation because the trees are larger, particularly of the genus *Sonneratia*. Further, the sediment in the area is made mostly of sand, which is greatly influenced by tides and waves. On the other hand, the other sites are near rivers that supply additional sediment and organic material, which then translate to more carbon.

Table 2: Total carbon stock per mangrove sampling site

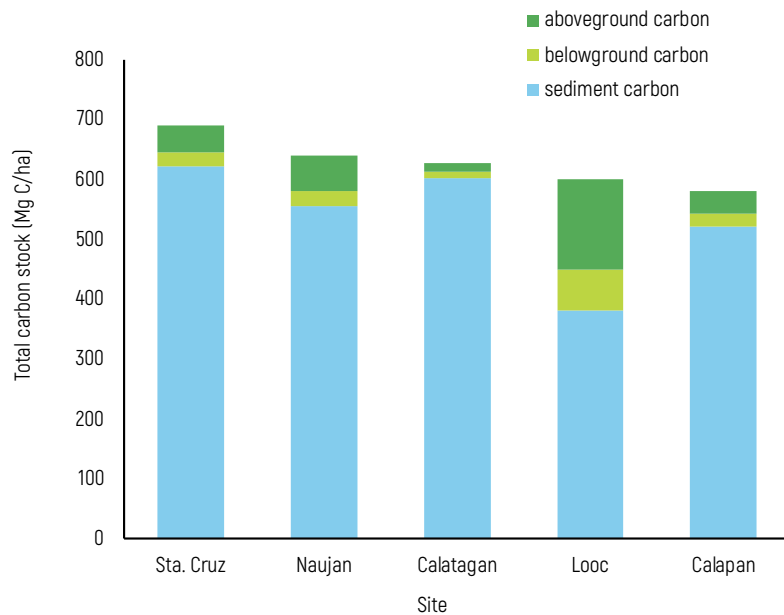| Site	Total carbon stock (Mg C/ha)
Sta. Cruz, Marinduque	689.57
Naujan, Oriental Mindoro	638.88
Calatagan, Batangas	625.91
Looc, Romblon	599.38
Calapan, Oriental Mindoro	579.73
mean	626.70

Figure 2: Total carbon stock in each mangrove sampling site

Most of the sediment carbon was found in the soil subsurface (Figure 3). The highest values were at 0-10 cm, then become uniform with some variation until 100 cm. Calapan, Naujan, and, to some degree, Calatagan showed fairly uniform patterns of carbon storage. Here, the greatest amount was observed in the upper depths, suggesting recent accumulation from decomposing vegetation. In Looc and Sta. Cruz, high amounts of carbon were also observed at the subsurface, though fluctuate constantly at various depths, indicating more erratic carbon gains and losses.

In Calapan and Naujan, signs of recent carbon accumulation show the effects of extreme events including the 7.1-magnitude earthquake in 1994 and powerful typhoons in 2016 and 2017. The earthquake caused the ground to uplift by about half a meter, severely disrupting the sediment (26-27). On the other hand, the typhoons damaged the trees and eroded the upper sediment layer, resulting in carbon losses in both the vegetation and the sediments.

Mangrove carbon stocks are known to increase from the seaward fringe to land. On the other hand, a couple of the sites showed the highest measurements in the middle zone, which may be due to other local factors (See Box) .
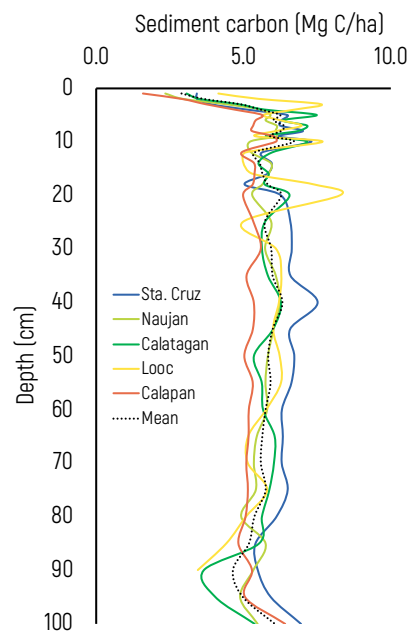

Figure 3: Sediment carbon up to 100-cm depth for each mangrove sampling site

SITE SPECIFIC RESULTS

Sta. Cruz, Marinduque

Mean total carbon stock in the Sta. Cruz mangrove was highest across all sites at 689.57 ± 33.17 Mg C/ha. Sediment carbon was also greatest here, accounting for 77-97% of total carbon stock in the site. There was no apparent pattern across mangrove zones, but carbon stock in the middle zone was relatively lower than in the landward and seaward zones. Sediment carbon fluctuated with depth, being highest at 0-15 cm and stable at 25-80 cm, then decreasing at 85-100 cm.
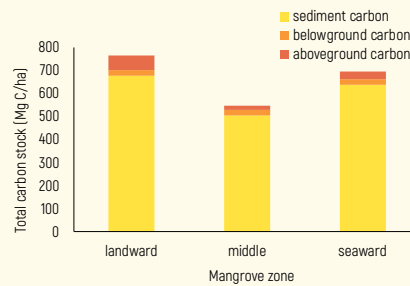

Figure 4: Total carbon stock per mangrove zone in Sta. Cruz, Marinduque

Figure 5: Sediment carbon up to 100-cm depth per mangrove zone in Sta. Cruz, Marinduque

Naujan, Oriental Mindoro

The mean total carbon stock in the Naujan mangrove was 638.88 ± 56.78 Mg C/ha, showing no apparent pattern with distance from the shoreline. Carbon stocks were highest in the middle zone, with the above- and belowground carbon in one sampling site contributing more to the total carbon stocks by 30-40%. Sediment carbon was greatest in the upper depths of 0-20 cm, and stable from 20-100 cm.

Figure 6: Total carbon stock per mangrove zone in Naujan, Oriental Mindoro

Figure 7: Sediment carbon up to 100-cm depth per mangrove zone in Naujan, Oriental Mindoro

Calatagan, Batangas

In the Calatagan mangrove, the mean total carbon stock was 636.55 ± 40.57 Mg C/ha, with more than 90% coming from the sediment. Highest carbon stocks were observed in the middle sites. The trend of sediment carbon across depth was erratic, but measurements were generally highest at 0-10 cm, stable at 10-80 cm, and increasing at 90-100 cm.

Figure 8: Total carbon stock per mangrove zone in Calatagan, Batangas

Figure 9: Sediment carbon up to 100-cm depth per mangrove zone in Calatagan, Batangas

Looc, Romblon

The mean total carbon stock in the Looc mangrove was 599.38 ± 88.62 Mg C/ha. Above- and belowground carbon accounted for up to 40% of the carbon stock, contrary to the other sites where these were marginal relative to sediment carbon. Carbon stocks were higher in the landward sites than in the seaward sites, likely because of the presence of large *Sonneratia alba* trees in the former. Sediment carbon showed an erratic pattern, generally oscillating with depth up to 100 cm.

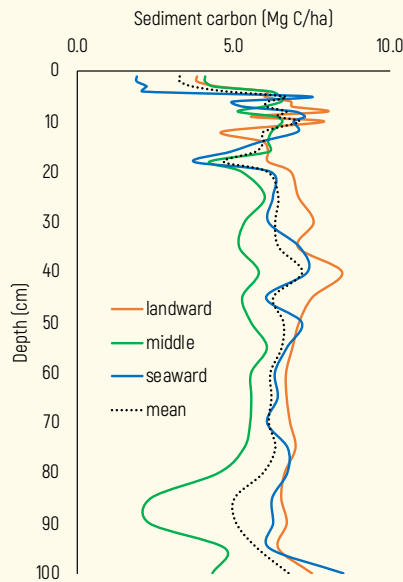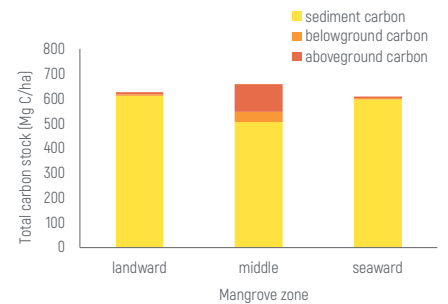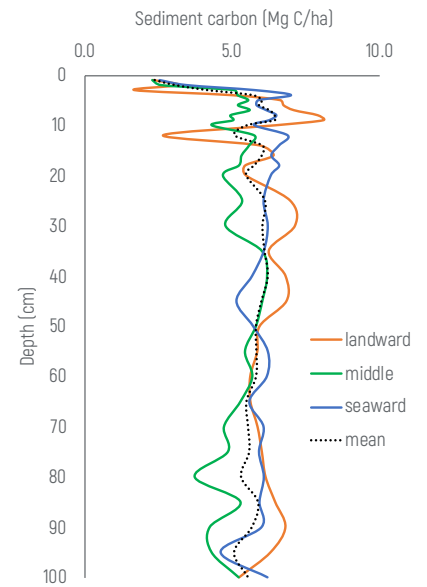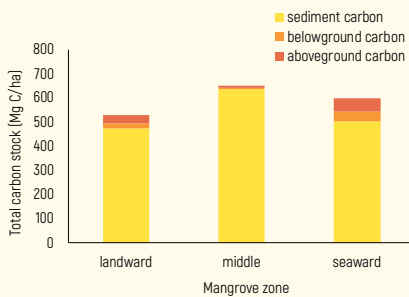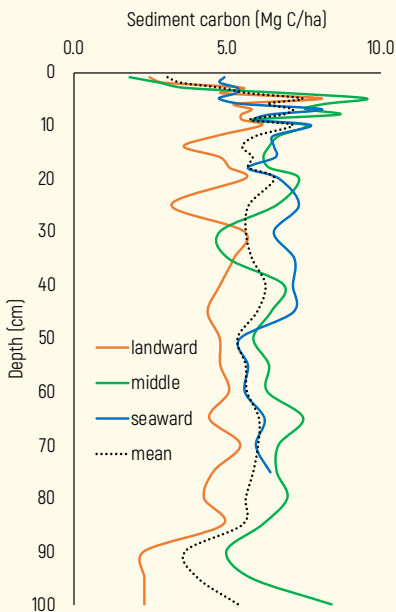Figure 10: Total carbon stock per mangrove zone in Looc, Romblon
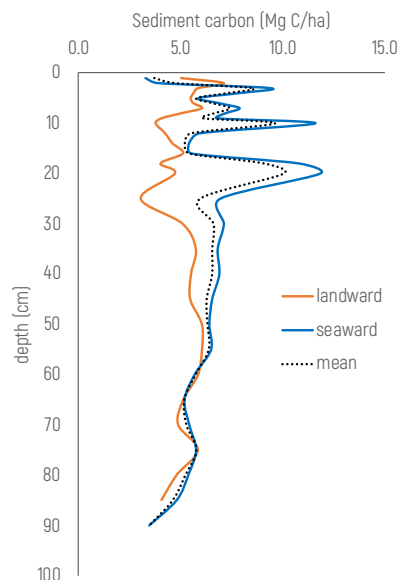
Figure 11: Sediment carbon up to 100-cm depth per mangrove zone in Looc, Romblon

Calapan, Oriental Mindoro

The mean total carbon stock in the Calapan mangrove was 579.73 ± 28.81 Mg C/ha, and increased with distance from the shoreline. About 90% of the total carbon stock was from the sediment. Carbon stocks were higher by 10-20% in the landward site than in the mid- and seaward sites. Sediment carbon stocks were high at a depth of 0-10 cm, stable until 90 cm, then increasing at 90-100 cm.
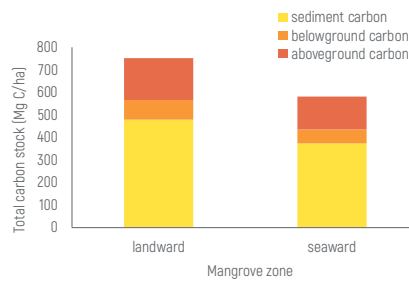

Figure 12: Total carbon stock per mangrove zone in Calapan, Oriental Mindoro
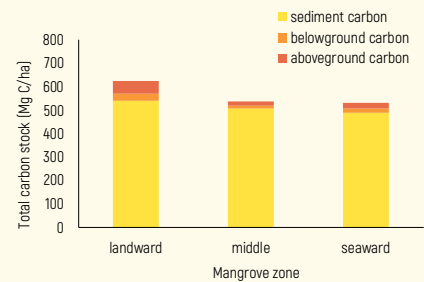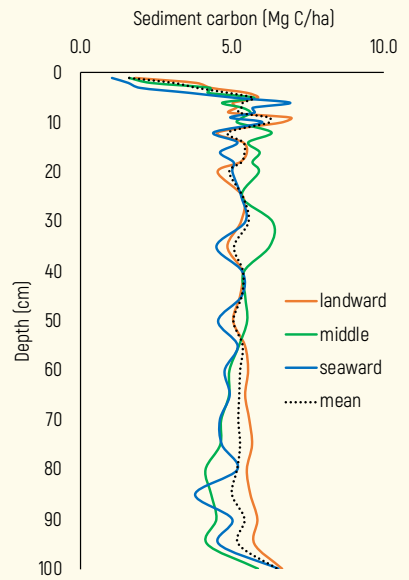

Figure 13: Sediment carbon up to 100-cm depth per mangrove zone in Calapan, Oriental Mindoro

III.
CARBON STOCKS IN THE VERDE ISLAND PASSAGE

Carbon stocks per province in the Verde Island Passage have been estimated based on spatial information on forest area and field measurements from representative mangrove sites.

Marinduque, with the greatest mangrove area, has the highest total carbon stock at 2.35 teragrams (Tg; 1 teragram = 1,000,000 megagrams), followed by Oriental Mindoro at 1.46 Tg (Table 4; see also Table 3 for carbon stock per sampling site). Romblon and Batangas, with relatively less mangrove area,

have lower stocks at 0.74 Tg and 0.33 Tg respectively. Total carbon stock in the mangroves of the Verde Island Passage, except Occidental Mindoro, is estimated at 4.88 Tg, which is equivalent to 17.89 Tg of carbon dioxide sequestered from the atmosphere.

The carbon stocks in Oriental Mindoro and Romblon have increased from 2000 to 2017, but those in Marinduque have slightly declined. No apparent changes were observed in Batangas for the time period (Figure 14).

Table 3: Estimated carbon stocks per sampling site

Municipality	Estimated mangrove area (ha) in 2010*	Estimated carbon stock (Tg C)	Equivalent CO_2 sequestered from the atmosphere (Tg CO_2)
Sta. Cruz, Marinduque	2,474.32	1.71	6.29
Calapan, Oriental Mindoro	618.13	0.36	1.30
Naujan, Oriental Mindoro	298.36	0.19	0.70
Looc, Romblon	253.50	0.17	0.62
Calatagan, Batangas	28.00	0.15	0.60

*Sources: 21, 28-30

Table 4: Estimated carbon stocks per province

Province	Estimated mangrove area (ha) in 2010	Estimated carbon stock (Tg C)	Equivalent CO_2 sequestered from the atmosphere (Tg CO_2)
Marinduque	3,197.58	2.35	8.61
Oriental Mindoro	2,391.72	1.46	5.35
Romblon	1,114.98	0.74	2.73
Batangas	610.94	0.33	1.20
Total*		4.88	17.89

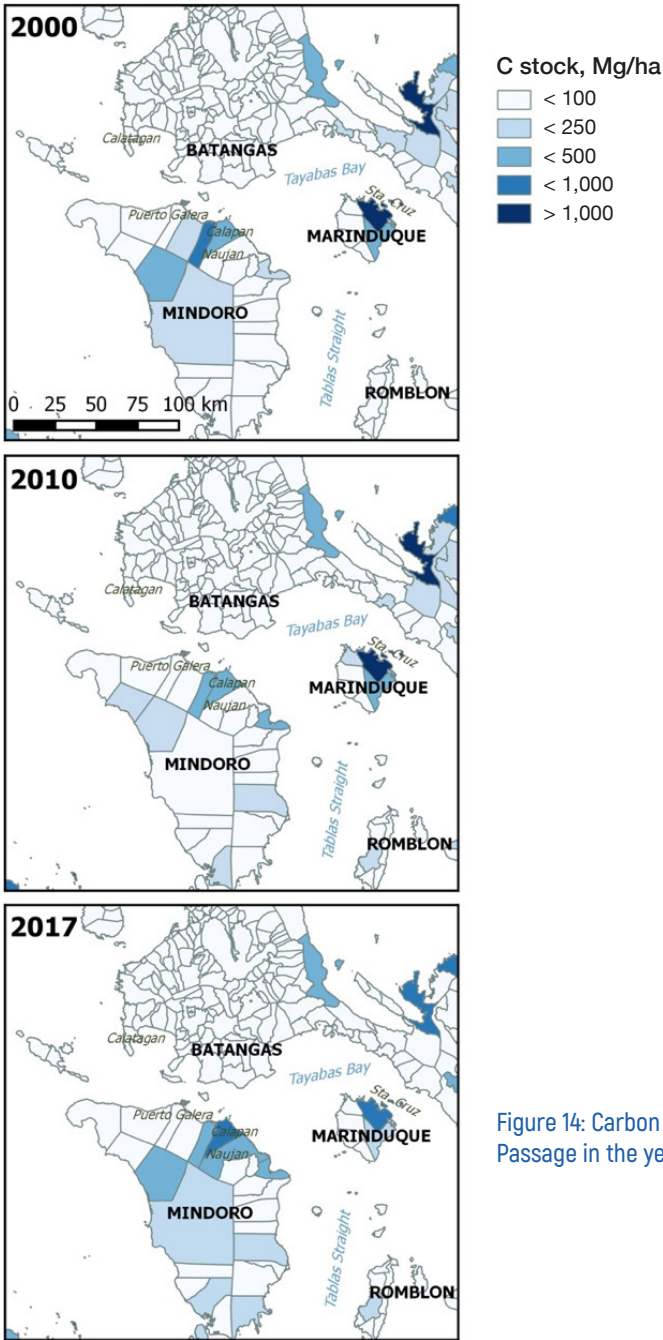*Does not include estimates for Occidental Mindoro

Figure 14: Carbon stocks in the Verde Island Passage in the years 2000, 2010, and 2017

IV. CARBON STOCKS IN THE PHILIPPINES AND SOUTHEAST ASIA

Mangroves in the Verde Island Passage are relatively healthy compared to most parts in the Philippines. The impacts of conservation are evident on the ground, though there are occasional signs of both natural and human-related disturbances. Field measurements of carbon stocks in representative sampling sites in the area were slightly higher than average in the Philippines, though reasonably within range (Table 5).

The field measurements from the different sampling sites around the Philippines, including the Verde Island Passage, were used to estimate carbon stocks across the country (Figure 15). Based on the calculations, the provinces of Palawan, Surigao, Tawi-Tawi and Isabela have the highest carbon stocks (Figure 16). The Verde Island Passage contributes about 10% to the national carbon stock.

In Southeast Asia, the greatest rates have so far been measured in sites in Indonesia and Malaysia (Table 6). Observed rates in the Philippines are within range in the region.

Table 5: Carbon stock estimates in Philippine mangroves*

Site	Carbon stock (Mg C/ha)
Subic Bay, Zambales [31]	1,461
Honda Bay, Palawan [6]	1,040
Dumangas, Iloilo [32]	700
Verde Island Passage [this study]	629
Panay Island [33]	441
Banacon Island, Bohol [34]	435
Bantayan Island, Cebu [31]	166
San Juan, Batangas [35]	116
mean	624

*Study coverage, i.e., passage- and bay-wide, municipal- and site-level
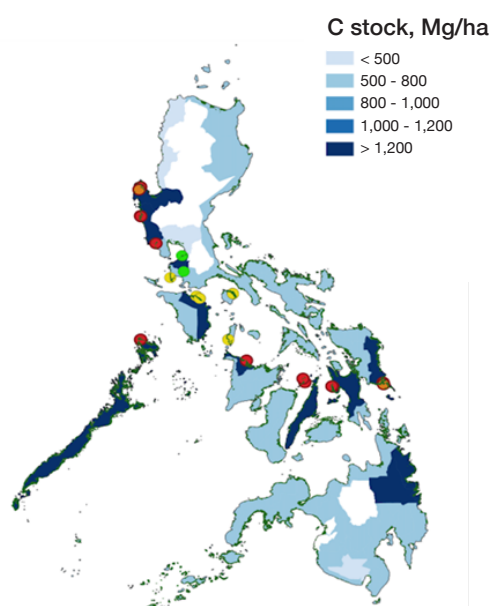
Figure 15: Estimates of carbon density in the Philippines
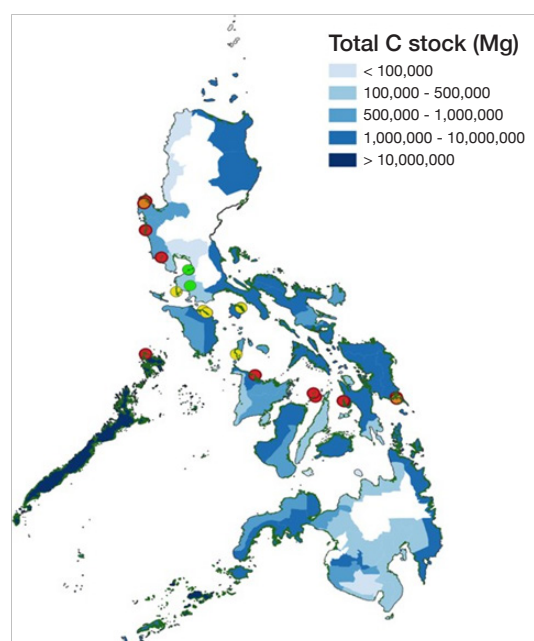
Figure 16: Estimates of total carbon stocks in the Philippines

Table 6: Carbon stock estimates in Southeast Asia

Country	Site	Carbon stock (Mg C/ha)
Indonesia	Bintuni [12]	1,567
Malaysia	Peninsular Malaysia [5]	1,267
Indonesia	Bunaken, Sulawesi [36]	939
Vietnam	Mekong Delta [37]	863
Thailand	Southern Thailand [5]	662
Indonesia	Segara Anakan, Java [36]	586
Malaysia	Kelantan [38]	305
Myanmar	Bogalay, Ayeyawady Delta [39]	240

V.
THE VERDE ISLAND PASSAGE IN BLUE CARBON RESEARCH AND MANAGEMENT

The Verde Island Passage is an ideal demonstration site for blue carbon in the Philippines. Here, mangroves are relatively healthy and well-protected, and have great potential to be harnessed as blue carbon. Further, long-term conservation programs in the area, mainly by Conservation International Philippines and local governments and communities, can provide the necessary baseline and monitoring information otherwise absent in other sites in the country.

The Verde Island Passage provides several opportunities for further research on blue carbon. To better understand the effects of ecosystem health, geographical location (i.e., mangrove zones) and other conditions on carbon storage, more representative sampling points in each of the provinces should be established. For example, comparing carbon stocks in intact mangroves such as in Marinduque, Romblon, and Occidental Mindoro with those in disturbed stands such as in certain areas in Batangas will reveal spatial patterns relative to ecosystem health, as well as improve the estimate of total carbon stocks in the area. Frequent and regular monitoring, at least once to twice a year, will further help in determining the variable rates of sequestration in different mangrove settings.

The Verde Island Passage is affected by natural disasters, which impact mangroves in various ways. For example, the earthquake in 1994, which resulted in sediment uplift of about 0.5 m, facilitated colonization and development of a mangrove in Calapan, Oriental Mindoro. Clear information on forest and sediment age, roughly 25 years in the case of Calapan, can be used to study how carbon stocks are accumulated or lost over time. Comparisons with natural or planted stands of different ages would then become possible.

Typhoons, depending on frequency and magnitude, can damage or destroy mangroves. This reduces their capacity to sequester and stabilize carbon (40; Plate 1). Mangroves will recover in most cases, with monospecific plantations being an exception, through seedling recruitment and coppice regeneration. In this way, carbon can eventually be regained. The impacts of natural disturbances on mangroves and their eventual recovery in the Verde Island Passage can further support understanding on how carbon is reduced and gained and regained over time.

Plate 1: Severe damage and mortality in mangroves in Calapan, Oriental Mindoro after Typhoon Nina (International: Nock-ten) in December 2016 (Photos: S Salmo III)

In the Verde Island Passage, there is an opportunity to restore mangroves in AUU fishponds. Trees planted in these fishponds, many of which were originally mangroves, would have a better likelihood of surviving than those planted in coastal fringes. If AUU fishponds are unrestored, there is a possibility they will contribute to GHG emissions (6).

Conservation International Philippines, partnered with the Provincial Government of Oriental Mindoro, is implementing the Mangrove Green Wall Program that aims to establish a greenbelt in the entire province. Certainly, the reversion of AUU fishponds would complement the rehabilitation and development of a contiguous mangrove in the province.

Most of the local governments and communities in the Verde Island Passage are meaningfully involved in marine conservation, contributing to activities such as enforcement and regular monitoring at various levels. In Oriental Mindoro, for example, monitoring coastal habitats including mangroves is undertaken at least once a year. Provincial plans on mangrove management also exist. The strong infrastructure for coastal management in the Verde Island Passage would be readily able to incorporate the regular monitoring, reporting, and validation needed for quality information on carbon stocks. In turn, a blue carbon program would enhance mangrove management in the Verde Island Passage.

Mangroves in Romblon
Photo: Severino Salmo III

VI.
BLUE CARBON AND BEYOND

Blue carbon as a mitigation strategy is an imperative to further strengthen mangrove conservation and restoration. In the Paris Agreement, the Philippines has committed to reduce greenhouse gas emissions by 70% by the year 2030. There are key opportunities to account blue carbon contributions in the National Climate Change Adaptation Plan (NCCAP) and other Philippine commitments to the UNFCCC. Information on carbon stocks in areas like the Verde Island Passage must be incorporated in such accounting (1, 41; see also 42).

Nationally, blue carbon initiatives are coordinated by the Climate Change Commission through the Blue Carbon Technical Working Group. At the regional level, blue carbon objectives are facilitated by the Climate Change Adaptation Working Group of the Coral Triangle Initiative. Global collaborations such as the International Partnership for Blue Carbon and the Blue Carbon Initiative have also been established to support efforts on blue carbon ecosystems.

Carbon stocks with corresponding prices can be traded through carbon financing platforms (43). The carbon sequestration service of mangroves is valued in recent global assessments at USD 3.3-4.8 per ton of carbon dioxide (44), so the mangroves in the Verde Island Passage are worth at least USD 59-78.7 million, on top of the other ecosystem services they provide (see also 45-48).

In the Philippines, blue economy has been gaining traction as a major component for national economic development (49). Mangroves, with their role in blue carbon, would be able to constitute a significant contribution.

Mangroves provide multiple services that are crucial in addressing the effects of global warming and rising sea levels. The emergence of blue carbon as a decisive mitigation strategy is further incentive to conserve and restore mangroves.

Mangroves in Odiongan, Romblon
Photo: Conservation International | Don Olavides

VII.
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Mangroves in Naujan, Oriental Mindoro
Photo: Conservation International | Don Olavides
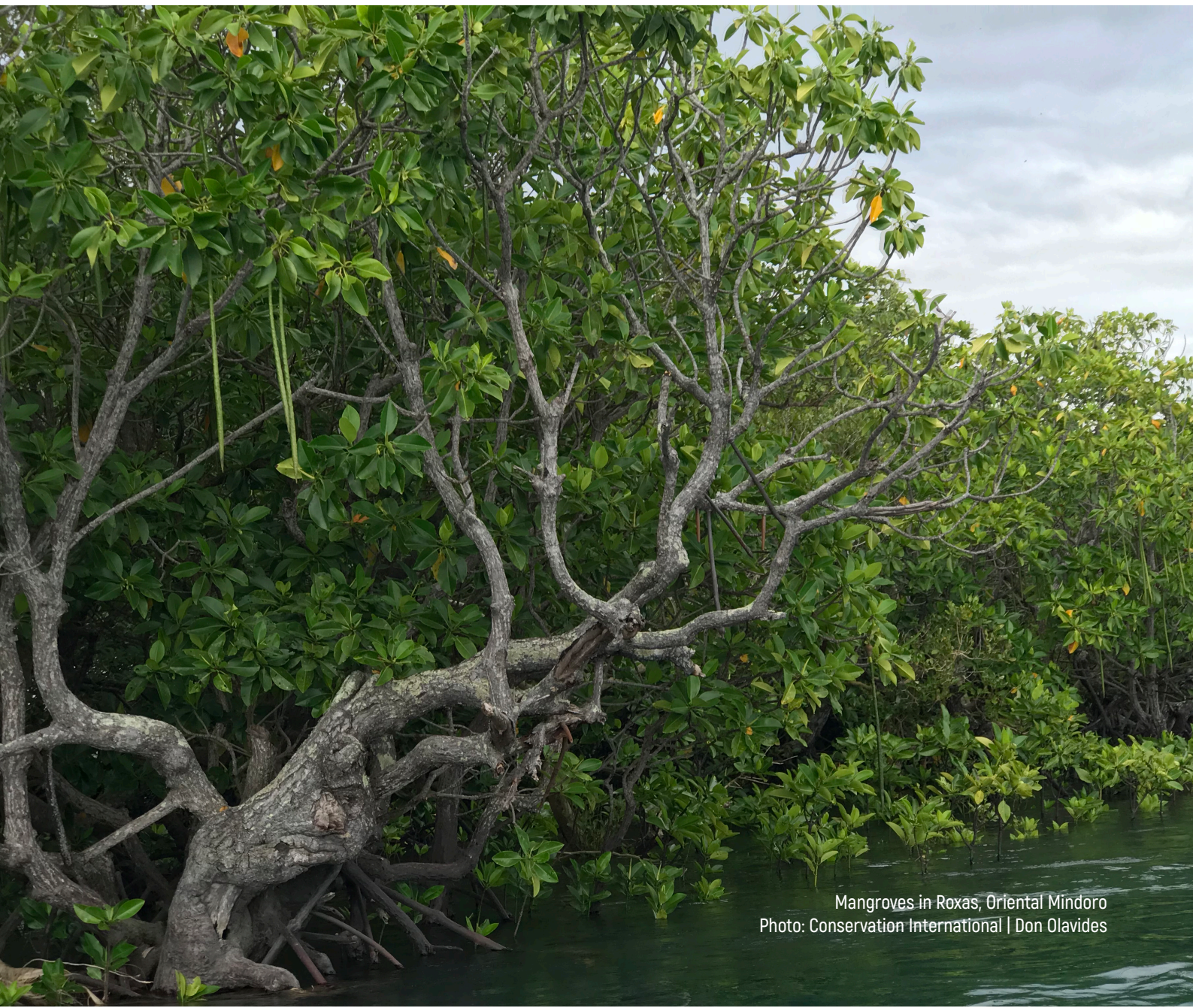
Mangroves in Roxas, Oriental Mindoro
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