J. Indian Soc. Coastal Agric. Res. 40(2): 1-13 (2022) https://doi.org/10.54894/JISCAR.40.2.2022.125737

A Case Study on Local Guyanese Population Influences on Mangrove Forest

ANNALISIA HOPKINSON, SIRPAUL JAIKISHUN and ABDULLAH ADIL ANSARI*

Department of Biology, University of Guyana, Georgetown, Guyana

Received: 18.07.2022 Accepted: 22.12.2022

Mangroves are coastal intertidal wetland forests with halophytic trees and shrubs in the environment. Mangrove forests are of considerable significance in Guyana. Human interactions with this easily available and rather easy access to resources are what allow local communities to develop their knowledge and approaches to benefit from the mangrove environments. Disruptions such as clearing for construction, aquaculture, timber and fuel output are caused by local population stressors. This research was carried out to assess the local Guyanese population's influences, positive or negative, on mangrove forests; more specifically their overall health and numbers at the three study sites located in regions 3 and 4, Guyana, during the period February-May 2021. The objective of this study was focused on determining whether human interactions within the forests influence the conditions and state of the mangroves, discovering techniques that locals within the study areas may apply to forest care, and figuring out whether the effects that locals have on the mangrove population would have been positive or negative. The data for this study was gathered using the methods of ecological assessments and questionnaires after which, the data was analyzed using relevant software programs.The results of this study revealed that locals within the selected areas did have their management techniques, and numerous ways of interacting with the forests and results have also shown that the effects on the mangroves resulted in some loss. Moreover, the local population then be further used to inform other communities perhaps to refrain from activities that have detrimental effects on the forests or even encourage the continuation of constructive actions that contribute to forest health improvements.

(***Key words:*** *Climate change, DBH, Intertidal zones, Mangroves, Population influences, Transect*)

Mangroves are coastal intertidal wetland forests that have the presence of halophytic trees and shrubbery (Friess, 2016). Mangrove forests have been known to provide numerous resources and services to local human populations and even play important roles within wetland ecosystems. Additionally, their roles in the ecosystem are as nursing and breeding grounds for the various mangrove-dwelling organisms (Alongi, 2002). They are normally found within tropical and subtropical regions with the greatest percentage belonging to the areas between 5° N and 5° S latitude (Friess *et al.,* 2019; Giri *et al.,* 2011).

In Guyana, mangrove forests are of great importance. This importance is in reference to the vital contributions they can provide; shoreline protection, erosion deterrent, home to a variety of fauna and carbon sequestration (Dinilhuda *et al.,* 2020; Kathiresan, 2012). A recently considered idea in Guyana is the notion that mangroves can be sustained as a key method of sea defence (Vaughn, 2017).

Mangroves survive within the complex and physiologically demanding environment that shifts within various periods and encounters difficulties such as pest infestations, lightning, severe storms and tropical storms quite frequently (Friess, 2016; Friess *et al.,* 2019). Even though these human activities can appear helpful to the well-being of mangroves, some behaviours may also have harmful consequences, either intentionally or unintentionally (Atu and Etim, 2017; Islam *et al.,* 2018). Mangroves are coastal forests found in protected estuaries, and in tropics and subtropics along river banks and lagoons (Maiti and Chowdhury, 2013).

Over the past years, the overall population of mangroves have decreased, as a result of both climate change and human interactions (Islam *et al.,* 2018). Notably, the rate at which mangroves are declining is about 1 to 2% annually all around the world. This rate

**Correspondence author:* E-mail: abdullah.ansari@uog.edu.gy

is about the same or even larger than the rate at which coral reefs and tropical forests are also being depleted (Dookie *et al.,* 2022; Duke *et al.,* 2007). In virtually all countries which have mangroves, depletion takes place and occurrences seem to increase more significantly in developing countries, in which greater than 90% of the world's mangroves are found (Duke *et al.,* 2007). Within the last quarter of a century, and based on observation, the range of loss notably stretches from 35% to around 86% (Duke *et al.,* 2007).

Huang *et al.* (2012) conducted their study on the effects of waves caused by boats on mangroves in the Dongzhai Harbor of Hainan. In the study area, it was observed that mangrove zone distribution located on the tidal inlet sides was negatively impacted by the waves produced by boats. These waves are of a comparable quality to normal wind-propelled waves more specifically they can be similar or greater in amplitude (Huang *et al.,* 2012). The mosquito crafts produced stronger waves in comparison to normal waves and the wash produced as a result of those waves was the reason for notable erosion along the tidal flats (Dookie *et al.,* 2022). With the erosion, some of the trees living ground areas collapsed, mangrove plant mortality increased and areas, where mangroves were known to have regenerated and extended, were reduced (Huang *et al.,* 2012).

In the Ayeyarwaddyregion, Myanmar, Aye *et al.* (2019) conducted their study to figure out how mangrove forests in the area contribute to the local community's livelihood. This study determined that the livelihood of the local population primarily relies on the mangrove forests. Using the gathered data, it was determined that profits from mangrove forest resources, farm earnings and non-farm earnings were the main sourcesof livelihood needs for residents in the area (Aye *et al.,* 2019). This effect on populations was observed in other keystone species of gastropoda that are normally found dwelling in Caribbean mangroves, negative impacts on their populations would lead to disruptions in the ecosystems within the mangroves or loss of habitat (Blanco *et al.,* 2012). Both biomass and carbon reservoir has reduced, which leads to an increase in the population of the invasive species of *Laguncularia racemose* and *Acrostichum aureum* (Blanco *et al.,* 2012). However, *R. mangle* and *A. germinans,* show decreases in population and density as a result of logging and reduced storage capacity of both species as a result of the decreases in biomass and carbon reservoir (Blanco *et al.,* 2012).This study was carried out to bring awareness to the persons who live in those areas and how anthropogenic influence affects the mangrove ecosystem.

MATERIALS AND METHODS

Sampling sites

This study was undertaken in three sites within region 3 (Vreed-En-Hoop, Herstelling) and region 4 (Beterverwagting) of Guyana. These areas were selected as a result of their accessibility, interactions with and proximity to local populations. All three of these study areas have local community members who interact with the mangroves with various activities, for example, fishermen and vessel captains. The areas chosen also seem to be easily accessed by local populations.

Sample collection procedures

For this study a collection of any literature related to the research interest was gathered, questionnaires were distributed and ecological assessments were carried out.

Questionnaire

The questionnaire used for this study comprised 15 questions which were a mixture of dichotomous yes or no questions, multiple choice questions and one open-ended question. The sample size was determined to be 138 using the statistical formula $n^1 = Z^2*p*(1-p)/ME^2$ where Z is the z-score, ME is the margin of error, p is the initial proportion estimate and n^1 is the required sample size (Jayaraman, 2000). They were distributed amongst the persons in the three selected study areas following a voluntary response sampling method. Whilst the distribution of questionnaires was done, informal discussions with persons living in the area were also undertaken.

Ecological assessments

This was conducted on the mangroves in the three areas in focus. More specifically the assessments were; landscape, habitat and species-level assessments. These ecological assessments focused on trends or fluctuations in the size of mangrove forests based on aerial and satellite imagery that was gathered using Google Earth

Pro, gathering of data for species distribution, diversity, size of plots and abundance.

Landscape-level assessment

Google Earth Pro was used in this part of the assessment as it enables users to access satellite images, maps, landscapes and even the topography of the seafloor. Additionally, there is a feature that enables users to produce large amounts of geospatial data (Ngucha, 2017). GIS (Geographic Information System) was introduced using historical aerial photos or satellite imagery from various years and then that data was used to map the measure of mangroves in separate components to depict the growth and reduction of mangrove populations throughout the years (Myers and Lowrance, 2005).

Habitat-level assessment

This includes the data gathered in the study area which provided knowledge on the functioning of the ecosystem or species. Data sets for this assessment included the distribution and abundance of species and seedling densities. For the data concerning the distribution and abundance of species, three 50 m transects were established at each sampling site. These transects were then divided up to produce five 10 mx 10 m plots. Within each plot, the number of mangroves present was tallied up. For seedling densities, 10 random quadrats in each sampling site were established and seedlings of all species within that 1 m x 1m quadrat were counted (Fourqurean *et al.,* 2010; Jaikishun *et al.,* 2017) seedling numbers were recorded to approximate the seedling densities.

Species-level assessment

This level of assessment examined effects ranging from localized individuals to entire populations in size. The diameter at breast height (DBH) for every tree within the 10 m x 10 m plots was recorded using diameter tape and was then categorized accordingly by the site numbers (Jaikishun *et al.,* 2017).

Data Analysis

After data collection and tabulation from both questionnaires and mangrove assessment were done, the quantitative data were represented on the appropriate charts and tables. The data was then analyzed using descriptive statistics from the respective software programs (Excel and R studio). The DBH data was applied in the drawing up of size-frequency diagrams for mangrove species found in the three different sampling sites. Density variances noted in the mangrove seedlings observed in the mangrove species from the study areas were analyzed via one-way ANOVA.

RESULTS AND DISCUSSION

Sample demographics

A total of one hundred and thirty-eight people were surveyed in Vreed-En-Hoop (50), Herstelling (50), and Beterverwagting (38) during this study. Each questionnaire collected four types of demographic information including age, gender, education level and employment status. The majority of individuals surveyed were female (55%) with more than half of the participants above 31 years of age (73%). The majority of survey participants listed their education level as secondary (62%), followed by (26%) at the primary level and the remaining (12%) at the tertiary level. Finally, most of the participants were employed (60%), this was followed by 35% being unemployed and 5% currently were students.

Changes, interactions and mangrove management

Most persons that have been living in the study sites for longer than 5 years have indicated that they have noticed changes in the mangroves over the years. In the Vreed-En-Hoop area, persons have stated that they have seen mangroves being washed away over the years and even seen regrowth in certain areas over time (Fig. 1a). Persons at the Beterverwagting site have noted that they see much regrowth of the mangroves in their area in comparison to the years before (Fig. 1b). Those living in the Herstelling area have also noted changes pertaining to increases in both the number and sizes of the mangrove trees in their area (Fig. 1c). Based on the correlation test ($p=0.05$), there is a strong negative correlation ($r=-0.95$) between interactions with mangroves.

In all three sites,the majority of the respondents have indicated that they have had interactions with the mangroves. These interactions included shrimp farming, wood harvesting, boat waves, land development and other activities (Fig.1). From responses to the questionnaire as well as informal discussions with the

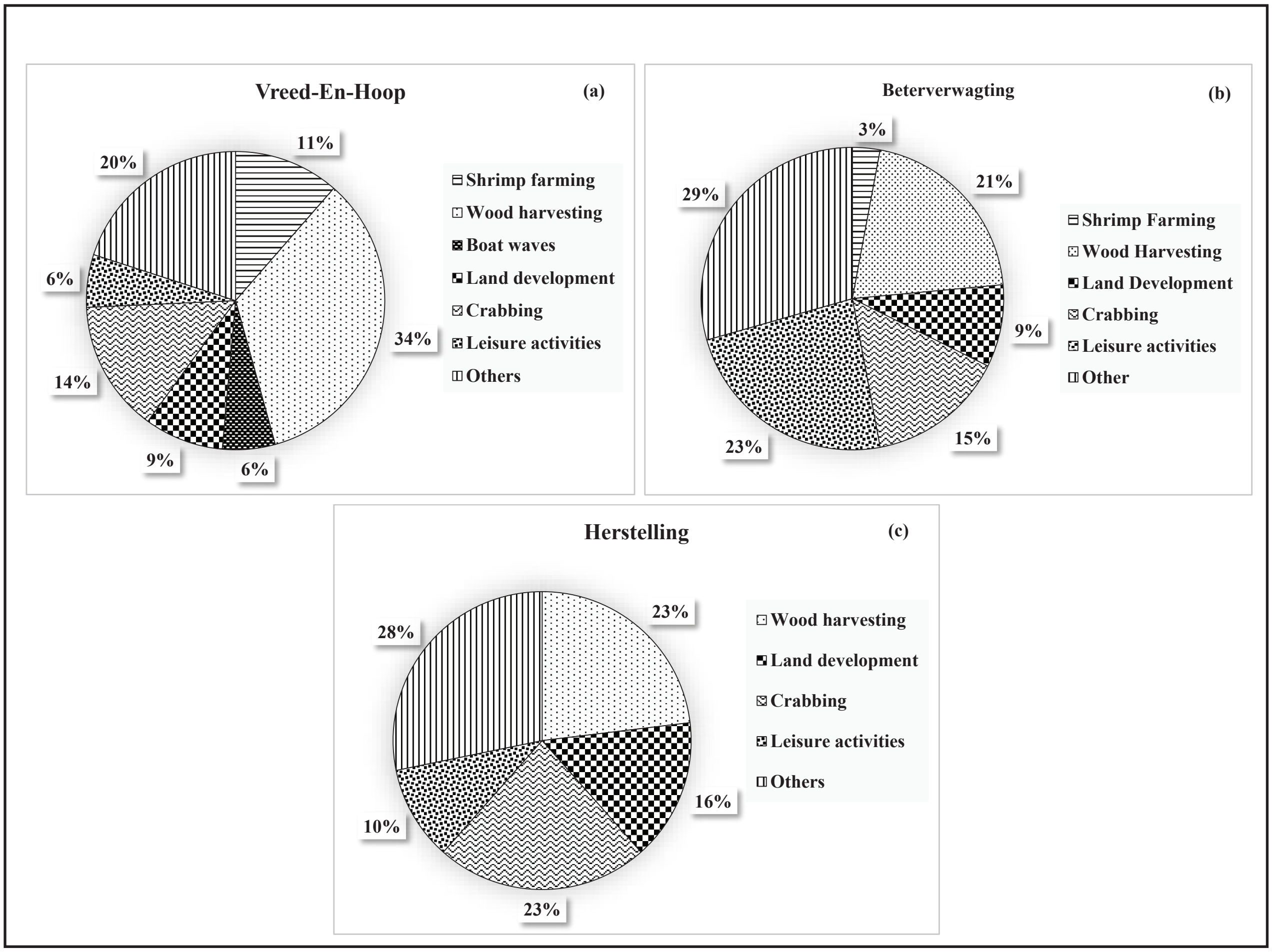

Fig. 1. *Interactions with mangroves at (a)Vreed-En-Hoop, (b) Beterverwagting and (c) Herstelling*

residents, a common activity that involves interaction with the mangrove, as well as fauna within, includes hunting for crab or the persons making their way through the mangroves to go fishing or shrimping. Digging tunnels aids in the removal of surplus salt and the lowering of soil salinity. By establishing air holes, the burrows ultimately help to raise oxygen levels in the mud; these holes are also home to a variety of organisms, such as fish, molluscs, and worms (Mokhtari *et al.,* 2013; Pestana *et al.,* 2017).

At the Herstelling site, there had been the establishment of a type of walkway straight through the mangroves which persons have indicated that they use to carry out religious works and leisure activities. When asked about that development, it was stated that thought was put into building the walkway in a way that does not disturb much of the mangroves (Fig. 1A). The level of anthropogenic disturbances is determined by the mangrove's accessibility to the local population (Hayashi *et al.,* 2019; Kihia, 2014). Similar results obtained in other research, indicate that mangrove invertebrates along with other flora and fauna utilization have also been reliant on location proximity (Kihia, 2014; Rasyid *et al.,* 2016). These interactions and their influences on the mangroves therefore can be attributed to the proximity of the locals to the three mangrove sites. Studies found an apparent increasing loss in forest diversity due to human activities, providing an additional indication of human adverse effects on mangrove ecosystems (Das Gupta and Shaw, 2013; Kihia, 2014).

Numerous researchers (Maiti and Chowdhury, 2013; Thanh-Nho *et al.,* 2019; Usman *et al.,* 2013) have discovered non-nutrient metal buildup in mangrove sediments and bioaccumulation throughout aerial tissues. The mangrove environment is regarded as an efficient pollution sink, with pollutants from a variety of industrial and human activities being channelled into it (Maiti and Chowdhury, 2013). The impact of residual contaminants like trace metals, oil particulates, certain herbicides and raw sewage on mangrove plants has been studied in-depth in under-regulated settings (Maiti and Chowdhury, 2013; Thanh-Nho *et al.,* 2019; Usman *et al.,* 2013).

The Gazi forest in Kenya has been subjected to human interference in the manner of overuse of forest and non-forest resources (Kihia, 2014; Lang'at and Kairo, 2013). Mangrove extraction diminishes the number of trees having ideal stem sizes and species, rendering the forest monopolized by young, stunted and ancient Avicennia trees (Kihia, 2014; Scales and Friess, 2019). Yet the capability of mangroves to regenerate between openings generated by cutting may disguise patterns of diversity and abundance fluctuation caused by the natural re-establishment of the ecosystems formed (Kihia, 2014; Scales and Friess, 2019). Controlling rates of anthropogenic influences is therefore critical for the survival of these vulnerable ecosystems, allowing for the regeneration of intact ecosystem features (Friess *et al.,* 2019; Kihia, 2014).

When asked about methods of managing a majority of persons responded no, however, those that did respond yes mentioned that the ways they believe that they help to manage the mangroves included keeping grazing animals away from the mangroves, avoiding the act of littering, cleaning up areas close to the mangroves occasionally, harvesting only fallen/washed up mangrove woods for use, educating themselves and others about the importance of mangroves and even avoiding the use of harmful chemicals, for example, herbicides around the mangroves (Fig. 2). The Kenya Marine and Fisheries Research Institute (KMFRI) had launched community-based mangrove management projects in Gazi Bay, Mida, and Wasini Island to encourage various uses of the mangrove habitat. The project's primary economic activities include integrated aquaculture in mangrove areas, ecotourism, and bee keeping. Minimal community-based involvement was an issue when it came down to forest management (Lang'at and Kairo, 2013). Lang'at and Kairo (2013) believed that with the development of a clear action plan and the addition of a participative management strategy in which all stakeholders, particularly local populations were included that mangrove forest management could be better accomplished.

Mangrove forests in Guyana

Mangroves could be observed throughout much of Guyana's coastline, with the greatest concentrations located seen between Pomeroon and Waini Rivers to the west, constituting the nation's largest unbroken mangrove forest (FAO, 2005; Jaikishun *et al.,* 2017). Additional important mangrove forests can be found mostly on the northern coasts of Wakenaam and Leguan Islands,

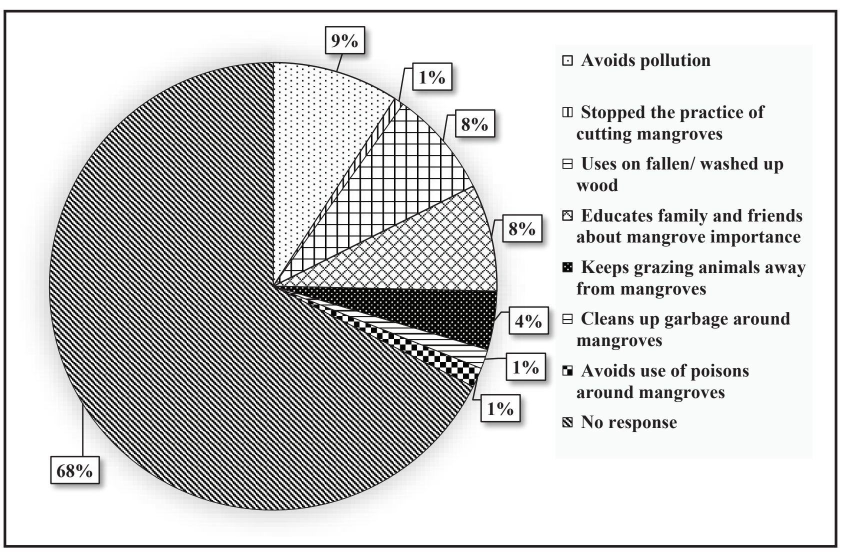

Fig. 2. *Management techniques indicated by respondents from all three sites*

as well as on Hogg Island (FAO, 2005). A*vicennia germinans, Rhizophora mangle* and *Lagncularia racemosa* are the three mangrove species which can be found in Guyana. The white mangrove (*L. racemosa*) is the smallest species amongst these prevalent mangrove trees, reaching up to 6 m height and the red mangrove (*R. mangle*) grows to be as tall as 25 m in sufficiently protected locations (Bovell, 2010; CI, 2018; Dookie *et al.,* 2022; FAO, 2005). The *A. germinans*, colloquially known as courida or black mangrove, prevails on open coastal mudflats, where it might reach heights of 20 to 25 m but can also be as short as 12 m, this species grows in both pure and mixed forests, and it is abundant along the Mahaica River's mouth (Bovell, 2011; FAO, 2005).

Landscape-level assessment

In order to recognize historical patterns in habitat loss or growth, deforestation, or mangrove depletion over time, this type of assessment is appropriate. To identify the growth and reduction of mangrove populations throughout time different forms of imagery and aerial photography are used (Myers and Lowrance, 2005). Using the Google Earth Pro application satellite images of the three study sites were studied for the years 2002 and 2021. Looking at the images of the Vreed-En-Hoop area, there does not seem to be much noticeable change from the year 2002 to 2021, however, the images for the Beterverwagting area (Fig. 3) show a very noticeable change in the mangrove population with a definite increase in the forest size from the year 2002 to 2021. Finally, the images of the Herstelling site (Fig. 4) in the years 2002 to 2021 show the filling in of a few patchy areas along with a slightly noticeable increase in forest size. According to the Shannon Wiener Diversity Index, of which the lower values indicate more diversity while higher values indicate less diversity, the Beterverwagting (0.20) site was the most diverse of all three sites, whereas the Herstelling site (0.69) was the one with the least diversity.

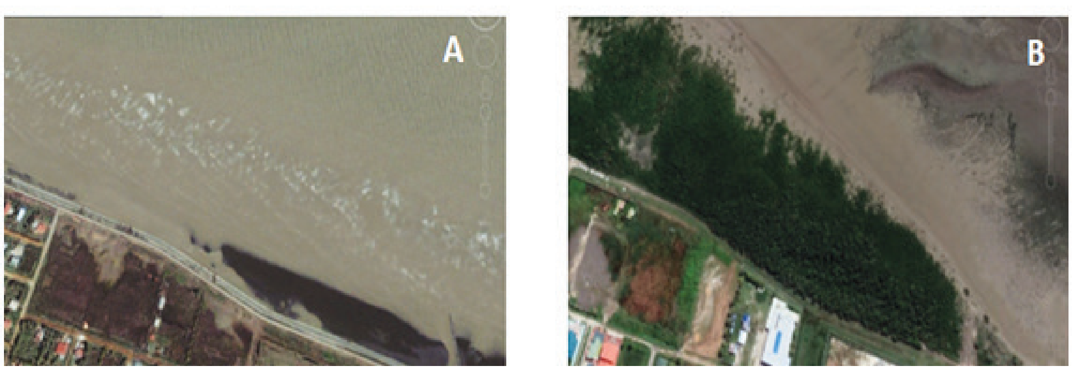

Fig. 3. *Mangroves at the Beterverwagting site in 2002 (A) and 2020 (B)*

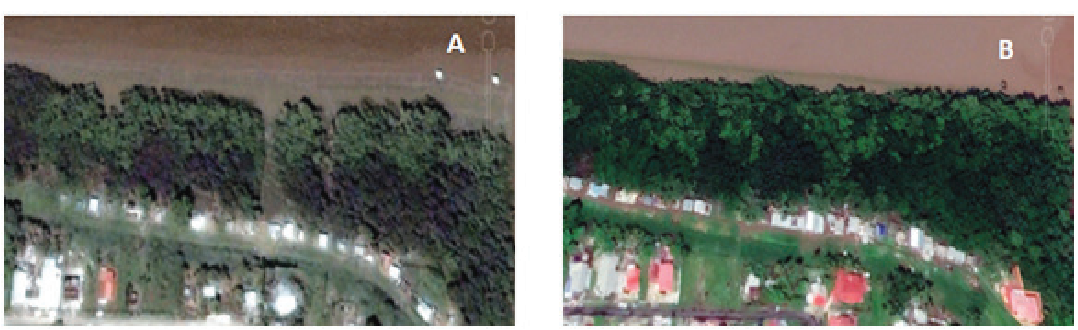

Fig. 4. *Mangroves at the Herstelling site in 2002 (A) and 2021 (B)*

Species abundance and breast height diameter

Both *R. mangle* and *A. germinans* were found in the study region in region 3, Vreed-En-Hoop, whereas *L. racemosa* was noticeably lacking. Most of the trees measured were in the range of 5.1 cm to 6.0 cm and were followed closely by the trees in the 4.1 to 5.0 cm range (Table 1). Only 8 of the total trees exceeded the 9.0 cm mark. The mean DBH per species at this site included 3.08 cm for red mangroves and 5.55 cm for black mangroves (Fig. 5).

The Herstelling study area in region 4 had R. mangle, *A. germinans* and *L. racemosa* representing this site and had the largest breast height diameter recordings of all the three sites visited. In total there were 85 trees recorded of which 44 belonged to *R. mangle* and 41 were *A. germinans* (Fig. 5). The maximum breast height diameter was recorded at 27.3 cm whilst the minimum breast height diameter was 0.9 cm. Most of the trees measured were within the range of 2.1 to 6.0 cm followed closely by the trees in the 6.1 to 8.0 cm range and 21 of the total number of trees exceeded the 10.0 cm DBH. The mean DBH per species included 4.89 cm for red mangroves and 9.02 cm for black mangroves (Table 1).

In the Beterverwagting study area in region 4 only

Table 1. *Diameter at breast height (DBH) of different mangrove species for the three study sites,*

Species	Vreed-En-Hoop	Herstelling	Beterverwagting
	DBH (cm)*		
R. mangle	3.08 ± 0.41	9.02 ± 5.64	-
A. germinans	5.55 ± 1.43	4.89 ± 2.95	1.61 ± 0.38
L. racemosa	-	-	1.49 ± 0.28

**Values are Mean ±SD*

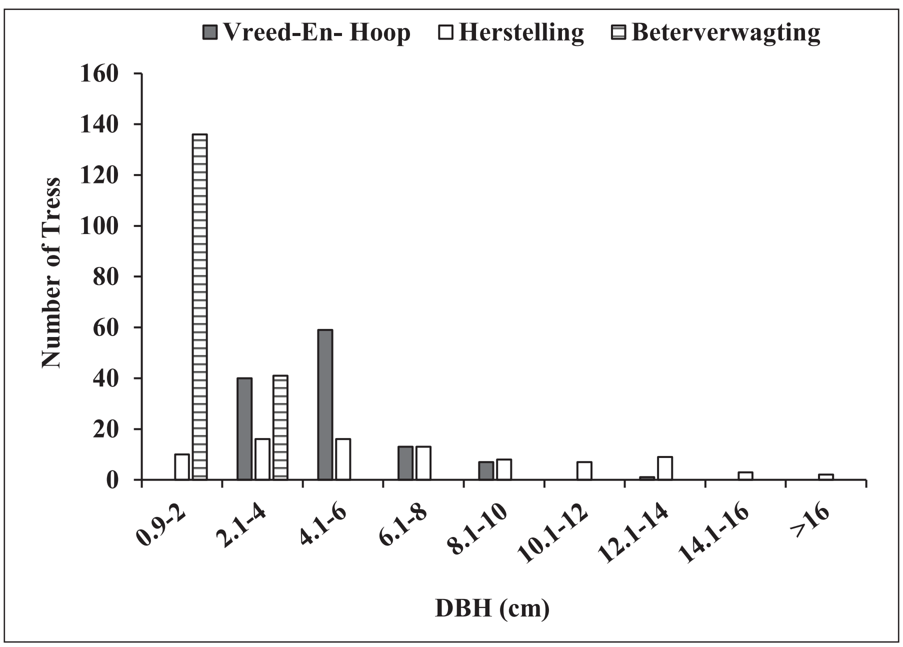

Fig. 5. *Number of mangrove trees in different DBH ranges at the different locations*

A. germinans and *L. racemosa* were present and this site had the smallest breast height diameter recordings of the three sites visited. In total there were 177 trees recorded of which 168 were *A. germinans* and 9 were *L. racemosa.* The maximum breast height diameter was recorded at 2.5 cm whilst the minimum breast height diameter was 1.0 cm. The trees at this site were notably quite young, however, this is of course, attributable to the erosion that affected the area as well as the recent replanting of mangroves in the area. The mean DBH per species included 1.61 cm for black mangroves and 1.49 cm for white mangroves (Table 1).

The overutilization of mangroves results in the formation of vast breaks within the ecosystem (Kihia, 2014; Pinzón *et al.,* 2003; Rajkaran and Adams, 2012). In the study done by Kihia (2014), the euryhaline *Avicennia* species thrived against the *Rhizopora* species in heavily damaged locations as a result of the various integrated adaptations including reproductive and growth mechanisms. Considering those adaptations and their relation to species dominance, the gaps in openings would then be dominated by the species better adapted to the area's substrate-dominant physicochemical profiles as well as the regenerative potential of the colonizing tree species. The study done by Gilman *et al.* (2008) brings attention to the changes to be expected in the various characteristics of the mangrove forests from climate change leading to increases in growth with the more tolerant species or decreases in the numbers of the less tolerant species. When there are increases in temperature faster evaporations rates are to be expected which leads to rises in salinity (Geng *et al.,* 2021). With increased salinity, the more salt-tolerant mangrove species like *A. germinans* and *L. racemosa* in Guyana have set out to have higher numbers than those of the less salt-tolerant species, *R. mangle* (Lugo, 1980), which can be observedin the Vreed-En-Hoop and Beterverwagting site results. Based on two-way ANOVA (p=0.05) there were no significant differences in the means with reference to trees in the study (p=0.8). Also as per the one-way ANOVA (p=0.05) there were no significant differences among the mean DBH for the three sites (p=0.3).

Seedling data

The site with the most seedlings was the Beterverwagting study site. This site also happened to have the trees with the smallest breast height diameter measurements. At this site, there was the presence of seedlings from *A. germinans* (Black mangrove) and *L. racemose* (White mangrove), whereas the Vreed-En-Hoop had the presence of *R. mangle* (Red mangrove) and *A. germinans* seedlings and Herstelling had the presence of *R. mangle*, *A. germinans* and *L. racemosa* (Table 2). The least number of seedlings came from the Herstelling area which may be a result of this study site having more competition for resources, for example, sunlight in comparison to the other sampling sites where the trees had less canopy cover, lesser DBH and were even less mature (Fig. 6). Red mangrove seedlings showed more presence at the Vreed-En-Hoop site in comparison to the Herstelling site and complete absence in the Beterverwagting site. White mangrove seedlings were present in both Herstelling and Beterverwagting sites, however, they were notably more numerous in the Herstelling site where the trees were more mature, unlike the Beterverwagting site. Considering all of these variables in mind, it can be inferred that the Herstelling site had the most matured forest area (Fig. 6). The large trees restrict seedlings of light and nutrition, therefore there were fewer seedlings throughout the Herstelling area. This along with the spread and height of the trees would result in more shadowing and therefore hinders the development of younger seedlings.

The Beterverwagting site had recently been restored and as such is necessary to highlight that the generation of seedlings for the recovery of deteriorated mangroves can lead to higher survival and growth of the species than any of those currently found in the natural ecosystem. Seedlings need somewhat firmer soils to colonize (Elster, 2000) and so the muddy circumstances at Beterverwagting may have resulted in substantial seedling mortality. The root system of the mangrove is designed to thrive in anaerobic soils (Srikanth *et al.,* 2016). He also deduced that types of soil affect the elevation of mangrove seedlings though not on their diameter. In conclusion, soil types have a substantial influence on mangrove spread and as a result the further the soil properties shift as a direct consequence of human influences, the more invasive species they accommodate (Hossain and Nuruddin, 2016; Numbere, 2018). Additionally, soil moisture content impacts the

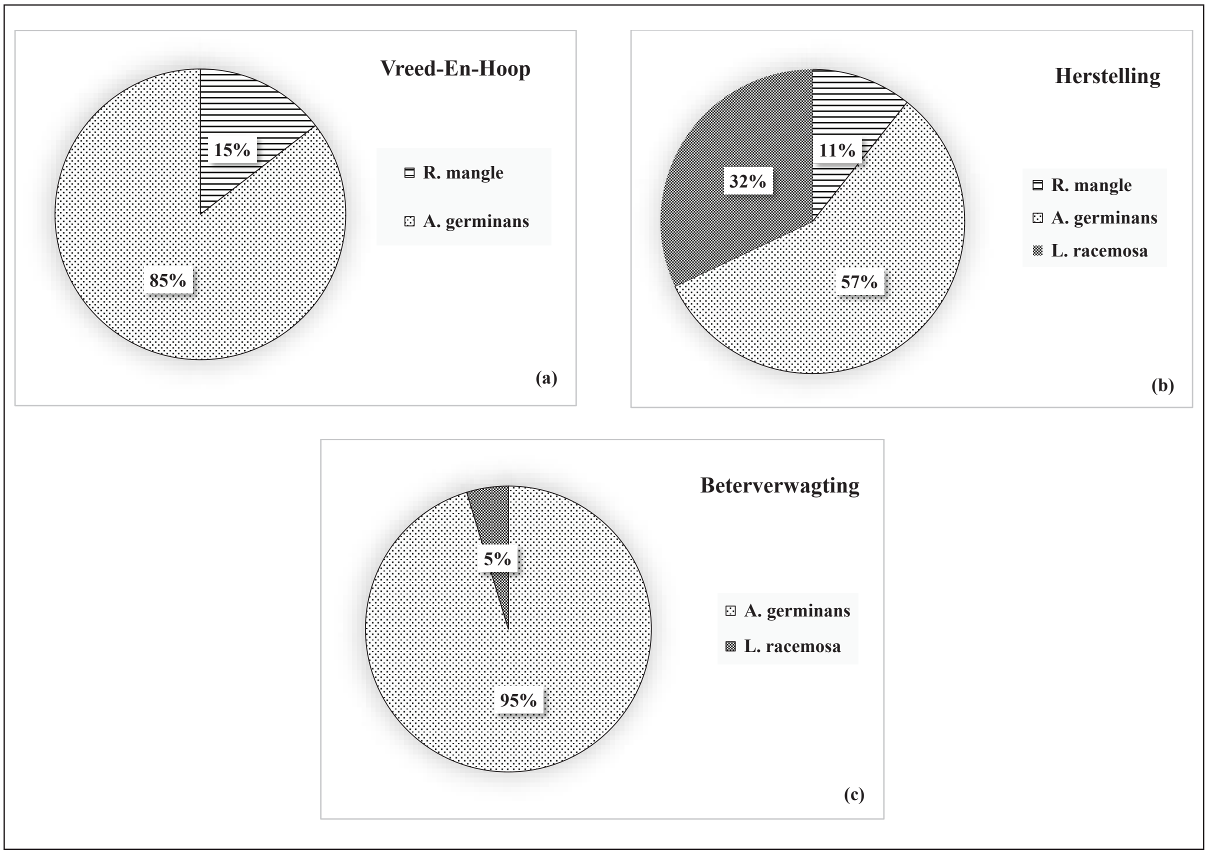

Fig. 6. *Seeding species composition at (a) Vreed-En-Hoop (b) Herstelling and (c) Beterverwagting*

concentration of organic matter in sediments (Alsumaiti and Shahid, 2018). Furthermore, due to tidal fluctuation, mangrove seedlings are distributed by tidal currents, and so as a result, terrestrial barriers impede their freedom of movement, resulting in a fragmented distribution (Bryan-Brown *et al.,* 2020; Numbere, 2018; van Bijsterveldt *et al.,* 2021; Van der Stocken *et al.,* 2018).

However, another issue of note, the garbage washed up in the study areas, could also affect the seedling population and even mangrove numbers as they can cover both the seedlings and roots of the trees which prevents the roots from breathing effectively. Pollution appears to affect the mangrove species' development and growth (van Bijsterveldt *et al.,* 2021). The notable piles of garbage appeared to have been transported and washed up and in from other areas. Other challenges involve rising sea levels that can overwhelm fringe mangroves, as well as global cooling and warming, that can cause range shifts as well as the loss of organisms (Abd Rahman and Asmawi, 2018; Carugati *et al.,* 2018; Numbere, 2018).

Awareness of mangrove depletion

When asked about their awareness of the issue of mangrove depletion majority of respondents (70%) selected the yes option while the minority selected no (30%). Following this question options were provided for respondents to choose which they believe contribute to the issue. In all three study areas the most selected option had been pollution, this was even selected by persons who have never visited, interacted with the mangroves or were even aware of the mangrove depletion issue. Persons in the Vreed-En-Hoop area were more selective of the boat wave options than persons from the other study areas, this can be attributed to persons from that study area being more likely to use the boats that cross the river into town. The two other issues that were selected frequently included wood harvesting and land clearing. Although persons indicated that they were aware of the issue of mangrove depletion, based on the responses to the follow-up question, it can be determined that they were not well informed on the issue. The study by Abd Rahman and Asmawi (2018), conclusively indicates that the inadequacy of awareness campaigns results in less knowledge being acquired by the locals, resulting in low involvement in mangrove management. The notable challenge in the development of local community mangrove management includes a lack of awareness of the mangroves and any issues that affect them, hence, public comprehension and awareness of mangrove ecological and economic significance are critical to maintaining sustainable management of this resource (Abd Rahman and Asmawi, 2018; Setiyaningrum, 2019).

From this study, we can see that the different interactions that the locals have with both the flora and fauna of the mangrove forests do have impacts on the condition and state of the mangroves. The numbers within the mangrove population when correlated with the local's interactions lead to the conclusion that with more of their interactions, the mangrove numbers decrease. The mangrove management techniques explored in the study seemed more individualized rather than community-based which would have had a greater impact on the mangroves. Consequently, in Guyana, if we can increase the spread and depth of awareness among the people on the issues affecting mangroves, we can look further into developing plans that can include our local communities and raise the levels of positive influences on mangroves. Once levels of awareness are strengthened, for example, about the sustainable practices of mangrove forests, the government could perhaps guide their locals to undertake a community-based mangrove management program so that the status of mangrove ecosystems improves and also the resources obtainable from the presence of mangrove forests will be progressively regarded as advantages for the community.

CONFLICTS OF INTEREST

The authors declare that there are no competing interests.

REFERENCES

Abd Rahman, M.A. and Asmawi, M.Z. (2018). Mangrove degradation: Issue and awareness. *Asian Journal of Quality of Life* **3**(10): 89-96.

Alongi, D.M. (2002). Present state and future of the world's mangrove forests. *Environmental Conservation* **29**(3): 331-349.

Alsumaiti, T. and Shahid, S. (2018). Comprehensive analysis of mangrove soil in eastern lagoon National Park of Abu Dhabi Emirate. *International Journal of Business and Applied Social Science* **4**(5): 39-56.

Atu, J.and Etim, U.E. (2017). Agriculture and the mangrove ecosystem of Akpabuyo, Cross River State, Nigeria. *World Environment Journal* **1**(2): 1-10.

Aye, W.N., Wen, Y., Marin, K., Thapa, S. and Tun, A.W. (2019). Contribution of mangrove forest to the livelihood of local communities in Ayeyarwaddy region, Myanmar. *Forests* **10**(5): 414. https://doi.org/10.3390/f10050414.

Blanco, J.F., Estrada, E., Ortiz, L.F. and Urrego, L.E. (2012). Ecosystem-wide impacts of deforestation in mangroves: The Urabá Gulf (Colombian Caribbean) case study. *International Scholarly Research Notices* **2012.** https://doi.org/10.5402/2012/958709.

Bovell, O. (2010). *A Situational Analysis of Coastal Mangrove Sites in Guyana (Shell Beach to Mahaica),* Guyana Mangrove Restoration Project, Georgetown, Guyana.

Bovell, O. (2011). The *Code of Practice for Mangrove Harvesting,* Guyana Mangrove Restoration Project, Georgetown, Guyana. 51 p.

Bryan-Brown, D.N., Connolly, R.M., Richards, D.R., Adame, F., Friess, D.A. and Brown, C. (2020). Global trends in mangrove forest fragmentation. *Scientific Reports* **10**(1): 1-8.

Carugati, L., Gatto, B., Rastelli, E., Lo Martire, M., Coral, C., Greco, S. and Danovaro, R. (2018). Impact of mangrove forests degradation on biodiversity and ecosystem functioning. *Scientific Reports* **8**(1): 1-11.

CI. (2018). *Setting the Foundations for Zero Net Loss of the Mangroves that Underpin Human Wellbeing in the North Brazil Shelf LME: State of Mangroves in Guyana: An Analysis of Research Gaps, and Recommendations.* Report by Conservation International (CI), Guyana. 45 p.

DasGupta, R. and Shaw, R. (2013). Cumulative impacts of human interventions and climate change on mangrove ecosystems of South and Southeast Asia: An overview. *Journal of Ecosystems* **2013**. https://doi.org/10.1155/2013/379429.

Dinilhuda, A., Akbar, A. A. and Herawaty, H. (2020). Potentials of mangrove ecosystem as storage of carbon for global warming mitigation. *Biodiversitas Journal of Biological Diversity* **21**(11).

Dookie, S., Jaikishun, S. and Ansari, A.A. (2022). A comparative study of mangroves in degraded, natural, and restored ecosystems in Guyana. *Biodiversity* **23**(2): 40-48. https://doi.org/10.1080/14888386.2022.2107570.

Duke, N.C., Meynecke, J.O., Dittmann, S., Ellison, A.M., Anger, K., Berger, U., Cannicci, S., Diele, K., Ewel, K.C. and Field, C.D. (2007). A world without mangroves? *Science* **317**(5834): 41-42.

Elster, C. (2000). Reasons for reforestation success and failure with three mangrove species in Colombia. *Forest Ecology and Management***131**(1-3): 201-214.

FAO. (2005). *Global Forest Resources Assessment 2005, Thematic Study on Mangroves, Guyana.* FAO, Rome, Italy. pp 1-10.

Fourqurean, J.W., Smith, T.J., Possley, J., Collins, T.M., Lee, D.and Namoff, S. (2010). Are mangroves in the tropical Atlantic ripe for invasion? Exotic mangrove trees in the forests of South Florida. *Biological Invasions* **12**(8): 2509-2522.

Friess, D.A. (2016). Mangrove forests. *Current Biology* **26**(16): R746-R748.

Friess, D.A., Rogers, K., Lovelock, C.E., Krauss, K.W., Hamilton, S.E., Lee, S.Y., Lucas, R., Primavera, J., Rajkaran, A. and Shi, S. (2019). The state of the world's mangrove forests: Past, present, and future. *Annual Review of Environment and Resources* **44**(1): 89-115.

Geng, Q., Wang, Z., Tao, J., Kimura, M.K., Liu, H., Hogetsu, T. and Lian, C. (2021). Ocean currents drove genetic structure of seven dominant mangrove species along the coastlines of Southern China. *Frontiers in Genetics* **12**: 615911. https://doi.org/10.3389/fgene.2021.615911.

Gilman, E.L., Ellison, J., Duke, N.C. and Field, C. (2008). Threats to mangroves from climate change and adaptation options: A review. *Aquatic Botany* **89**(2): 237-250.

Giri, C., Ochieng, E., Tieszen, L.L., Zhu, Z., Singh, A., Loveland, T., Masek, J. and Duke, N. (2011). Status and distribution of mangrove forests of the world using earth observation satellite data. *Global Ecology and Biogeography* **20**(1): 154-159.

Hayashi, S.N., Souza-Filho, P.W.M., Nascimento Jr, W.R. and Fernandes, M.E. (2019). The effect of anthropogenic drivers on spatial patterns of mangrove land use on the Amazon coast. *PloS One* **14**(6): e0217754. https://doi.org/10.1371/journal.pone.0217754.

Hossain, M. and Nuruddin, A. (2016). Soil and mangrove: A review. *Journal of Environmental Science and Technology* **9**(2): 198-207.

Huang, W., Liu, C.B. and Xiong, H.X. (2012). Effects of waves by boats on mangrove in Dongzhai Harbor of Hainan. In: *Advances in Environmental Science and Engineering,* Vols. 518-523, R. Iranpour, J. Zhao, A.J. Wang, F.L. Yang and X.Y. Li (eds), Trans Tech Publications Ltd., Verlag, C.H. pp 5217-5220.

Islam, M.M., Sunny, A.R., Hossain, M.M. and Friess, D.A. (2018). Drivers of mangrove ecosystem service change in the Sundarbans of Bangladesh. *Singapore Journal of Tropical Geography* **39**(2): 244-265.

Jaikishun, S., Ansari, A., DaSilva, P. and Hosen, A. (2017). Carbon storage potential of mangrove forest in Guyana. *International Journal of Bonorowo Wetlands* **7**(1): 43-54.

Jayaraman, K. (2000). *A Statistical Manual for Forestry Research.* FAO, Bangkok, Thailand. 242 p.

Kathiresan, K. (2012). Importance of mangrove ecosystem. *International Journal of Marine Science* **2**(10): 70-89.

Kihia, C. (2014). Impact of human physical disturbance on mangrove forest structure at the Gazi Bay, Kenya. *Egerton Journal of Science and Technology* **14**: 31-47.

Lang'at, J.K. and Kairo, J.G. (2013). *Conservation and Management of Mangrove Forests in Kenya.* Technical Report, Kenya Marine and Fisheries Research Institute, Kenya. pp 1-7.

Lugo, A.E. (1980). Mangrove ecosystems: Successional or steady state? *Biotropica* 65-72.

Maiti, S.K. and Chowdhury, A. (2013). Effects of anthropogenic pollution on mangrove biodiversity: A review. *Journal of Environmental Protection* **4**: 1428-1434. https://dx.doi.org/10.4236/jep.2013.412163.

Mokhtari, M., Ghaffar, M.A., Usup, G. and Cob, Z.C. (2013). The ecology of fiddler crab *Uca forcipata* in mangrove forest. *AIP Conference Proceedings* **1571**(1): 498-504. https://doi.org/10.1063/1.4858704.

Myers, J.E. and Lowrance, C. (2005). *Suggested Guidelines for Mangrove Assessment: An Ecosystem Approach.* SPE/EPA/DOE Exploration and Production Environmental Conference, Galveston, Texas, March 7-9, 2005. https://doi.org/10.2118/94364-MS.

Ngucha, M. (2017). *Google Earth Pro - A Useful Tool for Environmental Practitioners*. Retrieved from https://www.integratesustainability.com.au/2017/08/24/google-earth-pro-a-useful-tool-for-environmental-practitioners/

Numbere, A.O. (2018). Mangrove species distribution and composition, adaptive strategies and ecosystem services in the Niger River Delta, Nigeria. In: *Mangrove Ecosystem Ecology and Function,* S. Sharma (ed.), IntechOpen Limited, London, U.K. pp 17-39. https://doi.org/10.5772/intechopen.79028.

Pestana, D.F., Pülmanns, N., Nordhaus, I., Diele, K. and Zimmer, M. (2017). The influence of crab burrows on sediment salinity in a *Rhizophora*-dominated mangrove forest in North Brazil during the dry season. *Hydrobiologia* **803**(1): 295-305.

Pinzón, Z.S., Ewel, K.C. and Putz, F.E. (2003). Gap formation and forest regeneration in a Micronesian mangrove forest. *Journal of Tropical Ecology* **19**(2): 143-153.

Rajkaran, A. and Adams, J.B. (2012). The effect of harvesting on mangrove forest structure and the use of matrix modelling to determine sustainable harvesting practices in South Africa. In: *Sustainable Forest Management - Current Research,* J.M. Garcia and J.J. Diez Casero (eds.), IntechOpen Limited, London, U.K. pp 339-358. https://doi.org/10.5772/28919.

Rasyid, A., Akbar, A.S.M., Nurdin, N., Jaya, I. and Ibrahim (2016). Impact of human interventions on mangrove ecosystem in spatial perspective, 2nd International Conference, Indonesian Society for Remote Sensing (ICOIRS), October17-19, 2016, Yogyakarta, Indonesia. IOP Conference Series: *Earth and Environmental Science* **47**: 012041. https://doi.org/10.1088/1755-1315/47/1/012041.

Scales, I.R. and Friess, D.A. (2019). Patterns of mangrove forest disturbance and biomass removal due to small-scale harvesting in southwestern Madagascar. *Wetlands Ecology and Management* **27**(5): 609-625.

Setiyaningrum, I. (2019). Community perceptions on mangrove forest sustainability in Dukuh Bendo, Jatikontal Village, Purwodadi District, Purworejo Regency, Central Java, International Conference on Hazard mitigation in geographic and education perspectives, September 28-29, 2018, Yogyakarta, Indonesia. IOP Conference Series: *Earth and Environmental Science* **271**: 012017. https://doi.org/10.1088/1755-1315 /271/1/012017.

Srikanth, S., Lum, S.K.Y. and Chen, Z. (2016). Mangrove root: adaptations and ecological importance. *Trees* **30**(2): 451-465.

Thanh-Nho, N., Marchand, C., Strady, E., Huu-Phat, N. and Nhu-Trang, T.T. (2019). Bioaccumulation of some trace elements in tropical mangrove plants and snails (Can Gio, Vietnam). *Environmental Pollution* **248**: 635-645. https://doi.org/10.1016/j.envpol.2019.02.041.

Usman, A.R., Alkredaa, R.S. and Al-Wabel, M. (2013). Heavy metal contamination in sediments and mangroves from the coast of Red Sea: *Avicennia marina* as potential metal bioaccumulator.

Ecotoxicology and Environmental Safety **97**: 263-270.

van Bijsterveldt, C.E., van Wesenbeeck, B.K., Ramadhani, S., Raven, O.V., van Gool, F.E., Pribadi, R. and Bouma, T.J. (2021). Does plastic waste kill mangroves? A field experiment to assess the impact of macro plastics on mangrove growth, stress response and survival. *Science of the Total Environment* **756**: 143826. https://doi.org/10.1016/j.scitotenv.2020.143826

Van der Stocken, T., Vanschoenwinkel, B., De Ryck, D. and Koedam, N. (2018). Caught in transit: offshore interception of seafaring propagules from seven mangrove species. *Ecosphere* **9**(4): e02208. https://doi.org/10.1002/ecs2.2208.

Vaughn, S.E. (2017). Disappearing mangroves: The epistemic politics of climate adaptation in Guyana. *Cultural Anthropology* **32**(2): 242-268.