Mangrove Restoration following Hurricane Dorian

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Overview

From September 1-3, 2019, Hurricane Dorian made landfall multiple times on Abaco and Grand Bahama as a major hurricane. When it made first landfall it was the most powerful storm ever recorded to make landfall in the Atlantic and as it moved onto the Little Bahama Banks, it remained a major Hurricane affecting Abaco and Grand Bahama for three days before moving offshore to the north. During that time, it wrought destruction on both islands and their surrounding marine environments. Flooding for prolonged periods of time caused a significant loss of mangrove habitats, with conservative estimates putting loss of mangroves at over 4,000 hectares significant damage to another 3,000 hectares across both islands, and in many areas, there is still little regeneration or recruitment after 3 years (Dahlgren et al. in prep).

While the dead mangroves in place still provide some ecosystem services as fish habitat (Dahlgren et al. in prep), other ecosystem services are limited and they are rapidly decaying and expected to decline in habitat value as they do. As such, restoration of mangroves to facilitate their recovery is needed. In 2021, the Perry Institute for Marine Science (PIMS) evaluated mangrove areas across Abaco and Grand Bahama, assessing damage and recovery to prioritize restoration locations, collect baseline data to be used for monitoring natural recovery and/or restoration impacts, and to engage local communities to get input on their use and value of mangrove habitats as well as their ideas about where restoration should occur. Based on these inputs, PIMS developed a restoration strategy prioritizing areas for restoration (Dahlgren 2021). Specific sites selected as top priorities for restoration by PIMS and partners, Bonefish and Tarpon Trust (BTT) and Waterkeepers Bahamas (WKB) can be viewed online using this link: https://www.arcgis.com/apps/mapviewer/index.html?webmap=f9043c68b995452580c2c27e1028fa1c. It should be noted that the color coding of mangrove areas reflects the change in NDVI (an index in productivity) from Hurricane Dorian with the warmer colors (red and orange), showing greater loss than cooler colors (green and blue). A more complete explanation can be found in Greene (2022).

In late July 2022, PIMS received the necessary permits from the Bahamas Forestry Unit to commence restoration activities. This report summarizes the activities conducted in August and September 2022 under this permit.

Restoration

From August 12-August 23, 2022, Dr. Craig Dahlgren of PIMS led restoration efforts in several National Park areas of both Grand Bahama and Abaco partnership with the Bahamas National Trust (BNT). The restoration efforts consisted of collecting mangrove propagules from healthy mangrove systems on both islands that saw little to no impact from Hurricane Dorian and then

directly planting propagules in impacted areas. Both mangrove collection and planting efforts were conducted by PIMS and BNT staff as well as volunteers. On Grand Bahama, Dr. Craig Dahlgren (PIMS) and three BNT staff were joined by thirteen volunteers, including local community members from East Grand Bahama who were directly impacted by Hurricane Dorian, Kiwanis club members, and Waterkeepers Bahamas, another partnering organization in mangrove restoration. On mangrove planting days, these volunteers were joined by three local boat captains from east Grand Bahama. For Abaco, Dr. Craig Dahlgren was Joined by three BNT staff as well as 9 volunteers and two boat captains on days when planting occurred. For Abaco, volunteers consisted of 8 community members from Central Abaco, including 6 youths (two of whom were only available one day for propagule collection) and one college student. Prior to activities, volunteers, boat captains and any untrained BNT staff were trained in mangrove collection and planting practices.

Mangrove collections consisted of collection of red mangrove propagules directly from trees and from the ground/water in areas of healthy mangroves. Volunteers were instructed in how to collect propagules that were competent and had a minimum length of 10 cm, without harming trees, and how to identify viable propagules from those collected off the ground. On Grand Bahama, propagule collections occurred over three days from three different locations in the Freeport area. Two to the west of the port and one at Lucayan National Park (Table 1, Fig. 1). On Abaco, collections occurred over two days with collections from two locations to the north on Little Abaco and one location to the south at Crossing Rocks). In all cases, mangrove collections were made from healthy mangrove systems accessible from land. A total of 20,408 propagules were collected with 12,500 propagules collected from Grand Bahama for planting there and 7,908 collected from Abaco for planting on Abaco. All propagules collected were tracked by their source site to ensure genetic diversity during subsequent planting.

Table 1. Location of mangrove propagule collection sites for Grand Bahama and Abaco with mangrove growth type and total number of propagules collected.

Site code	Island	Site Name	Date	Lat	Lon	Dwarf	Fringe	No.
GB-MS-001	Grand Bahama	Paradise Cove	8/12/22	26.58048	78.86325		X	2760
GB-MS-002	Grand Bahama	Holmes Rock	8/13/22	26.56200	78.84351		X	5961
GB-MS-003	Grand Bahama	Lucayan National Park	8/16/22	26.60358	78.39998	X	X	3779
AB-MS-001	Abaco	Crossing Rock	8/20/22	26.15292	77.19002	X	X	3013
AB-MS-002	Abaco	Cedar Harbour	8/21/22	26.89796	77.65143	X	X	3756
AB-MS-003	Abaco	ABM004	8/21/22	26.9096	77.73116		X	1139
TOTAL							GB	12500
							Abaco	7908
							TOTAL	20408

Mangrove planting occurred at sites identified as priorities on both islands that were accessible by boat (Fig. 1). Prior to planting all volunteers and untrained BNT staff were instructed in mangrove planting practices. This included instruction in:

- Where to plant propagules to give them the best chance of survival (e.g., in the upper 1/3 of the tide range and in and around dead mangrove prop roots)
- Planting them to suitable soil depths that would allow them to take root and prevent dislodgement or burial
- Spacing of at least 75-100cm apart
- Avoiding planting in rows and using natural features of the site to dictate planting (e.g., not planting in small creeks but along edges and interior of mangrove areas.
- Safety including avoiding deep water (many volunteers could not swim), deep mud, and biological hazards like Cassiopeia jellyfish.

Mangrove plantings were conducted at four locations for Grand Bahama and three for Abaco, across a diverse range of mangrove types including large mangroves on over wash islands, large mangroves fringing creeks and dwarf mangroves on intertidal flats. In all locations, propagules were directly planted (Table 2, Fig. 2) with propagules collected from Grand Bahama being planted at restoration sites off Grand Bahama and Propagules from Abaco being planted at restoration sites for Abaco. At each restoration site, propagules collected from a particular site were planted together in a plot separate from propagules collected from other sites, usually with multiple plots at a site. This will allow us to track survival and growth of different source populations at each restoration site to determine if there are differences in success of plantings using different sources under different conditions and allow us to improve the success of future restoration efforts.

Table 2. Distribution of mangrove propagules planted/dispersed for Abaco and Grand Bahama with the total number planted at each location on each date shown for each propagule source site and in total.

Island	Site Name	Date	Lat	Lon	Method	Total	GB-MS-001	GB-MS-002	GB-MS-003
Grand Bahama	Round cay	8/14/22	26.55324	77.82281	Direct plant	1260	550	710	0
Grand Bahama	Bonefish Cay	8/15/22	26.65191	77.84943	Direct plant	2836	1200	1636	0
Grand Bahama	Crab Cay	8/17/22	26.68153	77.88697	Direct plant	3110	1010	700	1400
Grand Bahama	August Creek	8/18/22	26.68742	77.9022	Direct plant	2800	0	1800	1000
Grand Bahama	Round Cay	8/19/22	26.55324	77.82281	Release	494	0	115	379
Grand Bahama	Round Cay	8/19/22	26.55007	77.8192	Release	2000		1000	1000
					TOTAL GB	12500	2760	5961	3779
							AB-MS 001	AB-MS-002	AB-MS-003
Abaco	Opposite Trea	8/22/22	26.66539	77.31916	Direct plant	2013	913	600	500
Abaco	Opposite Trea	8/22/22	26.6649	77.31747	Release	500	100	400	
Abaco	Big Lake Cay	8/23/22	26.65607	77.34258	Direct plant	2759	1000	1256	503
Abaco	Thatch Cays 1	8/24/22	26.61489	77.37859	Direct plant	2636	1000	1500	136
					TOTAL Abaco	7908	3013	3756	1139
					TOTAL	20408			

There were two instances however, where some parts of a site were inaccessible to plant propagules directly into soils. In one case for Abaco, parts of a site had mangroves areas that were inaccessible due to high root densities that were impenetrable at depths needed to plant mangroves at part of the site (Fig. 3), and at one site for Grand Bahama shallow water depths prevented boat access and deep muds prevented walking into parts of the site.

In both cases where parts of a mangrove restoration site were not accessible, a subset of propagules at the site were not planted into the substrate but were dispersed using other means. In these areas, we attempted experimental restoration without planting directly into the soil using a "facilitated recruitment" strategy of natural restoration. In the dense root structure of Abaco, approximately 1,000 propagules were dispersed by simply tossing propagules into the mangroves to allow them to naturally become trapped I the roots and recruit to the sediment to take root. In location with shallow water but deep mud on Grand Bahama, we released ~2,000 propagules in tidal creeks on an incoming tide to be transported to the interior of the mangrove island.

Figure 1. Satellite image showing location of mangrove propagule collection sites (Blue) and Restoration sites (Red) for Abaco and Grand Bahama.

Figure 2. Mangrove propagule (foreground) planted in proximity to a dead dwarf mangrove off Abaco.

Figure 3. Example of a mangrove area of Abaco where direct planting was not possible along the outer edge of mangroves due to water depth and shallowed depths located within the matrix of dead mangroves was not accessible due to high density of dead roots and trees.
Additional photos and video from the mangrove restoration for Grand Bahama are available using this link:
https://www.dropbox.com/sh/i67t7a5czk9toee/AADU-thhV-jj8InkDOyLC8Ifa?dl=0
Photos and video from the mangrove restoration for Abaco are available using this link:
https://www.dropbox.com/sh/hn5e1vwnt6qypkb/AACJh6w7bCiVve-rAKnNLdIBa?dl=0

Monitoring

Following mangrove planting, baseline data was collected from planting sites and control sites where natural recovery is being assessed for both Abaco and Grand Bahama. Data collection at this time includes high resolution mapping of the site using drone based aerial photography (1cm resolution) and 10 bands of multispectral data (8 cm resolution). Data collection from 35 sites on Grand Bahama and Abaco occurred From September 7-13, 2022 (Fig. 4). This technology allows us to not only track the status of the site, but fate track individual mangroves (those regenerating, new natural recruits, and planted mangroves) to examine recovery and assess restoration success. Data is currently being processed to:

1. Determine the extent of natural recovery over the past year for sites where previous imagery exists.
2. Track the survival rate or mangroves planted prior to July 2021 by our partners.
3. Establish a baseline for examining the recovery of mangroves planted and dispersed during our August 2022 planting efforts.

Additional monitoring expeditions to examine changes in fish community structure and environmental parameters are planned for September-October 2022.

Related Activities

Restoration at more sites will occur from September 2022 through September 2023 with matching support from the Bahamas Protected Areas Fund, US Forest Service, and Disney Conservation Fund. In September 2022 PIMS will also be part of a workshop with The Nature Conservancy and other partners to examine how sale of carbon credits may provide additional support for restoration under new legislation in The Bahamas, which may further expand the spatial scale and timeline of restoration activities. Monitoring of existing and planned restoration will be conducted annually (at a minimum) through 2025.

In addition to these activities, PIMS is currently in the final stages of putting together a Mangrove Health Report Card for The Bahamas, the first of its kind for the region. This report card will examine health of mangroves using several indices related to the extent and function of mangrove systems, including:

1. Productivity
2. Change in mangrove area and productivity
3. Fragmentation of mangrove systems
4. Marine biodiversity
5. Nursery Value for key species

The report card will use data collected from this project and other data compiled over the past 20 years. Using the data for the report card and other available datasets, PIMS is also leading a mangrove restoration strategy for The Bahamas with NGO and governmental partners.

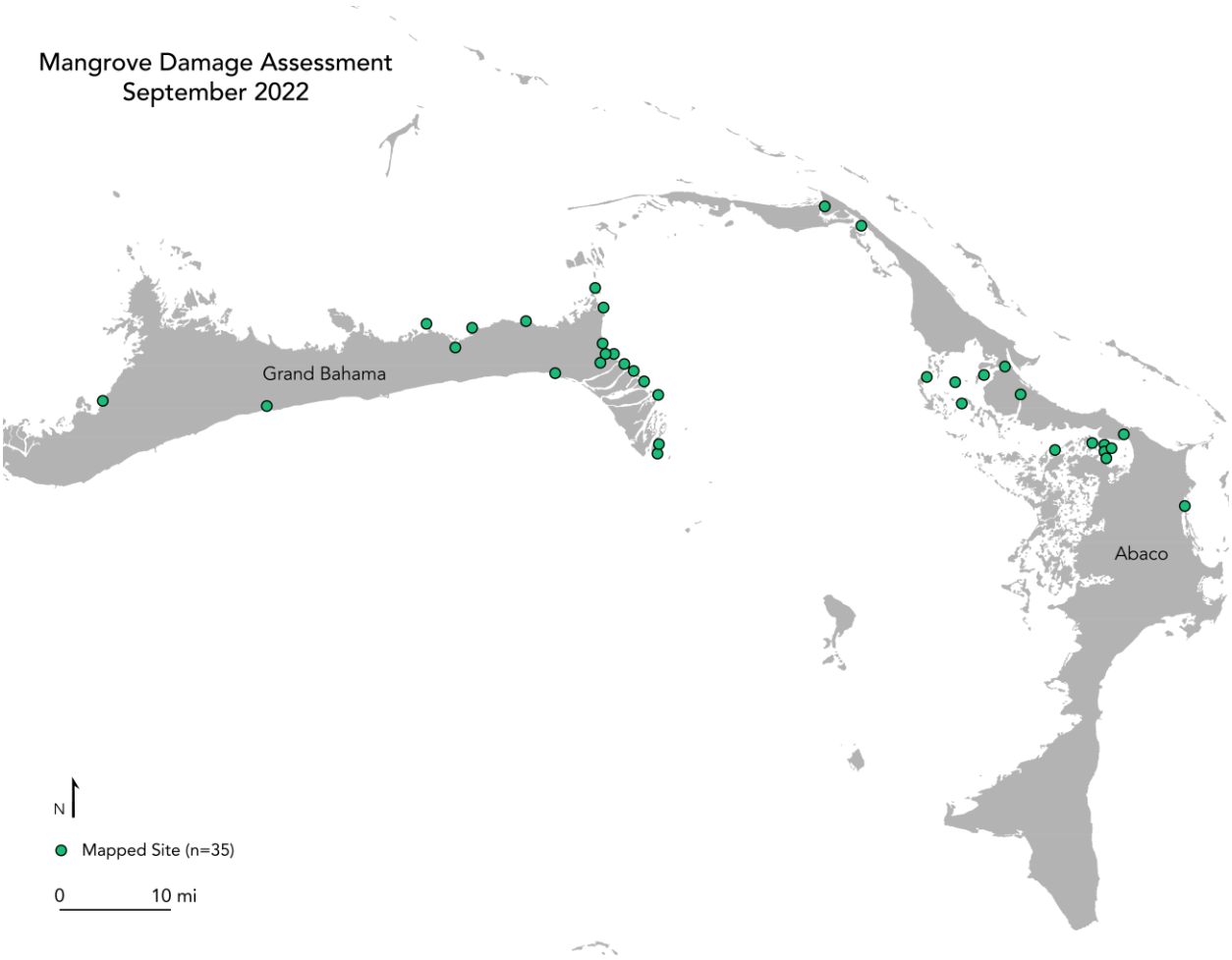

Figure 4. Sites where drone mapping occurred in September 2022 to monitor restoration sites and control sites for Abaco and Grand Bahama.

Literature Cited

Dahlgren, C. 2021. Perry Institute for Marine Science/Bahamas Undersea Research Foundation Post-Dorian Mangrove Restoration Plan. Report to the Government of The Bahamas. 11pp.

Greene, W. 2022. Mapping Hurricane Dorian Mangrove Damage. Report to the Government of The Bahamas. 16pp.