

ECOLOGICAL STATUS OF BELIZE'S SOUTHERN REEF SYSTEMS

Impacts of Hurricane Iris



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IMPACTS OF HURRICANE IRIS

Assessment Report

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Front cover: Large photo: The track of Hurricane Iris (Category 4) superimposed on a satellite image of the Caribbean and tropical Atlantic (Obtained from the Moreweather Tropical Atlantic 2001 Storm Archive). Bottom left photo: Broken stems (recently dead) of *Acropora cervicornis* (Staghorn Coral) and other reef debris on fore reef as a result of Hurricane Iris. Middle photo: A Geostationary Operational Environmental Satellite imagery of Hurricane Iris near the southern coast of Belize (Satellite image from NASA GSFC Visualization Analysis Lab, 2001). Right photo: Shallow water gorgonians suffered high mortality from Hurricane Iris. (Photos captured from digital video footage taken by Romy Badillo).



Acknowledgments

This project was sponsored by the Coastal Zone Management Authority and Institute (CZMAI). I am very grateful to Luke D'Silva (Laughing Bird Caye National Park), Florita Castillo (South Water Caye Marine Reserve), Hampton Gamboa (CZMI), Kirk Rodriquez (CZMI), Romy Badillo (CZMI) and John Rodriquez for assistance in the field. Special thanks to Dr. Melanie McField for contributing the GPS coordinates for selected sites.

Dedication

We dedicate this report to Luke D'Silva who, sadly, lost his life during the survey period. Luke, may you soar with the angels above!!

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Executive Summary

The Belize Barrier Reef Complex, the second largest in the world, extends 220 km along the coast of Belize “and covers 22,800 km², as a unique assemblage of lagoon patch reefs, fringing reefs, faroes and offshore atolls” (Kramer *et al.*, 2000). Belize’s location in the hurricane belt, however, may pose a serious threat to these fragile systems. In the past the major threat to Belize’s reefs was from hurricane damage and it now appears as if history might repeat itself because the frequency and intensity of these natural disturbances are increasing. Within the last four years alone, Belize has been impacted by three hurricanes, Mitch, Keith and Iris.

On October 8th, 2001, Hurricane Iris, a category 4 storm and the most recent of the aforementioned group, made landfall along the southern coast of Belize (near Monkey River Town) causing massive wind and flood damage to impacted areas. With assistance from the Belize Fisheries Department and the Laughing Bird Caye National Park, a small-scale survey was carried out to assess reef areas, which were believed to have been impacted by the hurricane. Reef sites within three marine protected areas were assessed. The survey results reveal impacts that ranged from minor to severe with a large degree of variability between sites.

Hurricane Iris was very small, exhibiting hurricane force winds extending approximately 15 miles (30 km) from its center. It was forecasted, however, that Iris was accompanied by storm surge flooding of 13 to 18 feet above normal tide levels and dangerously large battering waves (NOAA’s National Hurricane Center Advisory Archive). Discernible mechanical reef damage appears to be positively correlated to the narrow path traveled by Hurricane Iris. The amount and degree of hurricane damage was highly dependent on the reef’s location. The greatest degree of damage was observed at Laughing Bird Caye National Park, with over 60% of assessed colonies displaying mechanical damage along the forereef of this faro. Besides the immediate physical destruction caused by wave energy, there were also secondary effects such as sediment run-off that were much more difficult to quantify. Laughing Bird Caye, for example, was severely impacted by the hurricane. Damage incurred includes complete defoliation and uproot of its mangrove trees, moderate to severe land erosion, and the emergence of a channel (approximately 15 ft in width) that completely intersects the island.

The impact from Hurricane Iris is expected to have long-term ecological consequences for the Laughing Bird Caye National Park. The fore reef of this area is in a highly moderate to severe disturbed state. Recent coral mortality averages more than 15%. Furthermore, the extensive damage to certain coral species of this site (e.g. *Montastraea annularis* complex, *Agaricia agaricites*, *Siderastrea siderea*, *Porites asteroides*) is of particular concern given their roles as major reef builders. A thorough understanding of the secondary effects from Hurricane Iris, as well as the potential for recovery, may take sometime to fully elucidate and understand.

Introduction

The Belize Barrier Reef Complex, the second largest in the world and the largest in the Western Hemisphere, is one of the most significant ecosystems in the tropical western Atlantic. Extending for 220 km along Belize's coast, it encompasses an approximate area of "22,800 km² as a unique assemblage of lagoon patch reefs, fringing reefs, faroes and offshelf atolls" (Kramer *et al.*, 2000). This diverse and well-developed reef ecosystem represents the last extensive and flourishing reef environment in the Caribbean (Wildes 1992) and has also been rated among the best developed in the world. The reefs of Belize, however, have been recently experiencing an increased frequency and intensity of disturbances. A prime example of these types of disturbances is hurricanes. Within the past four years, Belize has been impacted by a total of four hurricanes. The most recent of these is Hurricane Iris, a category 4 storm that hit the southern coast of Belize on October 8th, 2001.

The passage of Hurricane Iris left many questions regarding the condition of the southern reef systems. There was an urgent need to understand the extent of damage and overall condition of these reefs. To address this need, the Coastal Zone Management Authority and Institute (CZMAI) with assistance from the Belize Fisheries Department and the Laughing Bird Caye National Park, conducted a small-scale field survey of coral reefs within the impacted zone. Concentration was proposed for reef sites within a total of four marine protected areas, namely Glovers Reef Marine Reserve, Gladden Split Marine Reserve, Laughing Bird Caye National Park and South Water Caye Marine Reserve. However, due to an unforeseeable tragedy, only three MPAs were assessed. Focus was placed mainly on scleractinians and milleporids (hard coral species), which are responsible for reef building and vital to the overall integrity of the reef systems. The specific objective was **to obtain an overview of the range of damage to major reef-building corals following Hurricane Iris.**

This report presents the result from our survey and discusses their implications.

Setting

The three marine protected areas (MPAs) that were assessed are located within the southern province of the barrier reef and on one offshore atoll. A brief description of the three MPAs is given below.

Glovers Reef Marine Reserve (308 km²): Glovers Reef is the southernmost of Belize's atolls, and one of the best developed in the Caribbean. It is approximately 32 by 12 km and lies 45 km east of the mainland coast. It is surrounded by a fringing reef that has 3 channels on the windward side. Its windward reefs have been reported to be of better development than the leeward reefs, and over 700 patch reefs and coral pinnacles stud its central lagoon (Gibson 1988). There is a chain of six cayes along its southeast rim. The reserve encompasses the entire atoll.

Gladden Split and Silk Caye Marine Reserve (105 km²): Located in the southern province of the barrier reef, this reserve encompasses Gladden Split and the Silk Cayes. Gladden Split is home to a wide variety of beautiful soft and hard corals that form spectacular coral gardens behind the barrier reef. The site has been characterized as having a short-sloping shelf, which “drops off steeply at about 40 m (130 ft) to over 2,000 m (6,600 ft) depth within 10 km of the reef” (Graham 2001). It is well known for whale sharks, which visit the area to feed on the spawn of aggregating snappers.

Laughing Bird Caye National Park (43 km²): Laughing Bird Caye is situated on the rim of a steep-sided faro, which is located within the southern section of the barrier reef lagoon, and is bordered to the east by the deep Victoria Channel. The National Park includes both the caye and the entire faro formation.

Background

Belize lies within the principal trajectories of the late season hurricanes and, over the years, has been affected by a number of large storms. Each had different paths, intensities and impacts on the Belize Barrier Reef Complex (BBRC). One of the most recent storms recorded to have significantly impacted the reefs of Belize is Hurricane Mitch (1998). Hurricane Mitch (Category 5), reaching windspeeds in excess of 180 mph, had created large storm waves that battered the coastlines throughout Belize and degraded many shallow reefs along the barrier reef and the southernmost atoll, Glover's Reef (Kramer and Kramer 2000). The occurrence of yet another high category storm just two years subsequent to reef recovery from Mitch, may again place some of these reefs in peril.

On October 8th, 2001, the southern coast of Belize found itself under the wrath of Hurricane Iris, a category 4 storm exhibiting maximum sustained winds of 140 mph. This storm, moving along a narrow tract in a southwestern direction from the eastern Caribbean area (See Fig. 1), made contact with Belize's coastline near Monkey River Town.

Figure 1.

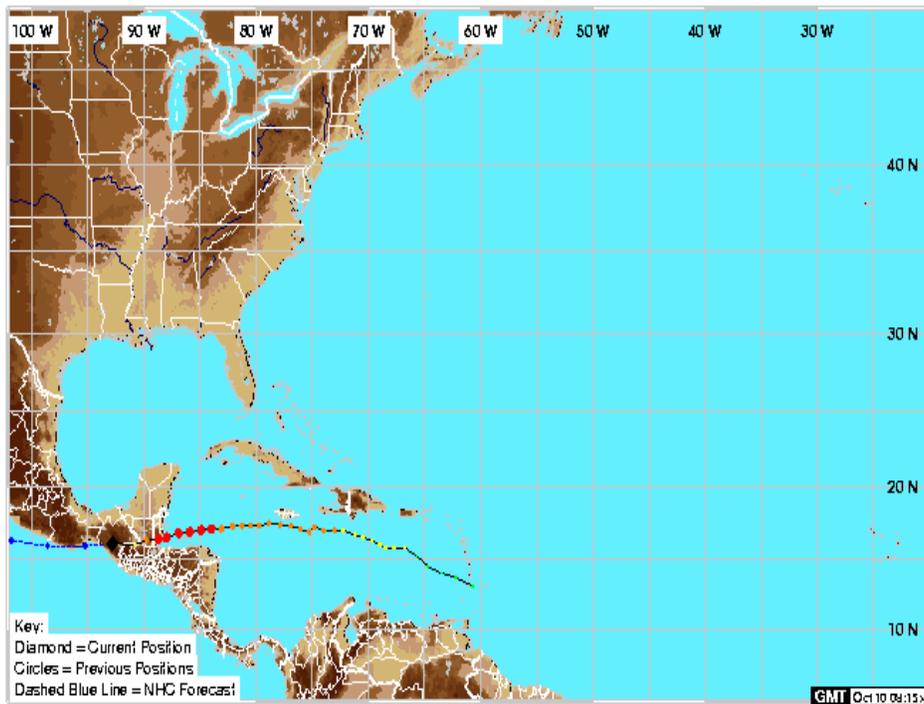


Figure 1: Track of Hurricane Iris from its point of origin to its ghostly remains west of Guatemala. Satellite image from the Moreweather Tropical Atlantic 2001 storm archive.

Compared to many previous storms that hit Belize, Hurricane Iris was very small. Hurricane force winds extended to only 15 miles (30 km) from its center. Belize's reef areas that were within this 15-mile radius were those of southern Glovers Reef and South Water Caye Marine Reserves, patch reefs southeast and west of South Water Caye Marine Reserve, barrier reef section north of Gladden Split, Gladden Split Marine Reserve, Laughing Bird Caye National Park, and the barrier reef section north of

Sapodilla Cayes Marine Reserve (See attached map entitled *Post Iris Coral Reef Assessment*).

Hurricane Iris was forecasted to be accompanied by dangerously large battering waves and storm surge flooding of 13 to 18 feet above normal tide levels (NOAA's National Hurricane Center Advisory Archive). These resulted in causing severe damage – destroying homes, docks and piers, flooding streets, defoliating and uprooting vegetation, and generating localized moderate to severe erosion – in coastal towns south of Belize City and on a number of southeastern cayes.

Photo 1a



1b.



Photo 1a-b. a.) Native vegetation destroyed along the southern end of Laughing Bird Caye as a result of Hurricane Iris. b.) Channel (approx. 15ft in width) that now splits the Laughing Bird Caye and complete defoliation and uproot of the mangrove population on the northern portion of the Caye as a result of Hurricane Iris. Photos captured from digital video footage taken by Nadia Bood.

Methods

The principal method employed for the field survey was rapid assessments of hard coral colonies at selected sites. Site (100 m scale) was defined as an area of habitat that was more or less homogenous and accessible from an anchored boat. Selection of sites was based on the projected path traveled by Hurricane Iris and were further narrowed down based on those previously identified and utilized by Dr. Melanie McField for her research. Sites were located in the field through the utilization of a GPS.

Both deep (i.e. fore reefs) and shallow (i.e. back and patch reefs) sites were assessed. A brief description, which included location (GPS coordinates), relief features (e.g. spur and grove) and depth, was prepared for each site surveyed (*See Site Description section*).

Due to an unforeseeable tragedy during the survey period, the survey came to a halt with only 5 sites surveyed, three deep and two shallow (*See attached map entitled Post Iris Coral Reef Assessment*). These were all surveyed between the 16-17 October, 2001.

Site Description

A brief description of each site is given below.

Deep Sites:

1. Glovers Reef Marine Reserve: Having GPS coordinates of N16° 42.652' W87° 50.766', this site is located on the fore reef northeast of South West Caye. South West Caye is the southernmost caye along the windward side of Glovers Reef Atoll. The fore reef tract of this area slopes gradually towards the drop-off and consists of low relief spur and grove formations. The site consists of medium to sparse coral cover and a moderate percentage of unconsolidated old coral rubble. The assessment was carried out along a depth range of 35 to 45 ft. A medium to strong current runs along this area.
2. Gladden Split Marine Reserve: Having GPS coordinates N16° 31' W87° 58', this site is located just east of the Gladden Split “elbow” along the cut in the barrier reef. It consists of a flat platform. It is densely covered with gorgonians (sea fans, sea rods, etc.) and to a lesser extent, low relief hard corals. The assessment was carried out at a depth of approximately 40 ft. A very strong current runs along this area.
3. Laughing Bird Caye National Park: Having GPS coordinates of N16° 26.203' W88° 11.941', this site is located on the faro's fore reef southeast of Laughing Bird Caye. The fore reef along this area exhibits a gradual slope and consists of low relief spur and grove formations. The site consists of mostly massive corals (a combination of living and dead) and a high percentage of unconsolidated coral rubble. The assessment was conducted between 35 to 45 feet.

Shallow Sites:

1. Glovers Reef Marine Reserve: Having GPS coordinates of N16° 42.887' W87° 51.366', this site is located beyond the western sandy reef flat on a shallow patch reef west of South West Caye. The area consists of sandy patches interspersed with scattered colonies of *Acropora cervicornis* (Staghorn coral), *Porites asteriodes* (Mustard Hill coral), *Montastraea annularis* (Boulder Star coral) complex, *Millipora alcicornis* (Branching Fire coral), and gorgonians. The assessment was conducted at a depth range of 5 to 8 feet.
2. Laughing Bird Caye National Park: Having GPS coordinates of N16° 26.691' W88° 11.832', this site is located on the shallow back reef immediately west of Laughing Bird Caye. The area consists of aggregated patches of *Halimeda* and *Penicillus* species together with seagrass and small patches of *Porites*, *Montastraea*, *Diploria* and *Siderastrea* species.

Coral Condition Assessments

During the survey assessments, two methods were employed.

1. A temporary 100 by 30m belt transect was installed at each site within which 4 observers, spaced approximately 15 ft apart, swam while recording observations of noticeable impacts on hard corals such as mechanical damage, bleaching, disease, and the frequency and type of coral species observed exhibiting the said impacts. Data generated from this method were use to supplement that of method number two.
2. One observer swam a transect using the “weighted bar swimming transect method” (McField 1999 and Kramer and Kramer 2000). In this method, a one meter $\frac{3}{4}$ ” diameter PVC tube with 5 markings spaced 25 cm apart was used to randomly census corals. The observer swam in a straight line parallel to the reef axis with the bar held horizontally perpendicular out in front (*See photo # 2a below*). Every 3 cycle-kicks, the bar was placed on the substrate (= 1 bar-drop) and the species and condition of the coral (≥ 10 cm) nearest to each mark was assessed. The five marks demarcated five adjacent non-overlapping circles and the closest coral within 12.5 cm of each mark was assessed. If no coral was observed within a given circle, it was recorded as zero. This technique is able to provide a measure of the relative importance of coral species and their condition as a function of coverage in each reef area (Kramer and Kramer 2000). For each “bar-drop”, anywhere from zero to five corals were assessed. The total number of “bar-drops” and corals assessed was recorded for each site. A minimum of 24 “bar-drops” was conducted at each site.

Photo 2 a.



2b.



Photo 2a-b: Surveyor a.) conducting “Bar-drop” technique and b.) Recording visual observation (within belt transect) at Gladden Split during the field survey on 17th October, 2001. Photo captured from digital video footage taken by Romy Badillo.

Each colony greater than or equal to 10 cm was assessed for species type, recent and old mortality (plan view), hurricane damage (knocked over, broken, abraded), bleaching (pale, partly bleached, bleached), and diseases.

Partial mortality (i.e. recent and old dead) was approximated as stipulated in the Atlantic and Gulf Rapid Reef Assessment (AGRRA) method (AGRRA Mesoamerican Reef System Workshop document 1999). Generally “the amount of “recent dead” approximates coral mortality that occurred within the previous days to months, while the amount of “old dead” represents an integration of disturbances that influence coral mortality over longer time scales” (Kramer and Kramer 2000). The causes of recent coral mortality were recorded focusing primarily on hurricane damage or bleaching, although diseases were also recorded. Bleached tissue was recorded as pale (discoloration of coral tissue), partly bleached (patches of fully bleached or white tissue not owing to other coral diseases), or wholly bleached (totally white tissue). Hurricane damage was classified as knocked over (entire colony dislodged from growth position), broken (part of colony or branches broken off), or abraded (tissue damage or loss due to chafing).

Data Analysis

Data collected for hurricane damage, bleaching and disease are presented as the percentage of total assessed colonies, which exhibited a particular condition or incidence.

Limitation

The survey only examined hard corals (scleractinians and *Millepora* spp.) and did not reflect damage, especially hurricane, to other benthic invertebrates (sponges, gorgonians, soft corals, etc.) or fish populations. At some sites, we observed a number of damaged gorgonians with minimal damage to hard corals. This incident was very evident at sites lacking significant scleractinian coral development.

Cumulative Impacts

Since there was variability in the level of disturbance from Hurricane Iris, a ranking system was utilized to help determine the condition of the reefs based on the cumulative amount of disturbance due to recent mortality, hurricane impacts, bleaching and disease. Level of disturbance is divided into three categories: “Low”, “Moderate”, and “Severe” (*See Result section for result*).

The five assessed reefs were placed in a category by ranking the main disturbance factors, which in this case are recent mortality, hurricane damage and bleaching. In the ranking process, recent mortality was given more weight. The other two, hurricane damage and bleaching had equal weights. “Low” disturbed reef experienced only minor damage with recent mortality of less than 10% and low to moderate hurricane damage or bleaching. “Moderate” disturbed reefs experienced moderate to severe damage with recent mortality between 10-15%, and a moderately high amount of hurricane damage or bleaching. “Severe” disturbed reefs experienced serious damage with recent mortality greater than 15% and high to extremely high hurricane damage or bleaching.

Result

This section summarizes the results of the field surveys paying particular attention to coral mortality, hurricane damage, coral bleaching, and disease incidence.

Recent Mortality and Hurricane Damage

The forereef site near Laughing Bird Caye received the greatest impact, with an average recent mortality of 19.6% and hurricane (mechanical) damage of 70.7% among assessed coral colonies. Second in line is the South West Caye forereef, which displays a 12.2% recent mortality and 52% mechanical damage. The other three sites, backreef west of Laughing Bird Caye, Gladden Split and patch reef near South West Caye, are much less impacted, 6.2% recent mortality and 26.7% mechanical damage for the backreef, 0.96% recent mortality and 6% mechanical damage for Gladden Split and 4% recent mortality and 28% mechanical damage for the patch reef (*See Graph 1 and 2*).

The greatest mechanical damage was incurred by *Acropora cervicornis* (Staghorn coral), *Porites asteroides* (Mustard Hill coral), *Montastraea annularis* complex (Boulder Star coral) and *Siderastrea siderea* (Massive Starlet coral) species. The type of mechanical damage that was most noticeable was “knocked over” of colonies. At the Laughing Bird Caye fore reef site, for example, 53% of assessed colonies were knocked over.

Although gorgonians were not assessed for impact, a great number appeared to have been impacted by the hurricane. This was especially noticeable on the patch reef near South West Caye, where a majority of the population was knocked over or completely detached from the substratum.

Photo 3 a



3b



Photo 3a-b. a.) The broken remains of a *Montastraea annularis* (Boulder Star coral) colony on the forereef near Laughing Bird Caye. b.) A “knocked over” gorgonian colony and coral rubble on patch reef near South West Caye.

Bleaching

The site displaying the greatest percentage bleaching is Gladden Split, with 58% of assessed colonies exhibiting bleaching. Second in line is the Laughing Bird Caye forereef with 45%. The forereef at South West Caye displays 42%, while the patch reef displays

21.7%. The Laughing Bird Caye backreef displays even less with only 20% of assessed colonies affected (See Graph 3).

The species that were most affected by bleaching were *Siderastrea siderea* (Massive Starlet coral) and the *Montastraea annularis* complex (Boulder Star coral).

Photo 4a



4b.



Photo 4a-b: a.) A pale bleached *Siderastrea siderea* colony, and b.) A part bleached *Montastraea annularis* colony on the deep reef at Gladden Split.

Disease Incidence

Disease incidence was low on all five assessed reefs. The highest was found on the South West Caye patch reef where 9% of the assessed corals exhibited disease infestation. The two sites with the highest disease incidence were the two shallow water sites (See Graph 4).

Comparison of current data to previously collected data

In comparing the collected data for two of the assessed sites, Laughing Bird Caye forereef and Gladden Split, to that, which were collected approximately one month prior to the hurricane (McField et al. 2001), it was found that there has been a significant increase in recent mortality on the forereef near Laughing Bird Caye. Approximately a month ago, this site exhibited a recent mortality of 2.8%, bleaching of 43.75, and mechanical damage of < 1% (See Table 1, 2 & 3).

Except for an increase in bleaching, Gladden Split, however, does not display any significant change subsequent to the hurricane. The previously collected data reveals a recent mortality of 0.88%, bleaching of 22.47% and mechanical damage of < 1% (See Table 1, 2 & 3).

Table 1. Percent recent mortality per site and time

Site	September 2001	October 2001
Laughing Bird Caye Deep	2.80%	19.6%
Gladden Split	0.88%	0.96%

Table 2. Percent mechanical damage per site and time

Site	September 2001	October 2001
Laughing Bird Caye Deep	<1%	70.69%
Gladden Split	<1%	5.97%

Table 3. Percent bleaching per site and time

Site	September 2001	October 2001
Laughing Bird Caye Deep	43.75%	44.83%
Gladden Split	22.47%	58.21%

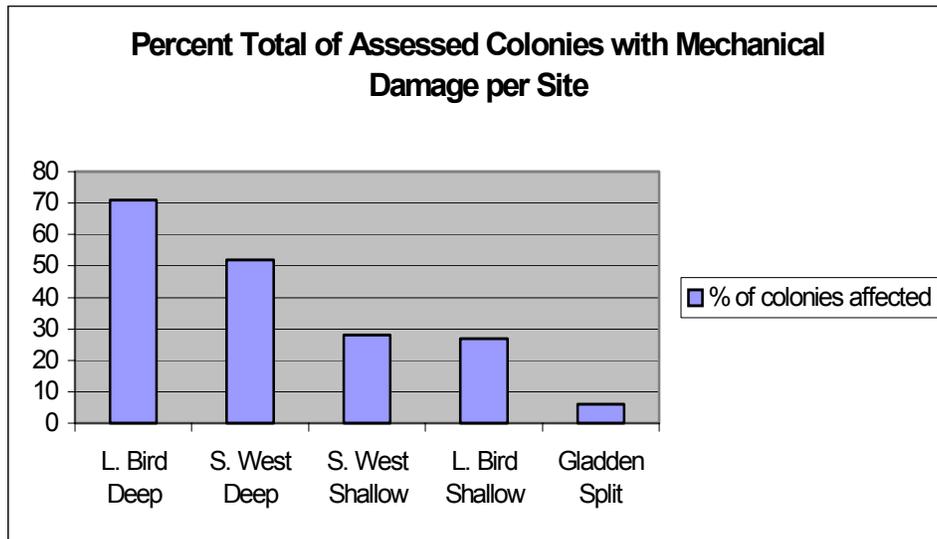
Sites Ranking on the Basis of Cumulative Impacts

Assessed sites were ranked based on the cumulative amount of disturbance due to recent mortality, hurricane damage and bleaching. Since the deep site near Laughing Bird Caye displayed a high recent mortality (19.6%), and an extremely high mechanical damage (70.7%) and bleaching (44.8%), it is considered to be severely impacted and, as such, ranked as the site that is most impacted by Hurricane Iris. South West Caye forereef, displaying a moderate percentage of recent mortality (12.2%), and a moderately high amount of mechanical damage (52%) and bleaching (41.7%), is considered to be moderately impacted, and has also been ranked as such.

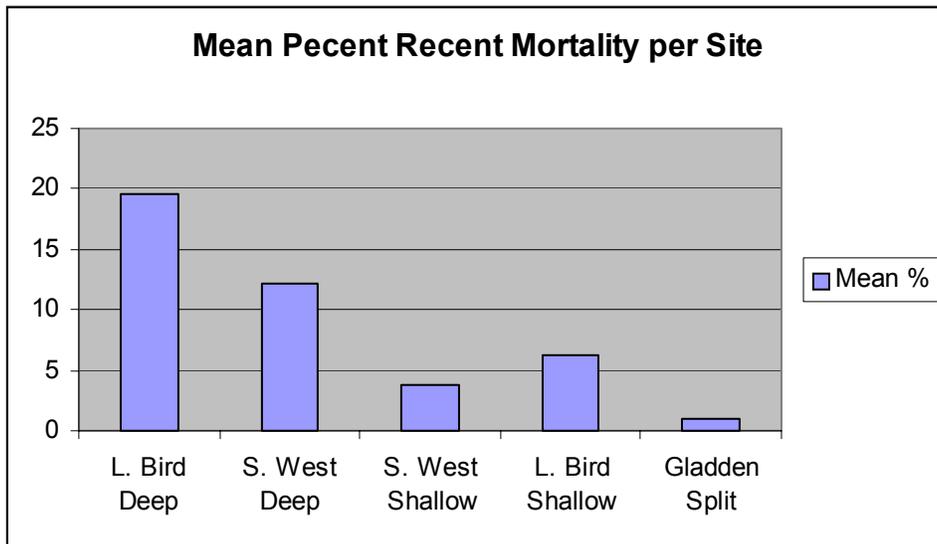
The other three sites display a recent mortality less than 10% (6.2% for Laughing Bird Caye shallow site, 0.96% for Gladden Split, 3.8% for South West Caye patch), and a low to moderate hurricane (mechanical) damage, 26.7% for Laughing Bird, 6% for Gladden Split and 28% for South West patch. With the exception of Gladden Split, which displays a moderately high percentage bleaching (58%), bleaching was also on a low to moderate range, 20% for Laughing Bird shallow and 21.7% for South West Patch. Since mechanical damage and recent mortality are low, they have all been ranked as “low” or minimally impacted by Hurricane Iris.

The location of each site and their ranking level is displayed on Map #2 of the Post Iris Coral Reef Assessment Sites map series that is attached.

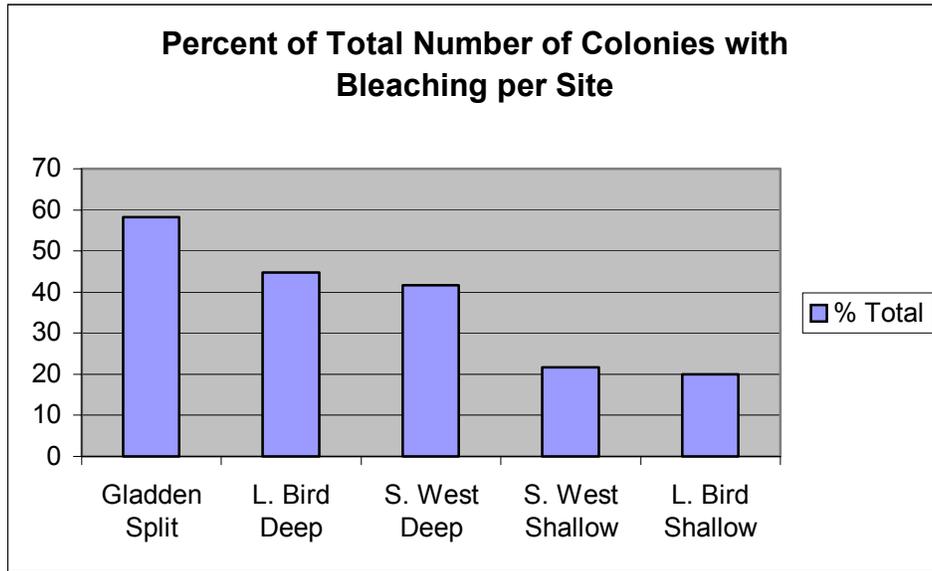
Graph #1.



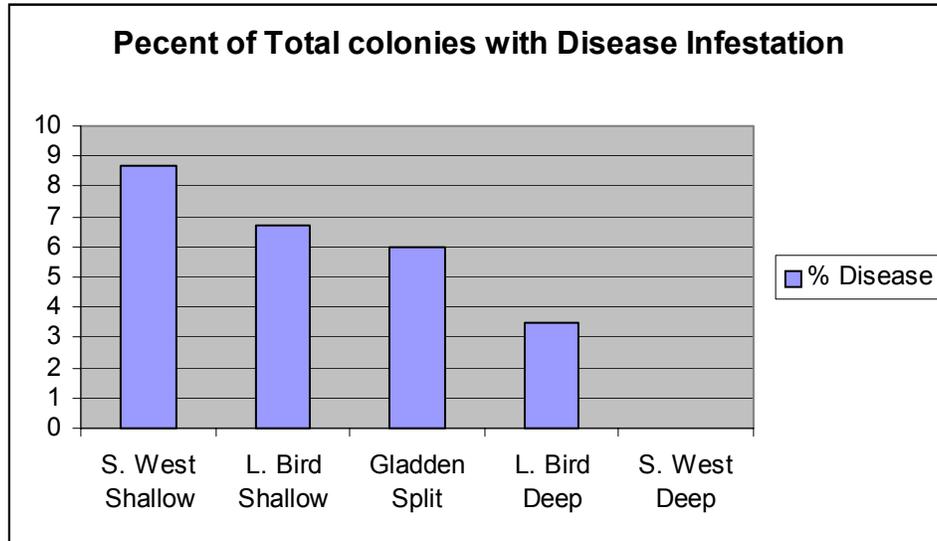
Graph #2



Graph #3



Graph #4



Discussion

Reefs, like many biological systems, are considered to be rather dynamic, undergoing both long-term and short-term changes depending on the degree and duration of stress factors. Thus, the role of both temporal and spatial scales is important in understanding observable trends in how reef communities and processes are affected by disturbances (Kramer and Kramer 2000). Over longer time scales, it is strongly believed that the robust character of reefs will allow them to withstand massive changes (such as those associated with sea level and climate changes) by shifting to more favorable growing locations. However, over shorter time scales, it is felt that storms and other disturbances could lead to dramatic changes, which may either be followed by recovery to pre-disturbance conditions or continued degradation. As coral reefs are frequently, and continue to be subjected to varied levels of perturbations, they may continually fluctuate through various stages of recovery in response to these natural disturbances. However, if the severity of these disturbances continues to increase on a constant basis, they may cease to persist. The ability to recover from severe disturbances will depend greatly on a number of factors including the availability of new recruitment, water quality, and the presence (or lack there of) of other stresses (Kramer and Kramer 2000).

A thorough understanding of the secondary effects from Hurricane Iris, as well as the potential for these reefs to recover, may take to some time to fully elucidate. In the mean time, further assessment and monitoring should be continued to record observable changes and potential stress factors.

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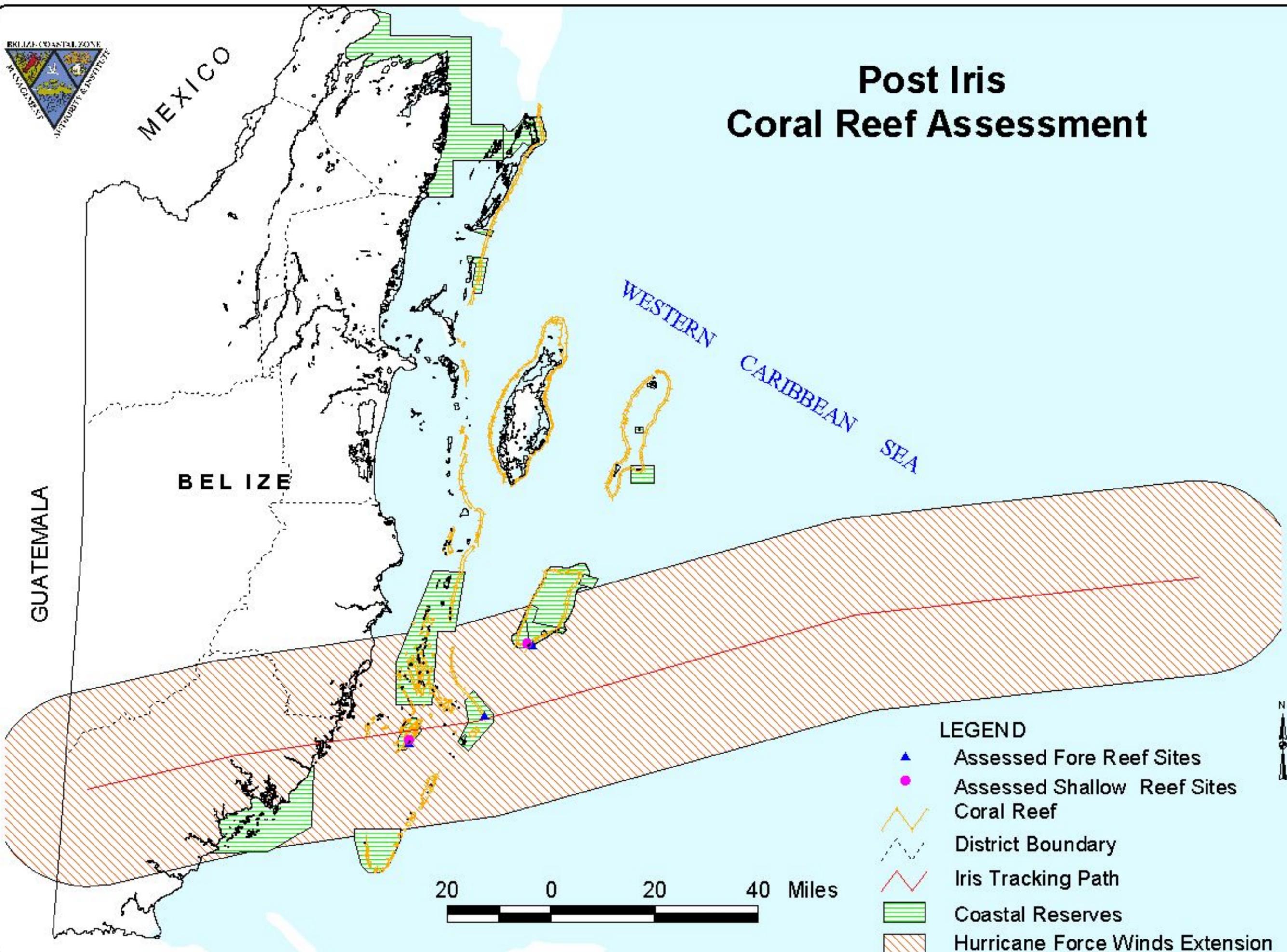
Post Iris Coral Reef Assessment

MEXICO

WESTERN
CARIBBEAN
SEA

BELIZE

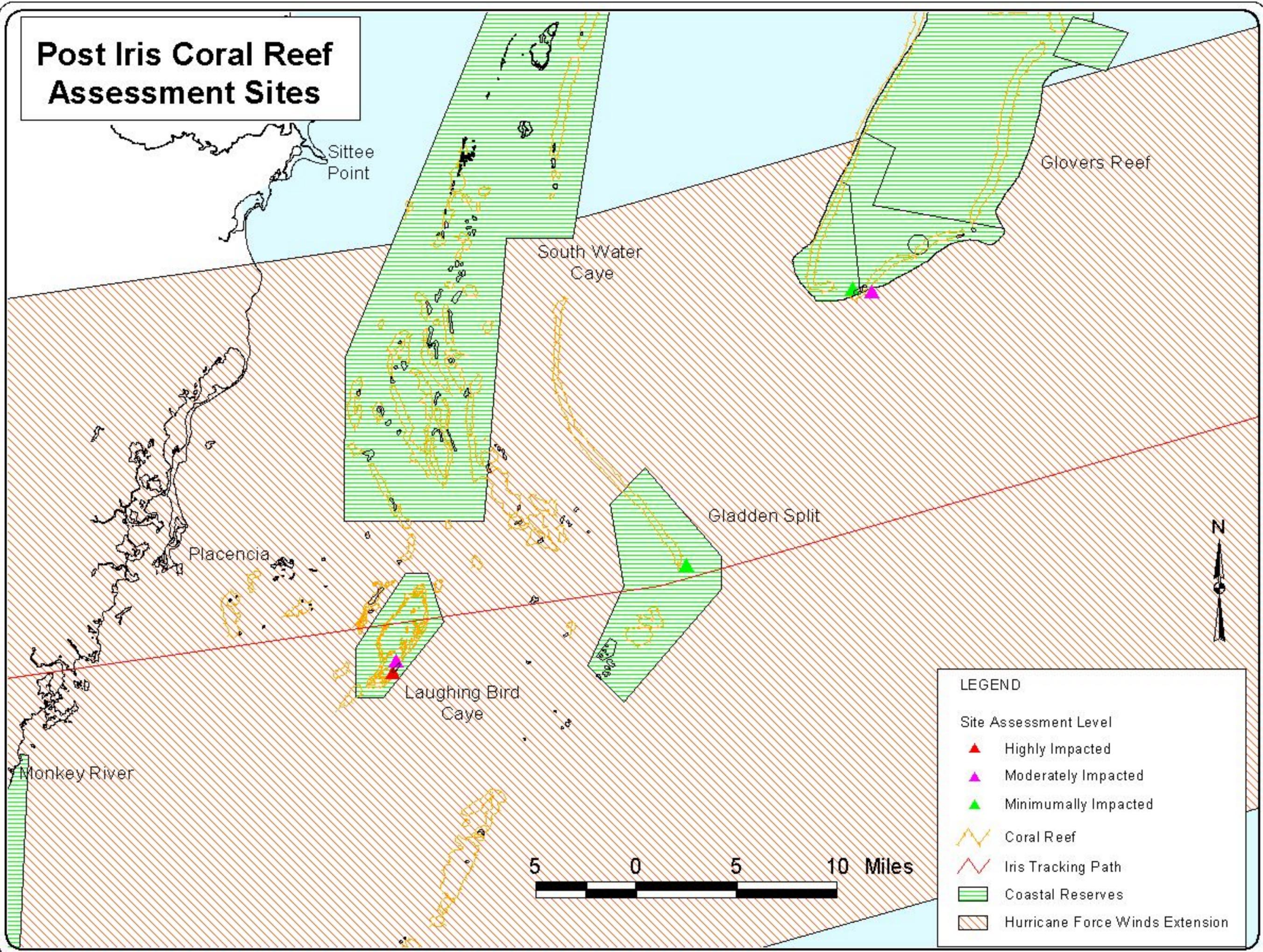
GUATEMALA



LEGEND

- ▲ Assessed Fore Reef Sites
- Assessed Shallow Reef Sites
- Coral Reef
- - - District Boundary
- Iris Tracking Path
- ▨ Coastal Reserves
- ▨ Hurricane Force Winds Extension

Post Iris Coral Reef Assessment Sites



LEGEND

Site Assessment Level

- ▲ Highly Impacted
- ▲ Moderately Impacted
- ▲ Minimumally Impacted

— Coral Reef

— Iris Tracking Path

— Coastal Reserves

— Hurricane Force Winds Extension