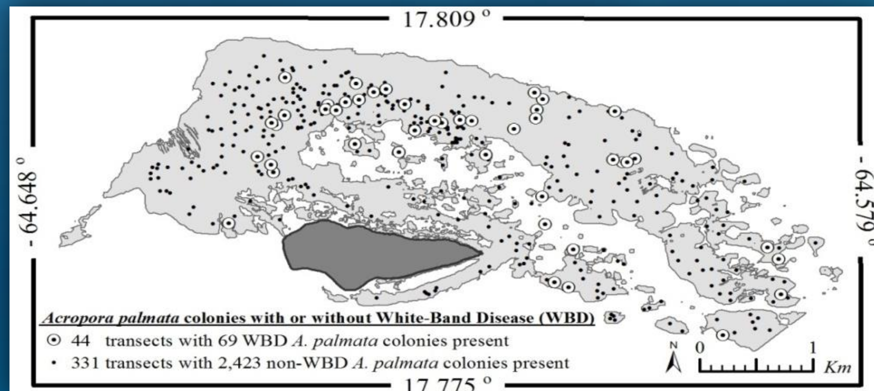
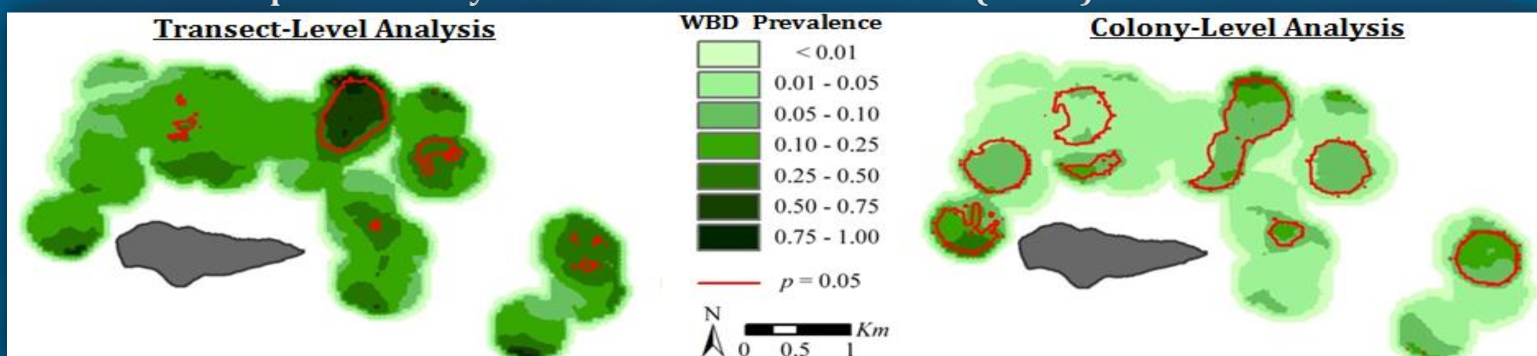
Developing A Geospatial Protocol For Coral Epizootiology

Dissertation Defense Presentation



Transect versus Colony-Level
Spatial Analysis of White-Band Disease (WBD) Prevalence



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March 29th, 2012

Purpose

The purpose of my doctoral research is to determine whether Geographic Information Systems (GIS) combined with specific geospatial analytical techniques

specifically, those techniques used in Spatial Epidemiology to map, detect, & spatially analyze disease epidemics

can be used to further our understanding of coral health and if so, how?

Presentation Outline

Part I Introduction & Background Information

Dissertation Chapters 1-3

Part II Developing the Analytical Protocol

Dissertation Chapters 4-7

Part III Applying the Protocol to Coral Disease data

Dissertation Chapter 8 (published by *PLoSone* in July 2011)

Part IV Discussion

Part V Summary & Conclusions

Dissertation Chapter 9

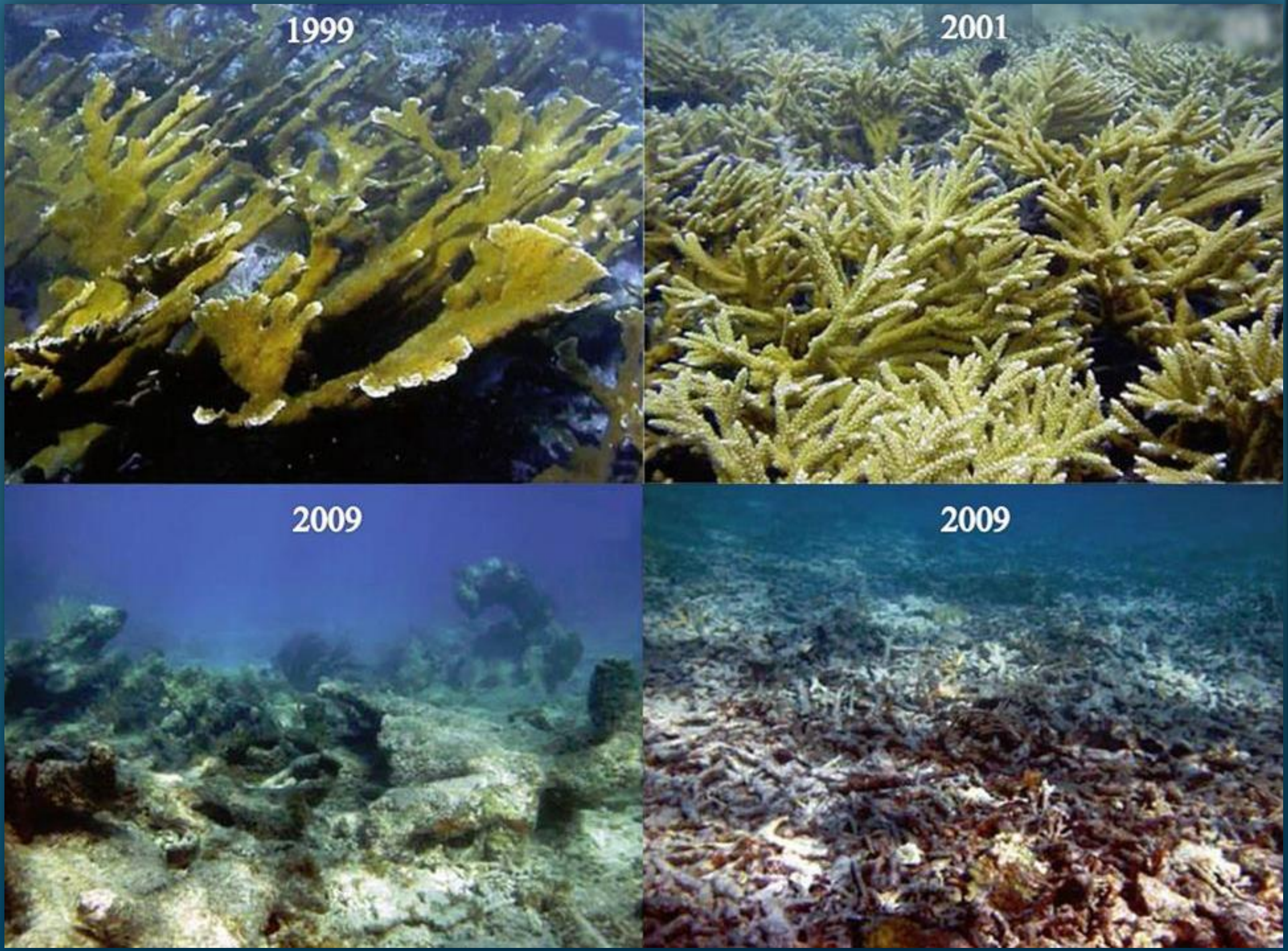
Part I

Introduction & Background Information

95% decline in Caribbean *Acropora*

Healthy Coral Thickets

Algal Dominated Reef Ruble



Disease Terminology

"Disease"
any deviation from an organism's normal, or "healthy," state

"Health"
an individual's ability to resist or adapt to various stresses, whether they are physical, chemical, biological, social, etc.

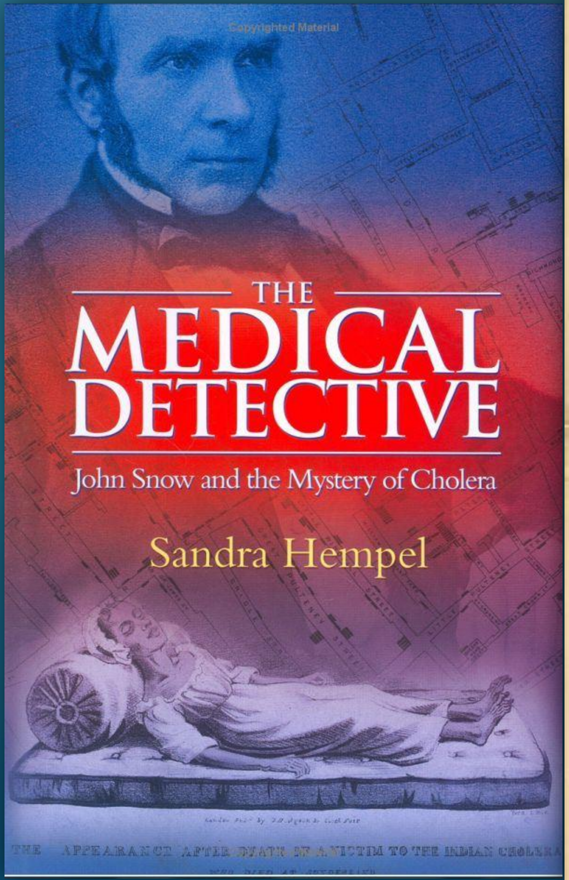
"Epidemiology" & **"Epizootiology"**
the study of the distribution & determinants of health-related states or events in specified populations, & the application of this study to control health problems

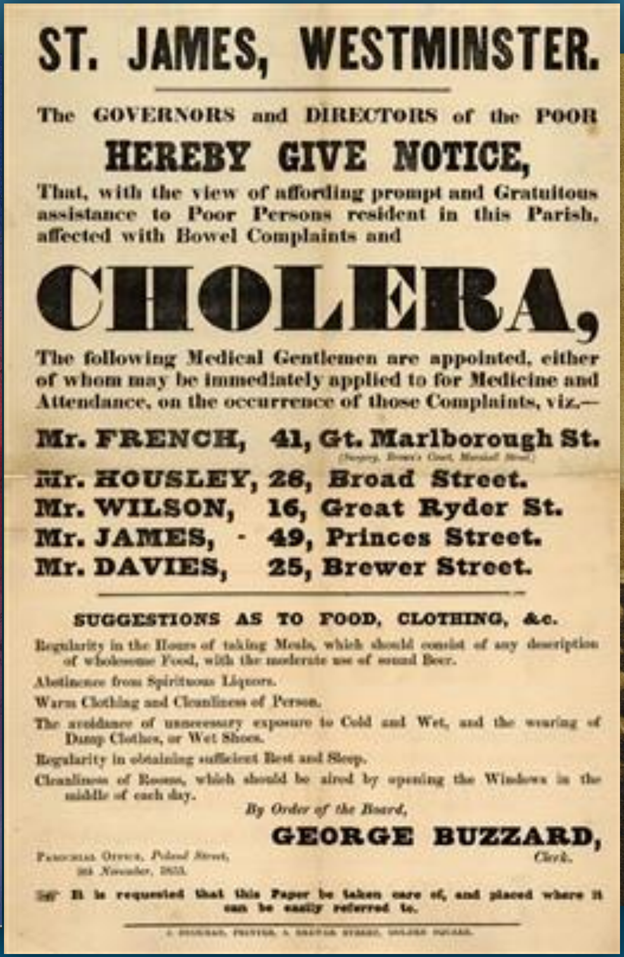
"Etiology"
the science & study of the causes of disease & their mode of operation

"Pathology"
the form of medical science & specialty practice concerned with all aspects of disease

Dr. John Snow (1813-1858)

"Father of **Modern Epidemiology**"





ST. JAMES, WESTMINSTER.

The GOVERNORS and DIRECTORS of the POOR

HEREBY GIVE NOTICE,

That, with the view of affording prompt and Gratuitous assistance to Poor Persons resident in this Parish, affected with Bowel Complaints and

CHOLERA,

The following Medical Gentlemen are appointed, either of whom may be immediately applied to for Medicine and Attendance, on the occurrence of those Complaints, viz.—

Mr. FRENCH, 41, Gt. Marlborough St.
Mr. HOUSLEY, 26, Broad Street.
Mr. WILSON, 16, Great Ryder St.
Mr. JAMES, - 49, Princes Street.
Mr. DAVIES, 25, Brewer Street.

SUGGESTIONS AS TO FOOD, CLOTHING, &c.

Regularity in the Hours of taking Meals, which should consist of any description of wholesome Food, with the moderate use of sound Beer.

Abstinence from Spirituous Liquors.

Warm Clothing and Cleanliness of Person.

The avoidance of unnecessary exposure to Cold and Wet, and the wearing of Damp Clothes, or Wet Shoes.

Regularity in obtaining sufficient Rest and Sleep.

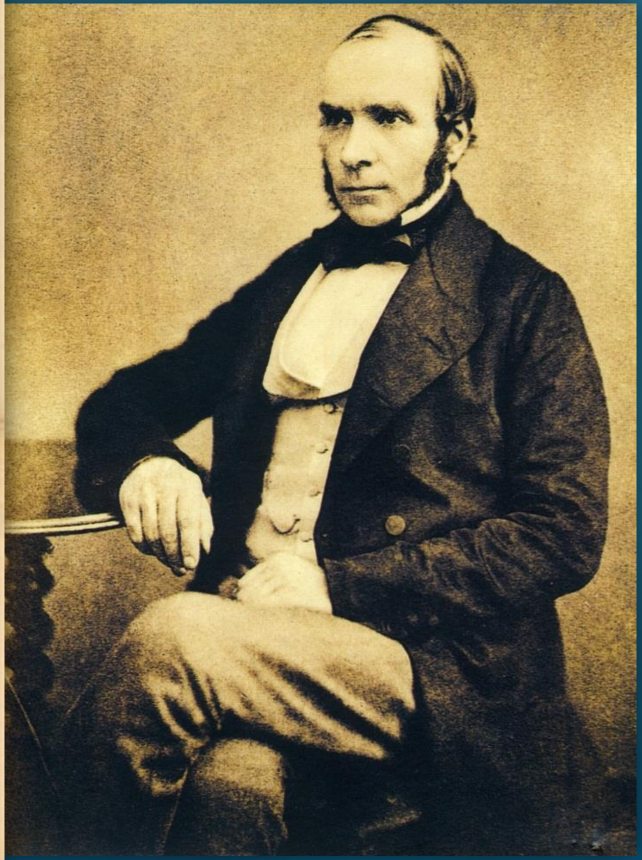
Cleanliness of Rooms, which should be aired by opening the Windows in the middle of each day.

By Order of the Board,

GEORGE BUZZARD,
Clerk.

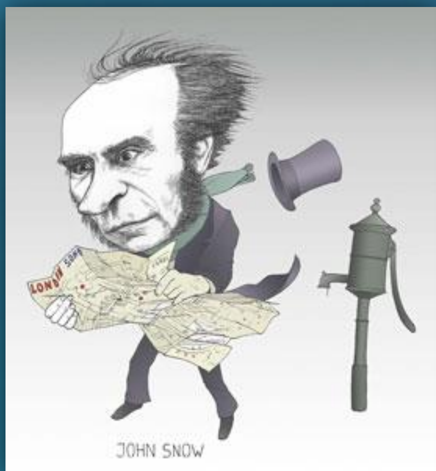
Parochial Office, *Poland Street,*

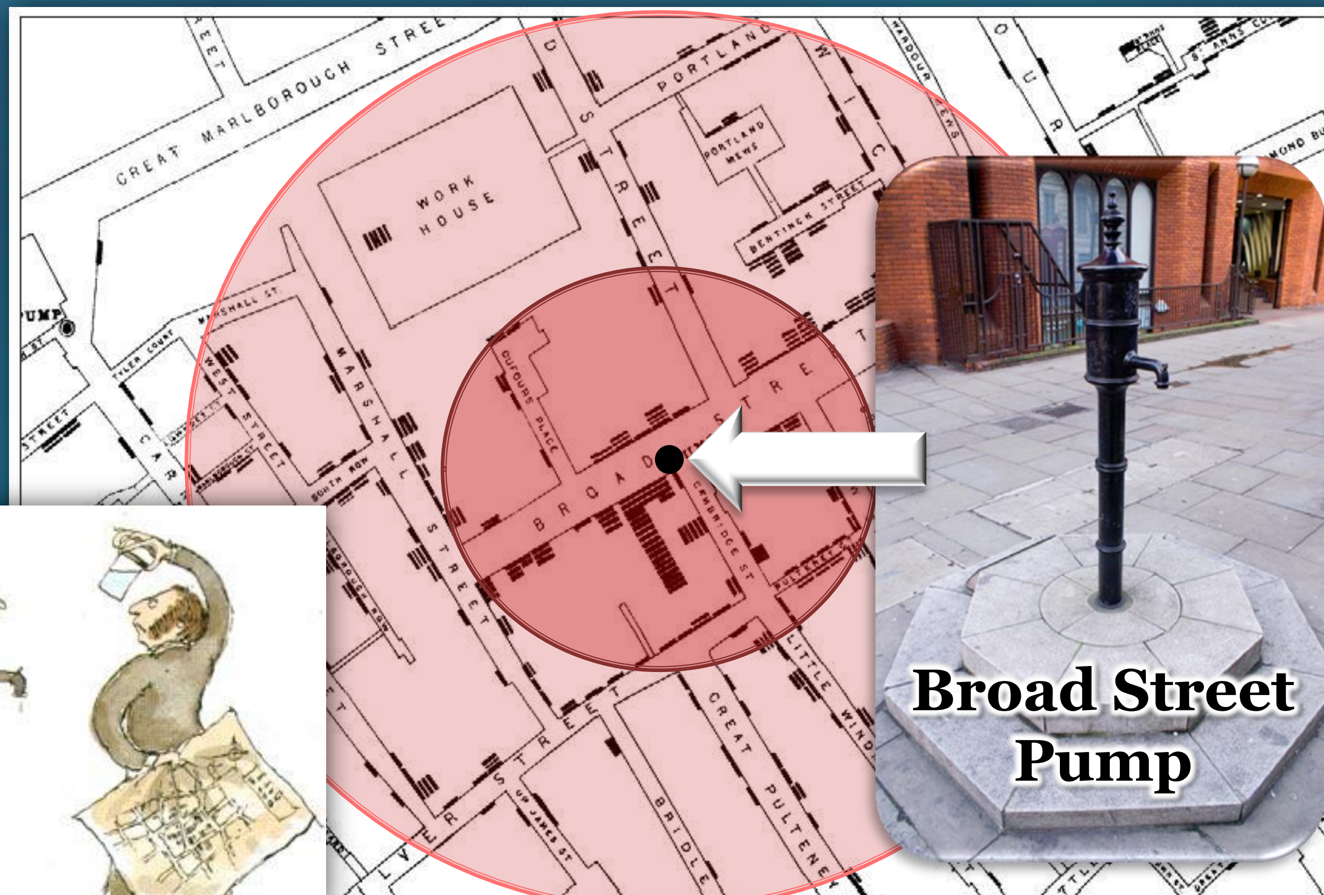
It is requested that this Paper be taken care of, and placed where it can be easily referred to.



Dr. John Snow (1813-1858)

"Father of **Medical Geography**"





Street map of cholera deaths in Soho in 1853 from John Snow's *On the Mode of Communication of Cholera*

Part II

Developing a Geospatial Analytical Protocol for studying diseased corals

through extensive
Exploratory Spatial Data Analysis (ESDA)
of an Artificial Dataset

Study Design

- different Types of Spatial Analysis & different Parameter Settings
  ↳ can produce **noticeably different results**

- **Poor Selection** or **Improper Use** of a given technique
  ↳ **Inaccurate Representations** of the Spatial Distribution and **False Interpretations** of the disease

	Denominator data (All Artificial Points)
Corrected Akaike's Information Criterion (AIC_c)	450.00m
Default search radius in ArcView's (AV) Kernel Densi	106.83m
Biased Cross Validation (BCV)	100.10m
Bailey and Gatrell's (BG) h	581.72m
Generalized Cross-Validation Criterion (GCV)	200.00m
Least Squares Criterion (LSC)	—
Least Squares Cross Validation ($LSCV$)	100.10m
Maximal Smoothing (max) Bandwidth	628.81m
Nearest Neighbor Analysis (Nna) Bandwidth	K_{01}: 81.61m K_{20}: 460.21m K_{mean}: 307.52m
Optimized (opt) Bandwidth	369.29m
Reference (ref) Bandwidth	473.37m
Visual Calibration (VC) using the Artificial dataset	100.00m

where...

- A is *Study Area*, which is the area of the surveyed be
- $AMISE$ is the *Asymptotic Mean Integrated Square E*
- h is the size of the *bandwidth* (i.e. the filter radius)
- $MISE$ is the *Mean Integrated Square Error*
- n is the *sample size* which is calculated as the total
- σ is *sigma* (also known as the *standard distance*), w *CrimeStat's* "standard distance deviation" tool ca
- $\hat{\sigma}$ is *sigma hat*, which is the estimated standard dev
- $tr(S)$ is the *trace* of the hat matrix (S) which is a fu
- v_1 is the *effective number of parameters in the model*
- $var_{x,y}$ is the mean variance in the x and y co-ordinat
- y_i is the value of the *dependent variable* at location
- $\hat{y}_i$ is the *fitted value* (aka. Estimated, Expected, or P

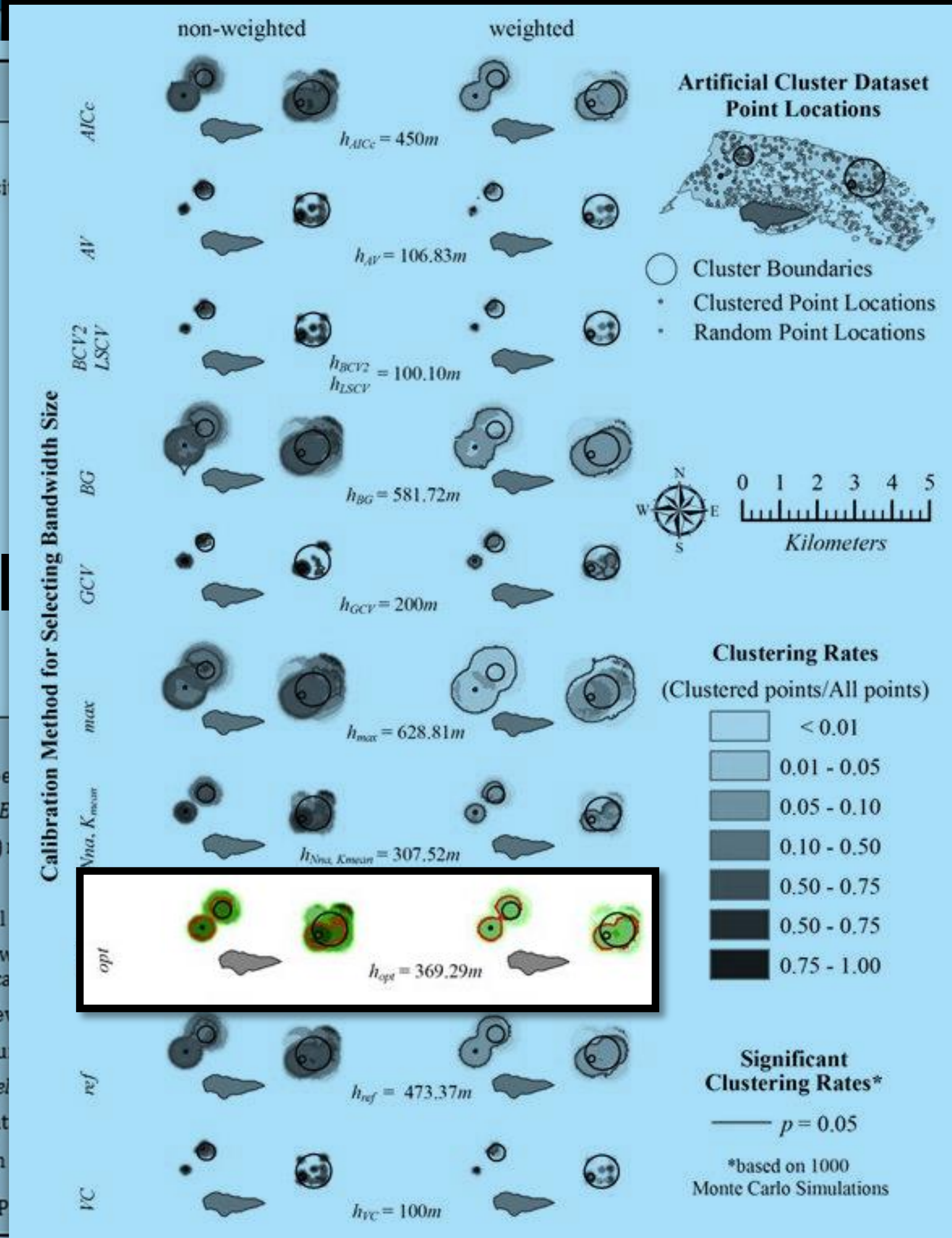


Figure 6.14 *DMAP*'s fixed distance dual KDEs of the artificial case and population data.

Study Design

- **Comprehensive Review** of many of the **Geospatial Analytical Techniques** commonly used by **Spatial Epidemiologists**
- **Each** of the reviewed techniques were then applied to an **Artificial Dataset** with **known cluster locations** in order to determine which methods provided the **most accurate** and **powerful results**
- In order to ensure that the **Scale** & **Spatial Distribution** of the Artificial Data would be similar to that of an actual coral disease dataset, I created the artificial dataset using the **geographic** & **biologic attributes** of data from an **actual coral disease outbreak** that occurred in the US Virgin Islands (USVI)
- These results were used to develop **different Geospatial Protocols** based on the **types of coral data available**
- I **applied the techniques** from one of the **recommended protocols** to data from the **original disease dataset** of a 2004 **White-Band Disease (WBD)** outbreak on an ***Acropora palmata*** population of corals in the USVI

Geospatial Protocol for Disease & Population data

The following techniques were used on both **non-weighted** (Transect-level) & **weighted** (Colony-level) versions of the White-band disease (WBD) & underlying *Acropora palmata* coral population data from Mayor et al.'s (2006) study

Mayor PA, Rogers CS, Hillis-Starr ZM (**2006**) Distribution and abundance of elkhorn coral, *Acropora palmata*, and prevalence of White-Band disease at Buck Island Reef National Monument, St. Croix, US Virgin Islands. ***Coral Reefs*** **25 : 239-242**

Coral Reefs (2006) 25: 239 242
DOI 10.1007/s00338-006-0093-x

NOTE

Philippe A. Mayor · Caroline S. Rogers
Zandy M. Hillis-Starr

Distribution and abundance of elkhorn coral, *Acropora palmata*, and prevalence of white-band disease at Buck Island Reef National Monument, St. Croix, US Virgin Islands

Received: 29 September 2005 / Accepted: 7 January 2006 / Published online: 7 March 2006

Abstract In the 1970s and 1980s elkhorn coral, *Acropora palmata*, declined dramatically throughout the Caribbean primarily due to white-band disease (WBD). In 2005, elkhorn coral was proposed for listing as threatened under the US Endangered Species Act. WBD was first documented at Buck Island Reef National Monument (BIRNM). Together with hurricanes WBD reduced live elkhorn coral coverage by probably over 90%. In the past decade some recovery has been observed at BIRNM. This study assessed the distribution and abundance of elkhorn coral and estimated the prevalence of WBD at the monument. Within an area of 795 ha, we estimated 97,232 134,371 (95% confidence limits) elkhorn coral colonies with any dimension of connected live tissue greater than one meter, about 3% of which were infected by WBD. Despite some recovery, the elkhorn coral density remains low and WBD may continue to present a threat to the elkhorn coral population.

Keywords *Acropora palmata* · Buck Island Reef National Monument · Elkhorn coral · US Virgin Islands · White-band disease

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Introduction

Elkhorn coral, *Acropora palmata*, is a major reef-building species and was the dominant coral in wave-exposed and high-surge reef zones throughout the Caribbean prior to the 1970s (Adey and Burke 1976). In the 1970s and 1980s elkhorn coral drastically declined primarily due to a bacterial syndrome called white-band disease (WBD) (Aronson and Precht 2001; *Acropora* Biological Review Team 2005). In the past two decades, mortality from disease has been compounded by hurricanes, bleaching events, and outbreaks of predators (Bruckner 2002), and elkhorn coral was proposed for listing as threatened under the US Endangered Species Act of 1973 (Oliver 2005).

Buck Island Reef National Monument (BIRNM), located 1.5 km to the northeast of St. Croix, US Virgin Islands, was created in 1961 to preserve a unique elkhorn coral barrier reef surrounding Buck Island. In 2001, it was expanded from 356 to 7,695 ha and all extractive uses have been prohibited. In the early 1970s, the first signs of WBD were noted by US National Park Service (NPS) staff (NPS reports, unpublished). Gladfelter et al. (1977) determined prevalence levels at about 3%, where prevalence is defined as the number of cases of a disease in a population at a specific time (Stedman 2000). At that time, the crest and forereef of Buck Island's barrier reef was composed of greater than 50% live elkhorn coral. Subsequently, WBD spread, and together with hurricanes reduced live elkhorn coral coverage by probably over 90%, leaving vast areas of dead standing colonies (Anderson et al. 1986; Bythell et al. 1989; Rogers et al. 2002). Within the past 10 years, some recovery has been noted at BIRNM, especially along the southeastern barrier reef that was heavily impacted by hurricanes (Z. Hillis-Starr, personal observations).

The objectives of this study were to assess the current elkhorn coral distribution and abundance within the monument boundary and to estimate the prevalence of WBD.

White-Band Disease (WBD)

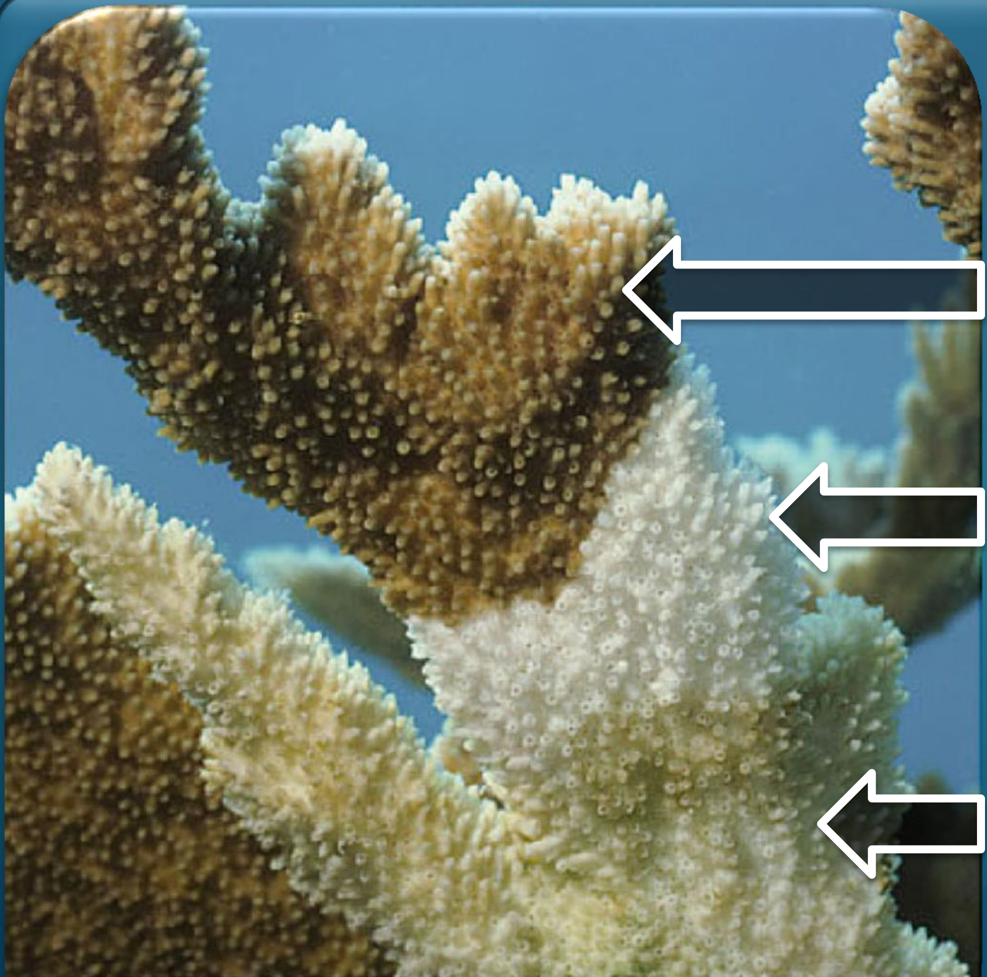


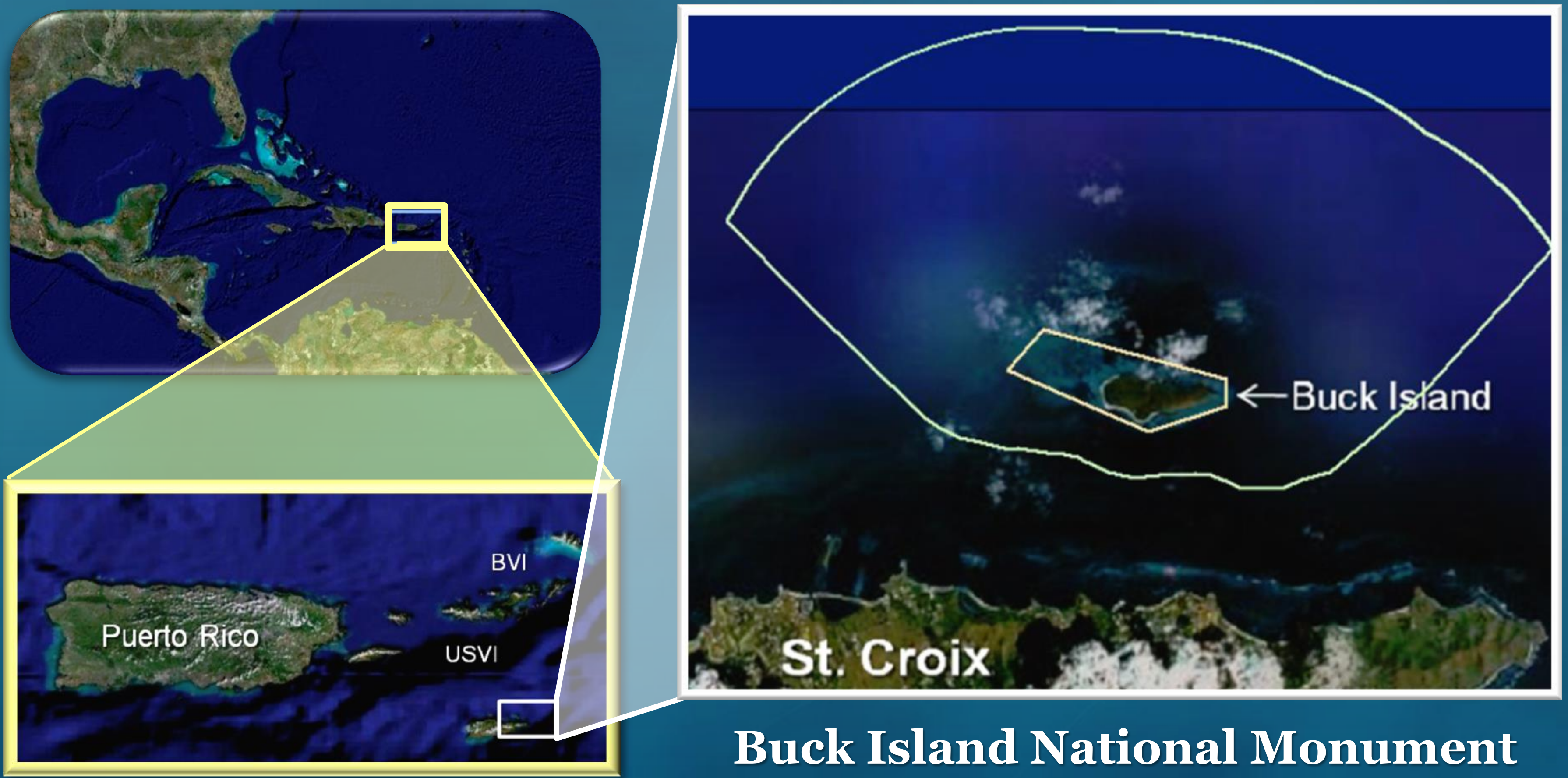
Fig.4.19: WBD; Caribbean *Acropora palmata* infected with WBD-I.
Sutherland et al, 2004

Healthy Tissue

Active WBD

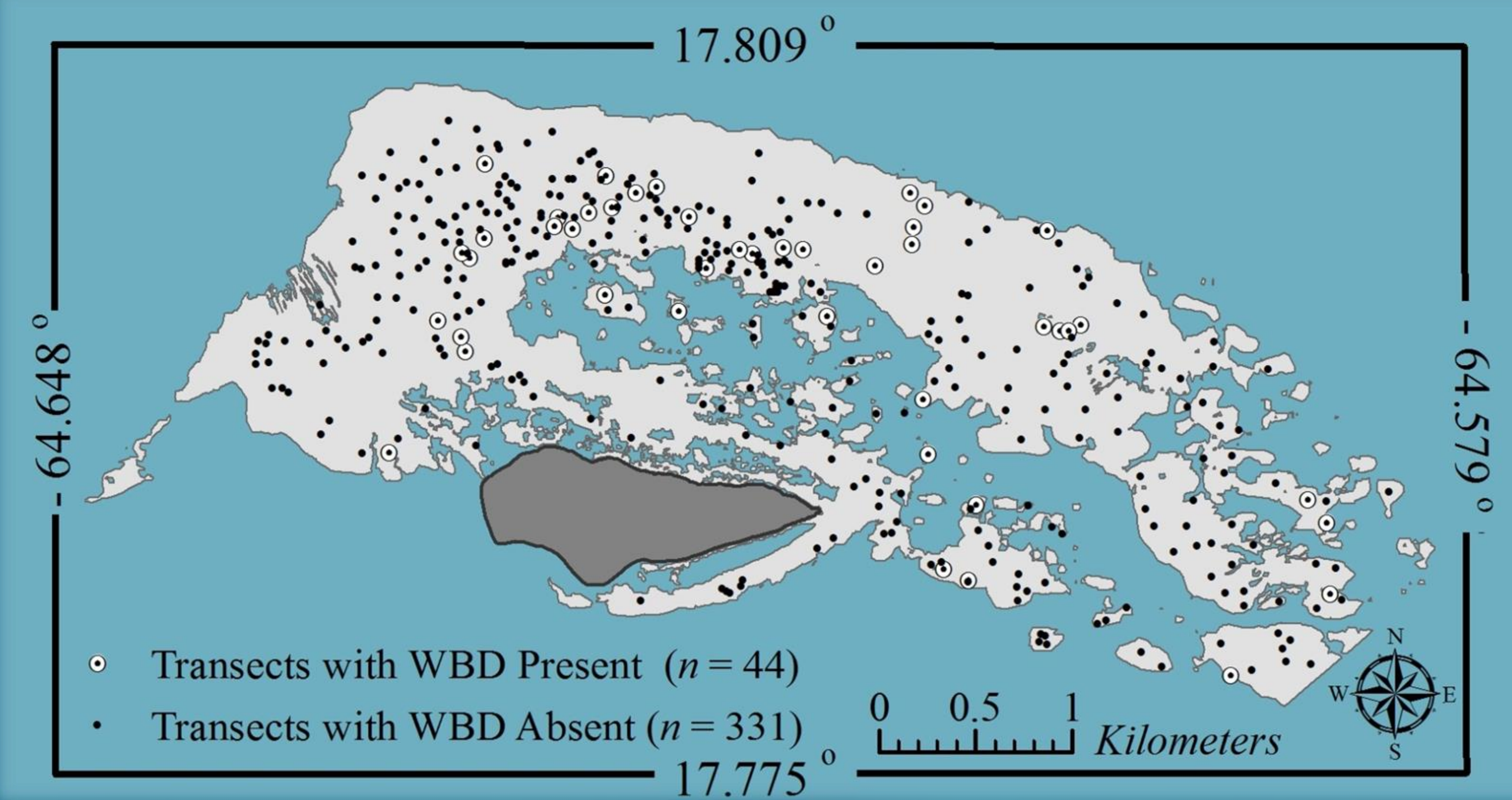
Recently Dead tissue
killed by WBD

Study Site



Buck Island National Monument

Mayor et al.'s (2006) BUIS Dataset



Buck Island Reef
National Monument

US Virgin Islands

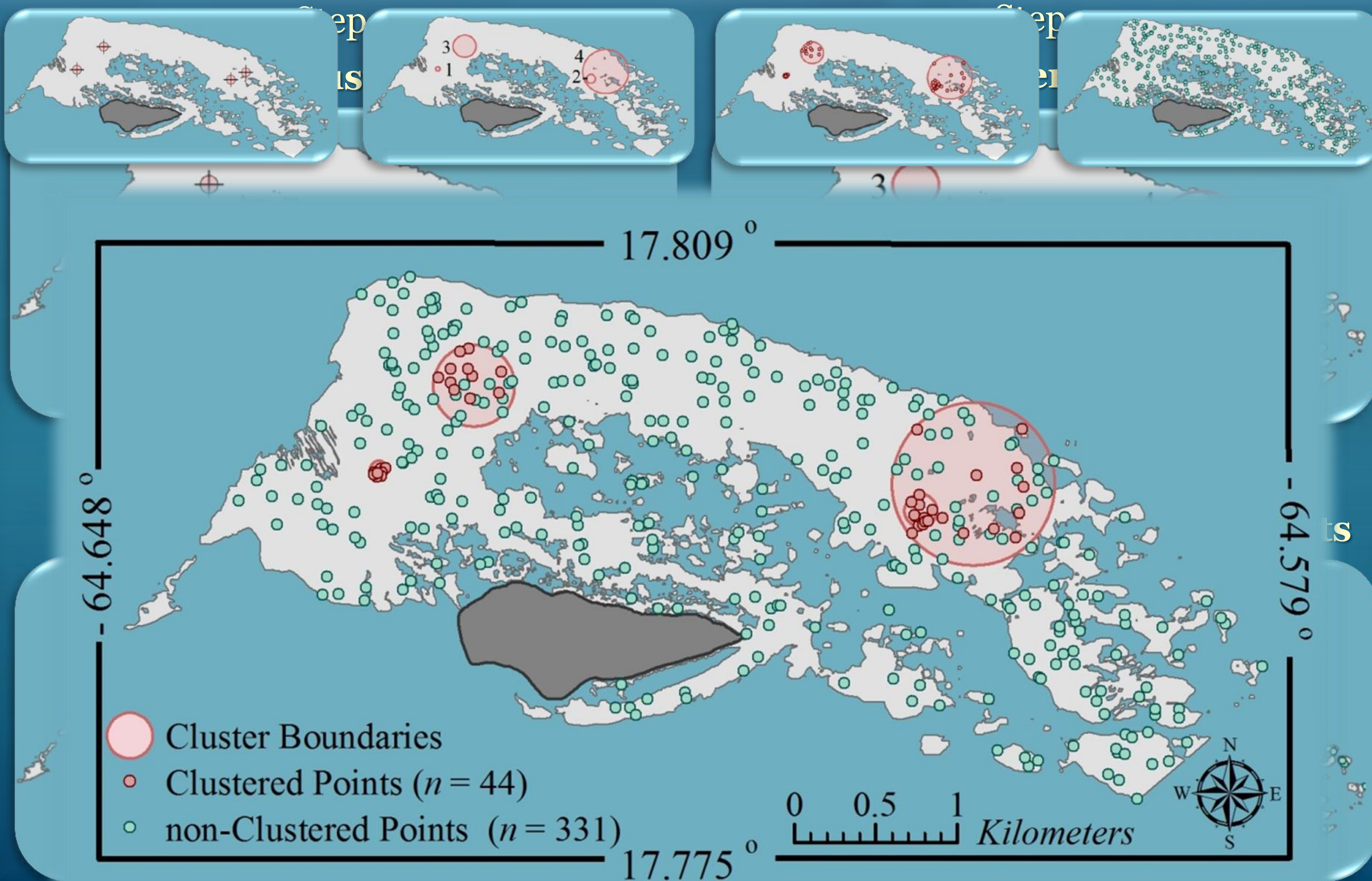
Colony-Level Data

A. palmata	Min	Max	Mean	S.D.	Total
with WBD	1	6	1.57	1.16	69
without WBD	1	40	6.48	5.87	2,423
Total	1	40	6.65	5.99	2,492

Surveyed Habitat

(< 10 *m* deep)

Creating the Artificial Dataset



All of the ESDA Methods used on the Artificial Data

Type of Spatial Analysis	Spatial Information Attained
1. Mapping & Visualizing Data	**Visualizing Spatial Distributions**
• Mapping Point Locations using points & polygons	• Visualizing the spatial distribution of data locations
• Scaling Point Symbols &/or colors to visualize intensity	• Visualizing the spatial distribution of data density (or intensity of an attribute)
2. Point Pattern Analysis	**Describe the General Spatial Distribution of the Data**
o Centrographic Statistics	o Demonstrate the location & spatial distribution of point patterns
• "Mean Center" estimates	• Identifying the central focal point of the points
• *Median Center* (*MdnCntr*)	• Useful when outliers are influencing the mean center
• *Minimum Convex Polygons* (*MCP*)	• Simplest method for estimating the Home Range of an animal
• Standard Distance & Deviation Estimates	• Estimate the general distribution of the data around a central focal point
o Distance Statistics	o Test hypotheses regarding the spatial distribution of points
• *Nearest Neighbor Analysis* (*Nna*)	• Examine spatial dependence (clustering or dispersion) at a given scale
• *Ripley's K* (*K*)	• How spatial dependence changes with distance & scales of measurement
3. Spatial Filtering and Smoothing	**The Presence, Degree, & Location of Clusters**
• Single Kernel Density Estimates (KDE)	• Density, Intensity, and Probability estimates
• Dual KDEs	• Prevalence, Odds Ratios, & Relative Risk Estimates
• *DMAP*'s Dual KDE with Monte Carlo simulations	• All of the above plus Significant Clustering Areas
4. Spatial Scan Statistics	**Scan Statistics are used to detect Outbreaks through the Cluster Analysis**
• Spatial & Temporal Scan Statistics	• Cluster Size, Significance, Relative Risk, Changes with time
5. Spatial Autocorrelation (SA)	**Whether or Not Clustering is Present**
o Global SA	o Whether or not Spatial Autocorrelation (SA) is present region-wide
• *Getis-Ord General G*	• Measures the degree of clustering for either "high" or "low" values
• *Moran's I*	• Measures the amount of SA based on feature locations & attribute values
o Local SA	o Where local SA is present
• *Getis-Ord* G_i^*	• Identifies where "high" or "low" values cluster spatially
• *Local Moran's* I_i	• Identifies the locations of high & low clusters, as well as spatial outliers
6. Spatial Regression	**Performs local regression analyses without assuming spatial homogeneity**
• *Ordinary Least Squares (OLS) Regression*	• OLS results output is used to build the GWR model
• *Geographically Weighted Regression* (*GWR*)	• Assesses spatial heterogeneity between independent & dependent variables

3 Tiered Approach to Geospatial Coral Epizootiology

3 Tiers of Geospatial Coral Epizootiology	Spatial Analysis Types according to ESDA Category	Description of the Types of Spatial Information Attained
(1) Disease Mapping & Visualization	**ESDA 1. Mapping & Visualizing Data** • Mapping Point Locations using points & polygons • Scaling Point Symbols &/or colors to visualize intensity	**Visualizing Spatial Distributions** • Visualizing the spatial distribution of data locations • Visualizing the spatial distribution of data density (or intensity of an attribute)
(2) Detection & Analysis of Disease Clusters		
(2A) General Disease Clustering Global spatial statistics assume the spatial distribution of the data is <u>homogeneous</u> & results generally have <u>no</u> spatial output	**ESDA 2. Point Pattern Analysis** **2.1 Centrographic Statistics** • "Mean Center" estimates • *Median Center (MdnCntr)* • *Minimum Convex Polygons (MCP)* • Standard Distance & Deviation Estimates	**Describe the General Spatial Distribution of the Data** **Shows the Location & Spatial Distribution of Point Patterns** • Identifying the central focal point of the points • Useful when outliers are influencing the mean center • Simplest method for estimating the Home Range of an animal • Estimate the general distribution of the data around a central focal point
	2.2 Distance Statistics • *Nearest Neighbor Analysis (Nna)* • *Ripley's K (K)*	**Test hypotheses regarding the spatial distribution of points** • Examine spatial dependence (clustering or dispersion) at a given scale • How spatial dependence changes with distance & scales of measurement
	ESDA 5. Spatial Autocorrelation (SA) **5.1 Global SA Analyses** • *Getis-Ord General G* • *Moran's I*	**Whether or Not Clustering is Present** **Whether or not Spatial Autocorrelation (SA) is present region-wide** • Measures the degree of clustering for either "high" or "low" values • Measures the amount of SA based on feature locations & attribute values
(2B) Specific Disease Clustering Local spatial statistics assume the spatial distribution of the data is <u>heterogeneous</u> & there is generally spatial (mappable) output associated with the results.	**ESDA 3. Spatial Filtering & Smoothing** • Single Kernel Density Estimates (KDEs) • Dual KDEs • Dual KDEs with Monte Carlo Simulations	**The Presence, Degree, & <u>Location</u> of Clusters** • Density, Intensity, and Probability estimates • Prevalence, Odds Ratios, & Relative Risk Estimates • All of the above plus Significant Clustering Areas
	ESDA 4. Scan Statistics • Spatial Scan Statistics	**Used to Detect Outbreaks through Spatial Cluster Analysis** • changes in Cluster Size, Significance, & Relative Risk (RR) in a given area
	ESDA 5. Spatial Autocorrelation (SA) **5.2 Local SA Analyses** • *Getis-Ord Local G* (G_i^*) • *Local Moran's I* (I_i)	**Whether or Not Clustering is Present** **Whether or not SA is present, & if so Where is it Occurring** • Identifies where "high" or "low" values cluster spatially • Identifies the locations of high & low clusters, as well as spatial outliers
(3) Disease Modeling, Prediction, & Ecological Analysis	**ESDA 4. Scan Statistics** • Space-Time Scan Statistics • Temporal Scan Statistics	**Used to Detect Outbreaks through Temporal Cluster Analysis** • changes in Cluster Size, Significance, & RR in a given area over time • changes in Cluster Size, Significance, & RR in over a specified time period
	ESDA 6. Spatial Regression Analyses (RA) • *Ordinary Least Squares (OLS)* Regression • *Geographically Weighted Regression (GWR)*	**Performs Local RA without assuming Spatial Homogeneity** • OLS results output are used to build the GWR model • Assesses spatial heterogeneity between independent & dependent variables

3 Tiered Approach to Geospatial Coral Epizootiology

- **Tier 1 : Disease Mapping & Visualization**

  spatial methods & visualization techniques used to visualize the spatial distribution of diseased corals through the creation of different types of maps

- **Tier 2 : Detection & Analysis of Disease Clusters**

  spatial methods designed to detect & analyze spatial clusters of diseased individuals

  2_A : General Disease Clustering

  results have no spatial output

  2_B : Specific Disease Clustering

  results have spatial output

- **Tier 3: Disease Modeling, Prediction, & Ecological Analysis**

  spatial methods used to model the relationship between the spatial distribution of diseased corals and other spatial, temporal, and ecological variables, in order to better understand how these variables influence the spatial nature of a given coral disease, test various hypotheses, and possibly even predict future disease outbreaks

Global vs. Local Statistics

- **General Disease Clustering** methods use **Global Statistics** to detect & analyze the "overall clustering tendency of the disease incidence in a study region"

- **Specific Disease Clustering** methods use **Local Statistics** to detect & analyze the locations of *specific* disease clusters within the study region

Global Spatial Statistics	Local Spatial Statistics
Used to emphasize the similarities over space	Used to emphasize the differences over space
Used to search for region-wide trends	Used to search for local exceptions
Spatial distribution is assumed to be homogeneous	Spatial distribution is assumed to be heterogeneous
Results are often non-spatial	Results contain spatial output
Results are usually single-valued statistics	Results are usually multi-value statistics

Part III

Appling the Geospatial Protocol to coral disease data

OPEN ACCESS Freely available online

PLoS one

Evaluating Patterns of a White-Band Disease (WBD) Outbreak in *Acropora palmata* Using Spatial Analysis: A Comparison of Transect and Colony Clustering

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Abstract

Background: Despite being one of the first documented, there is little known of the causative agent or environmental stressors that promote white-band disease (WBD), a major disease of Caribbean *Acropora palmata*. Likewise, there is little known about the spatiality of outbreaks. We examined the spatial patterns of WBD during a 2004 outbreak at Buck Island Reef National Monument in the US Virgin Islands.

Methodology/Principal Findings: Ripley's K statistic was used to measure spatial dependence of WBD across scales. Localized clusters of WBD were identified using the DMAP spatial filtering technique. Statistics were calculated for colony- (number of *A. palmata* colonies with and without WBD within each transect) and transect-level (presence/absence of WBD within transects) data to evaluate differences in spatial patterns at each resolution of coral sampling. The Ripley's K plots suggest WBD does cluster within the study area, and approached statistical significance ($p = 0.1$) at spatial scales of 1100 m or less. Comparisons of DMAP results suggest the transect-level overestimated the prevalence and spatial extent of the outbreak. In contrast, more realistic prevalence estimates and spatial patterns were found by weighting each transect by the number of individual *A. palmata* colonies with and without WBD.

Conclusions: As the search for causation continues, surveillance and proper documentation of the spatial patterns may inform etiology, and at the same time assist reef managers in allocating resources to tracking the disease. Our results indicate that the spatial scale of data collected can drastically affect the calculation of prevalence and spatial distribution of WBD outbreaks. Specifically, we illustrate that higher resolution sampling resulted in more realistic disease estimates. This should assist in selecting appropriate sampling designs for future outbreak investigations. The spatial techniques used here can be used to facilitate other coral disease studies, as well as, improve reef conservation and management.

Citation: Lentz JA, Blackburn JK, Curtis AJ (2011) Evaluating Patterns of a White-Band Disease (WBD) Outbreak in *Acropora palmata* Using Spatial Analysis: A Comparison of Transect and Colony Clustering. PLoS ONE 6(7): e21830. doi:10.1371/journal.pone.0021830

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Competing Interests: The authors have declared that no competing interests exist.

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Introduction

Over the past three decades, the incidence of coral disease has increased from sparse, localized sightings, to an apparent panzootic, as disease sightings have become commonplace among the world's reef systems. Since the first documented cases of coral disease in the late 1960s and early 1970s [1–4], scientists have been working to identify causes of these diseases [5,6]; however, progress has been slowed by the complexity of coral ecosystems and anthropogenic influences on these systems [5–15]. Given the corresponding increase in human population pressure during this time period, it has been suggested that anthropogenic related stressors are contributing to, if not directly causing, coral disease outbreaks [5,9,16–23]. While correlations between anthropogenic stressors and disease frequencies have been seen for quite some time [15,17,24–27], it was only recently that direct experimental evidence was able to actually show how anthropogenic stress factors (such as climate change, water pollution, and overfishing) were directly contributing to coral disease [6,26,28,29].

While coral diseases are occurring globally, their incidence appears to be the most severe in the Caribbean [9,11,12,26,30–39]. Over the past few decades reports show that disease is responsible for a roughly 80% loss in Caribbean coral cover [24,40,41]. Within the Caribbean, the *Acropora* coral genus appears to have been the hardest hit by disease, with *A. palmata* showing a 90–95% decline [12,42–44] and *A. cervicornis* populations collapsing across the region [41,42,45,46], causing them to be the first corals in history to be listed as "threatened" under the United States Endangered Species Act.

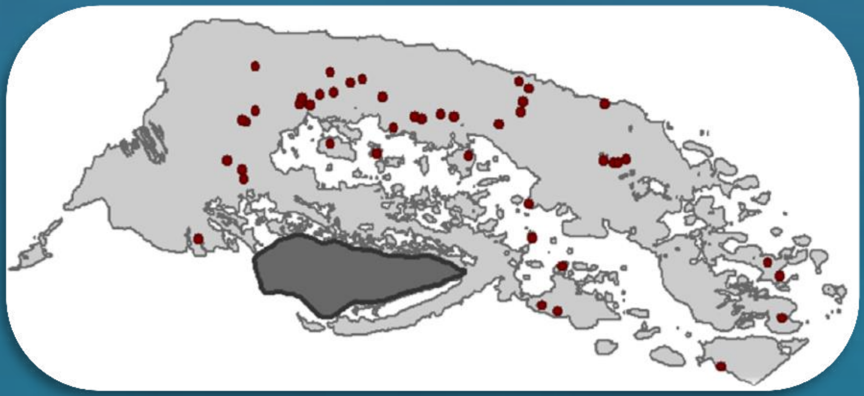
In 1977, shortly after the first documented coral disease, black-band disease (BBD) [1,2], a second "band" disease was also discovered in the Caribbean [3,44]. This new white-band disease

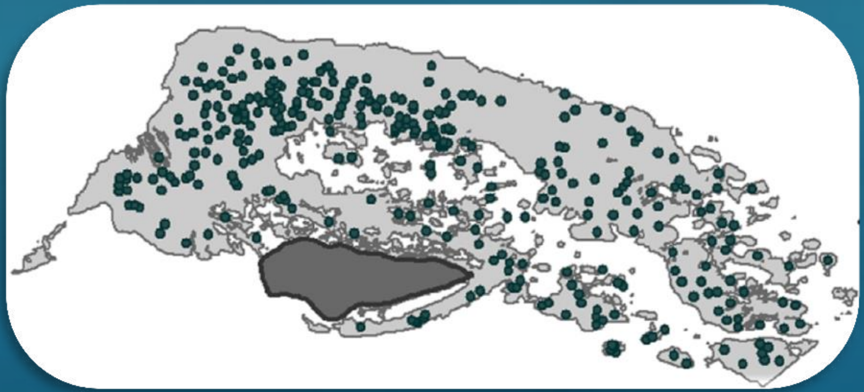
the material presented in this section was published earlier this year in *PLoS one*

Lentz JA, Blackburn JK, Curtis AJ (2011) Evaluating Patterns of a White-Band Disease (WBD) Outbreak in *Acropora palmata* Using Spatial Analysis: A Comparison of Transect and Colony Clustering. *PLoS one* 6 : e21830

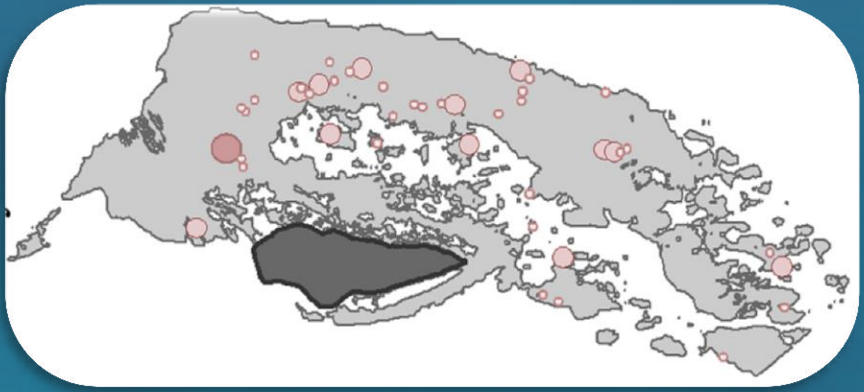
Tier 1 : Disease Mapping & Visualization

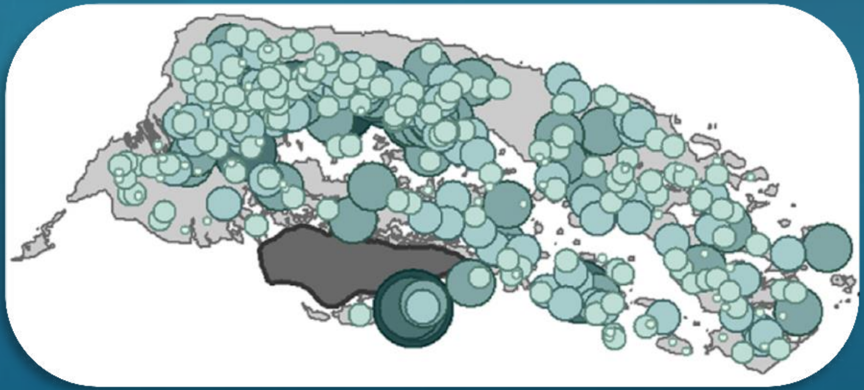
Transect – Level





Colony – Level





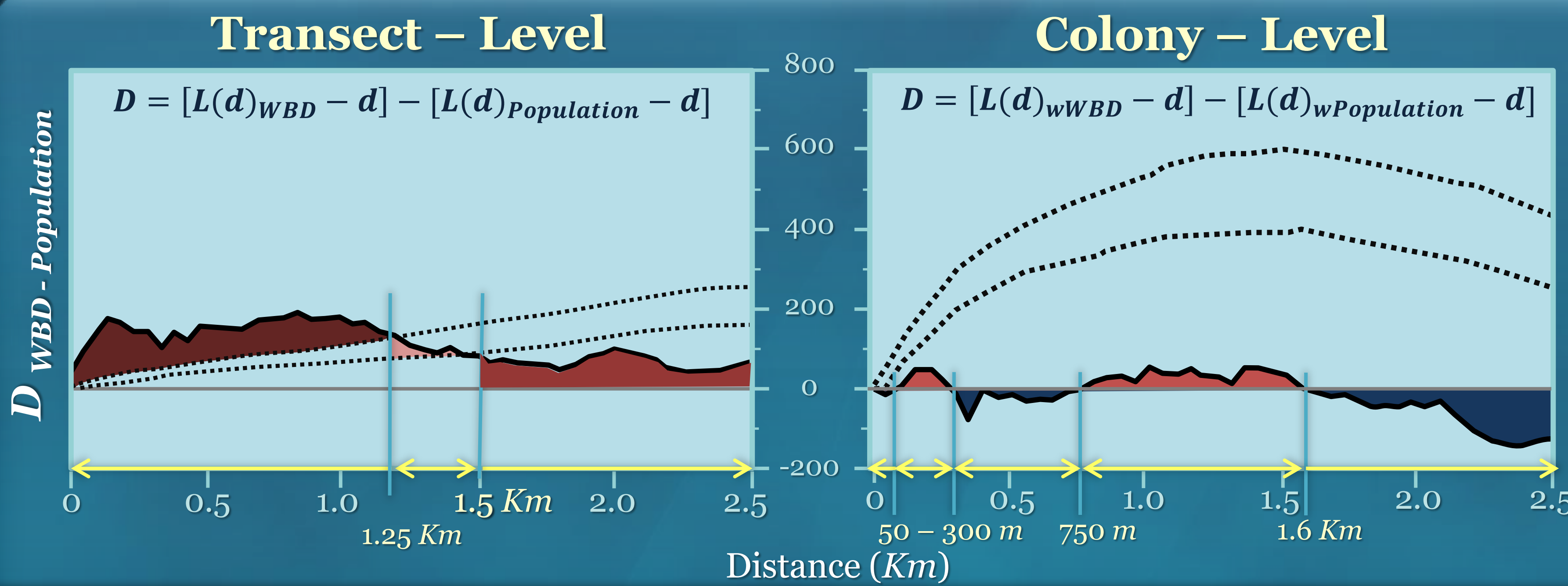
44 Total *A. palmata* transects **with** WBD
\+ **331** Total *A. palmata* transects **without** WBD

375 Total *A. palmata* transects

69 Total *A. palmata* colonies **with** WBD
\+ **2,423** Total *A. palmata* colonies **without** WBD

2,492 Total *A. palmata* colonies

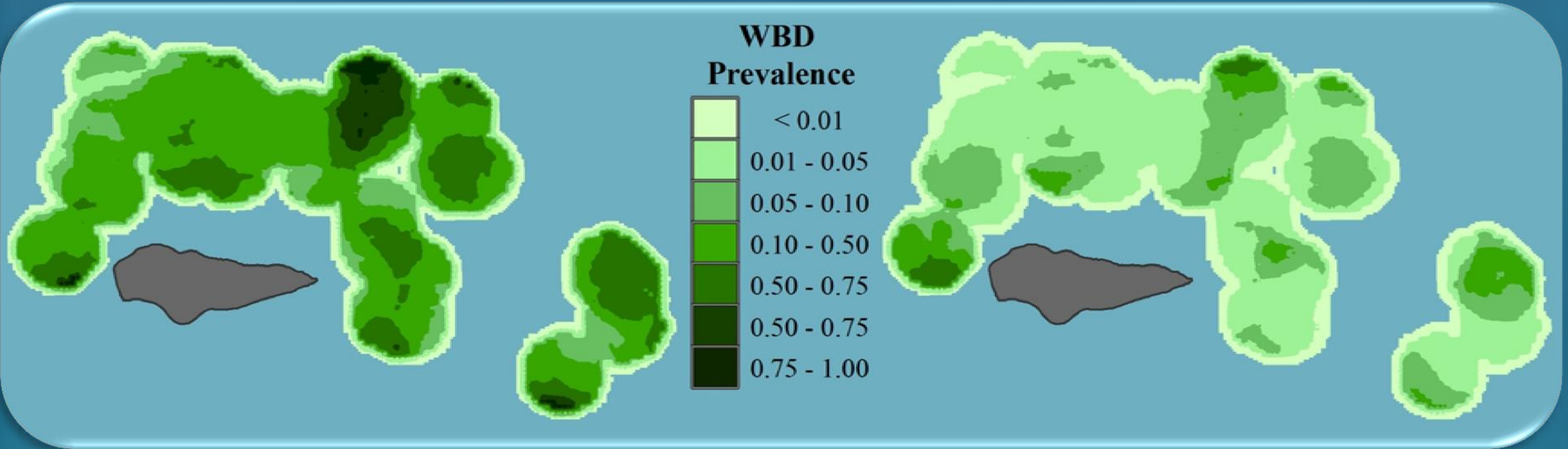
Ripley's K Analysis



- Normalized *Expected K* values (aka the "Poisson Distribution" or "CSR")
- 99% Confidence Intervals (CI) based on the normalized *Observed K* values for the **Population**
- *D* = (normalized *Observed K* for WBD) – (normalized *Observed K* for the **underlying Population**)
- **WBD** is significantly **More clustered** than the **clustered** distribution of the underlying population
- **Clustered** distributions of WBD and the **underlying Population** are not significantly different
- WBD is **significantly Less Clustered** than the **Clustered underlying Population**
- The spatial distribution of WBD is **significantly Dispersed**

DMAP’s Dual Kernel Analysis

Transect – Level **Colony – Level**

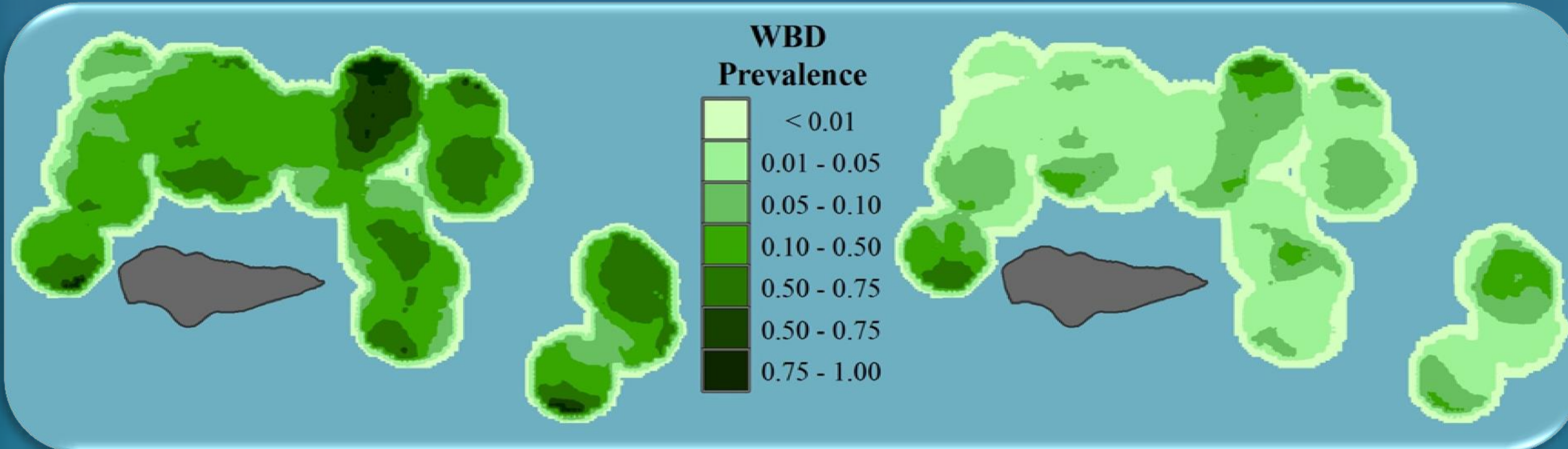


Total Surface Area with **WBD** Prevalence Estimates greater than zero was the **<u>same</u>** for both the **Transect** & **Colony-Level** analyses

However…

DMAP's Dual Kernel Analysis

Transect – Level | **Colony – Level**



Transect – Level

- **<u>High</u> WBD Prevalence Estimates**

$$\frac{\textbf{44 Transects with WBD}}{\textbf{375 Total Transects}} = 11.7\overline{3}\%$$

- Suggesting that **WBD** was present in **> 10%** of the *Acropora palmata* population
- Thus, the **disease surface** produced by the **Transect-Level** analysis indicates that the 2004 WBD outbreak was **<u>quite</u> severe**

Colony – Level

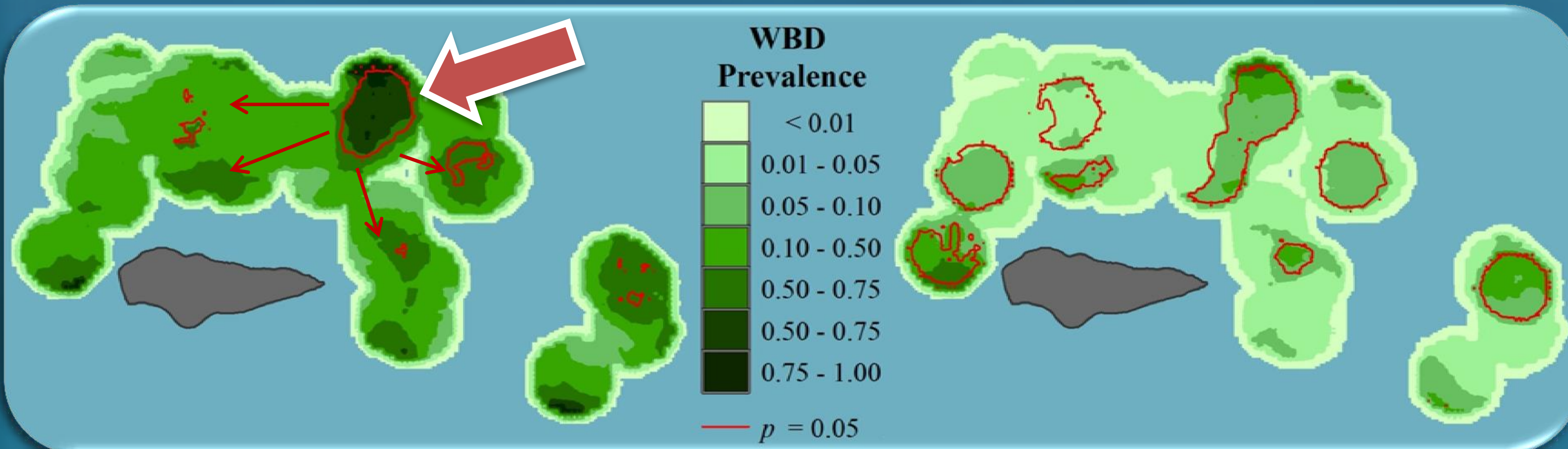
- **<u>Low</u> WBD Prevalence Estimates**

$$\frac{\textbf{69 Colonies with WBD}}{\textbf{2,492 Total } \textit{Colonies}} = 2.77\%$$

- Suggesting that **WBD** was present in **< 3%** of the *Acropora palmata* population
- Thus, the **disease surface** produced by the **Colony-Level** analysis indicates that the 2004 WBD outbreak **much <u>less</u> severe**

DMAP's Dual Kernel Analysis

Transect – Level | **Colony – Level**

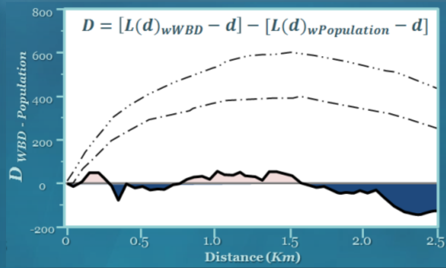


- **1 main area** with **significant** WBD prevalence
  - which also had the highest WBD prevalence
- The presence of a "**Primary Cluster**" suggests …
  - this may be the **origin** of the WBD outbreak
  - could be caused by a point-source contaminant
  - WBD is likely contagious

    spreading out from this primary cluster

- **8 areas** with **significant** WBD prevalence
  - located in areas with high & low WBD prevalence
  - distributed throughout the WBD prevalence area
  - significant clusters were fairly large in size (area)
  - this WBD outbreak appears to be a **chronic**
  - likely caused by a **ubiquitous stressor**

Implications & Importance of Results



- areas of significant disease clustering might indicate the presence of locally aggregated stress factors → surrounding corals more vulnerable to infection
    - By knowing where these clusters are occurring this hypothesis can actually be tested
- The low prevalence of WBD among *A. palmata* colonies, combined with the fairly random spatial distribution of WBD colonies, might indicate that the disease is caused by either air and/or water-born direct transmission of the causative disease agent from a terrestrial point of origin (Jolles et al. 2002)
- In addition, the dispersed WBD distributions might also indicate that the clustered coral population may offer protection from disease by providing physical barriers to the disease agents or toxins (Foley et al. 2005).

Part IV

Discussion

Limited by the Availability of Robust Datasets

Limited by the Availability of Robust Datasets

http://coraldisease.org/

coral disease mapping

http://development.unep-wcmc.org/GIS/coraldis/searchForm.cfm

REEFBASE

http://reefbase.org/

Designed to compile "information on the global distribution of coral diseases to contribute to the understanding of coral disease prevalence"

http://coraldisease.org/

The types of information they collect are NOT conducive to any type of accurate or meaningful spatial epidemiological analysis

- NO information is provided on the scale of the analysis (i.e. country, site, transect, colony, etc.)
- ONLY collect data on disease presence

Prevalence = "# of existing diseased cases in a given population over a specific period of time"

Limited by the Availability of Robust Datasets

Designed to compile "information on the global distribution of coral diseases to contribute to the understanding of coral disease prevalence"

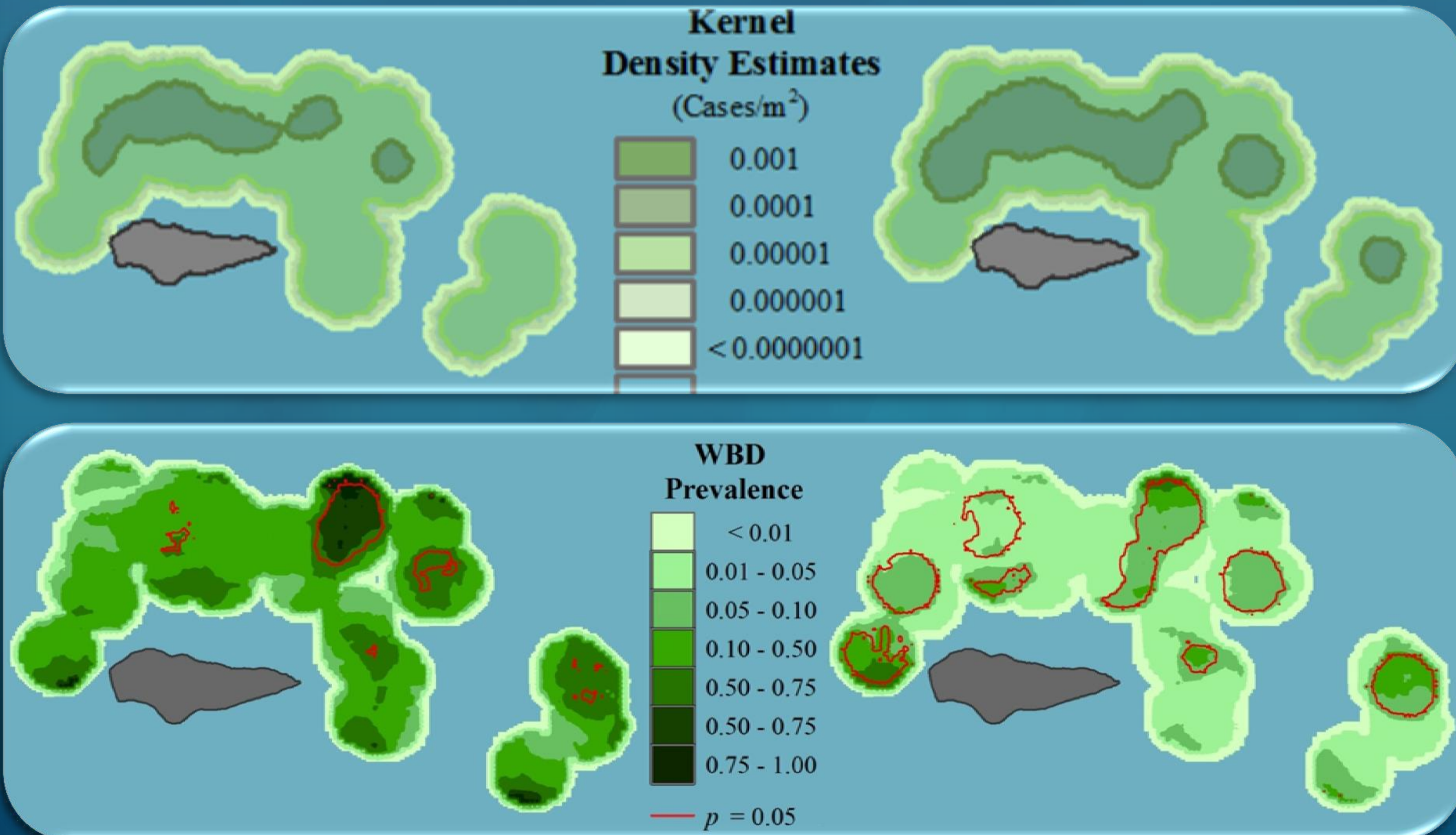
http://coraldisease.org/

Searched for records of Diseased *Acropora* in the Caribbean Between 1950 & 2012

Results showed a total of 9 disease counts & they were all in 2009

Single KDE of WBD vs. dual KDE of WBD/Population

Transect – Level | **Colony – Level**



Atlantic & Gulf Rapid Reef Assessment (AGRRA)

AGRRA

Atlantic and Gulf Rapid Reef Assessment

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The AGRRA
Rapid Assessment Protocol



• AGRRA Overview	
• **The AGRRA Protocols** Version 5.4, 2010	download in PDF format
• Fish and Coral Identification Aids (Training Materials)	
• AGRRA data sheets	download in Excel format

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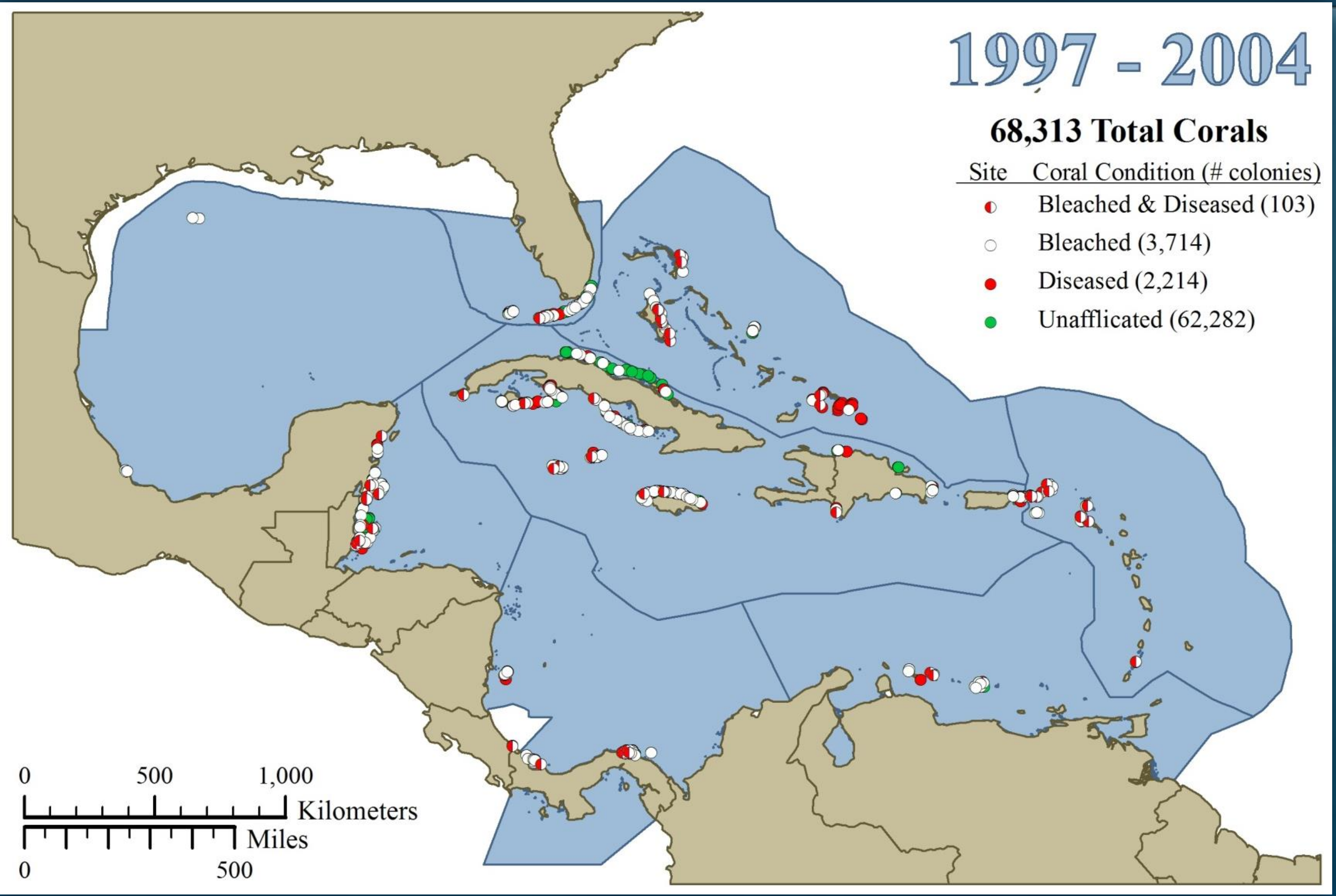
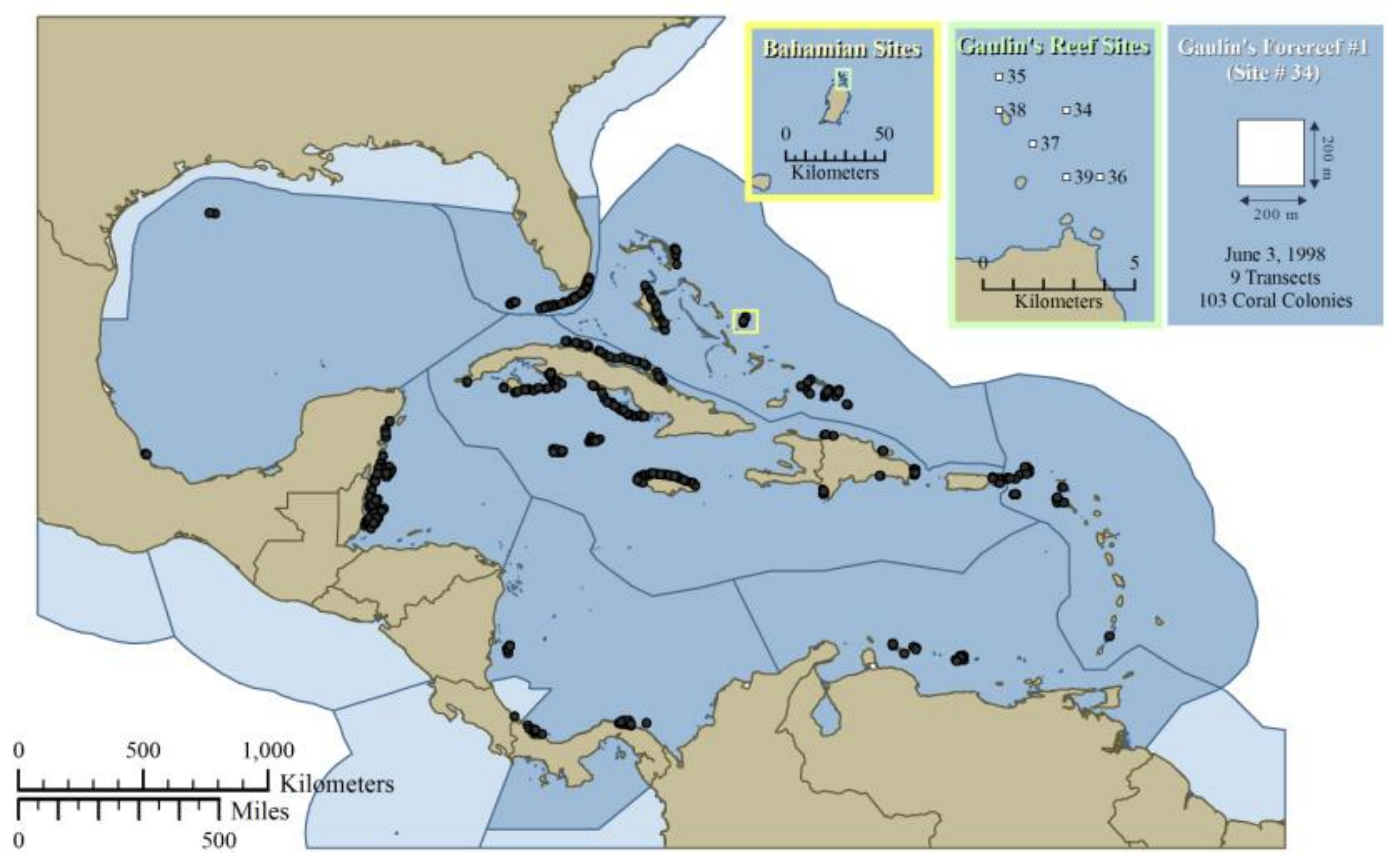
Atlantic & Gulf Rapid Reef Assessment (AGRRA)



Atlantic & Gulf Rapid Reef Assessment (AGRRA)



Part V

Summary & Conclusions

Summary & Conclusions

- Locations of significant clusters could be used to guide Microbial analyses

- Study the spatio-temporal changes in coral health

- Compare spatial distributions of different diseases at the same location

- Provide marine resource managers with information on the most vulnerable areas of the reefs

Geospatial Analysis of Corals

The use of GIS and
Spatial Analytical Methods
can provide researchers with
powerful tools that have the
potential to greatly improve our
current understanding of
Coral Epizootiology

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NOTE

Philippe A. Mayor · Caroline S. Rogers
Zandy M. Hillis-Starr

Distribution and abundance of elkhorn coral, *Acropora palmata*, and prevalence of white-band disease at Buck Island Reef National Monument, St. Croix, US Virgin Islands

Received: 29 September 2005 / Accepted: 7 January 2006 / Published online: 7 March 2006

Abstract In the 1970s and 1980s elkhorn coral, *Acropora palmata*, declined dramatically throughout the Caribbean primarily due to white-band disease (WBD). In 2005, elkhorn coral was proposed for listing as threatened under the US Endangered Species Act. WBD was first documented at Buck Island Reef National Monument (BIRNM). Together with hurricanes WBD reduced live elkhorn coral coverage by probably over 90%. In the past decade some recovery has been observed at BIRNM. This study assessed the distribution and abundance of elkhorn coral and estimated the prevalence of WBD at the monument. Within an area of 795 ha, we estimated 97,232 134,371 (95% confidence limits) elkhorn coral colonies with any dimension of connected live tissue greater than one meter, about 3% of which were infected by WBD. Despite some recovery, the elkhorn coral density remains low and WBD may continue to present a threat to the elkhorn coral population.

Keywords *Acropora palmata* · Buck Island Reef National Monument · Elkhorn coral · US Virgin Islands · White-band disease

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Introduction

Elkhorn coral, *Acropora palmata*, is a major reef-building species and was the dominant coral in wave-exposed and high-surge reef zones throughout the Caribbean prior to the 1970s (Adey and Burke 1976). In the 1970s and 1980s elkhorn coral drastically declined primarily due to a bacterial syndrome called white-band disease (WBD) (Aronson and Precht 2001; *Acropora* Biological Review Team 2005). In the past two decades, mortality from disease has been compounded by hurricanes, bleaching events, and outbreaks of predators (Bruckner 2002), and elkhorn coral was proposed for listing as threatened under the US Endangered Species Act of 1973 (Oliver 2005).

Buck Island Reef National Monument (BIRNM), located 1.5 km to the northeast of St. Croix, US Virgin Islands, was created in 1961 to preserve a unique elkhorn coral barrier reef surrounding Buck Island. In 2001, it was expanded from 356 to 7,695 ha and all extractive uses have been prohibited. In the early 1970s, the first signs of WBD were noted by US National Park Service (NPS) staff (NPS reports, unpublished). Gladfelter et al. (1977) determined prevalence levels at about 3%, where prevalence is defined as the number of cases of a disease in a population at a specific time (Stedman 2000). At that time, the crest and forereef of Buck Island's barrier reef was composed of greater than 50% live elkhorn coral. Subsequently, WBD spread, and together with hurricanes reduced live elkhorn coral coverage by probably over 90%, leaving vast areas of dead standing colonies (Anderson et al. 1986; Bythell et al. 1989; Rogers et al. 2002). Within the past 10 years, some recovery has been noted at BIRNM, especially along the southeastern barrier reef that was heavily impacted by hurricanes (Z. Hillis-Starr, personal observations).

The objectives of this study were to assess the current elkhorn coral distribution and abundance within the monument boundary and to estimate the prevalence of WBD.