Assessing the Relative Resilience Potential of Coral Reefs to Inform Management in the Northern Mariana Islands

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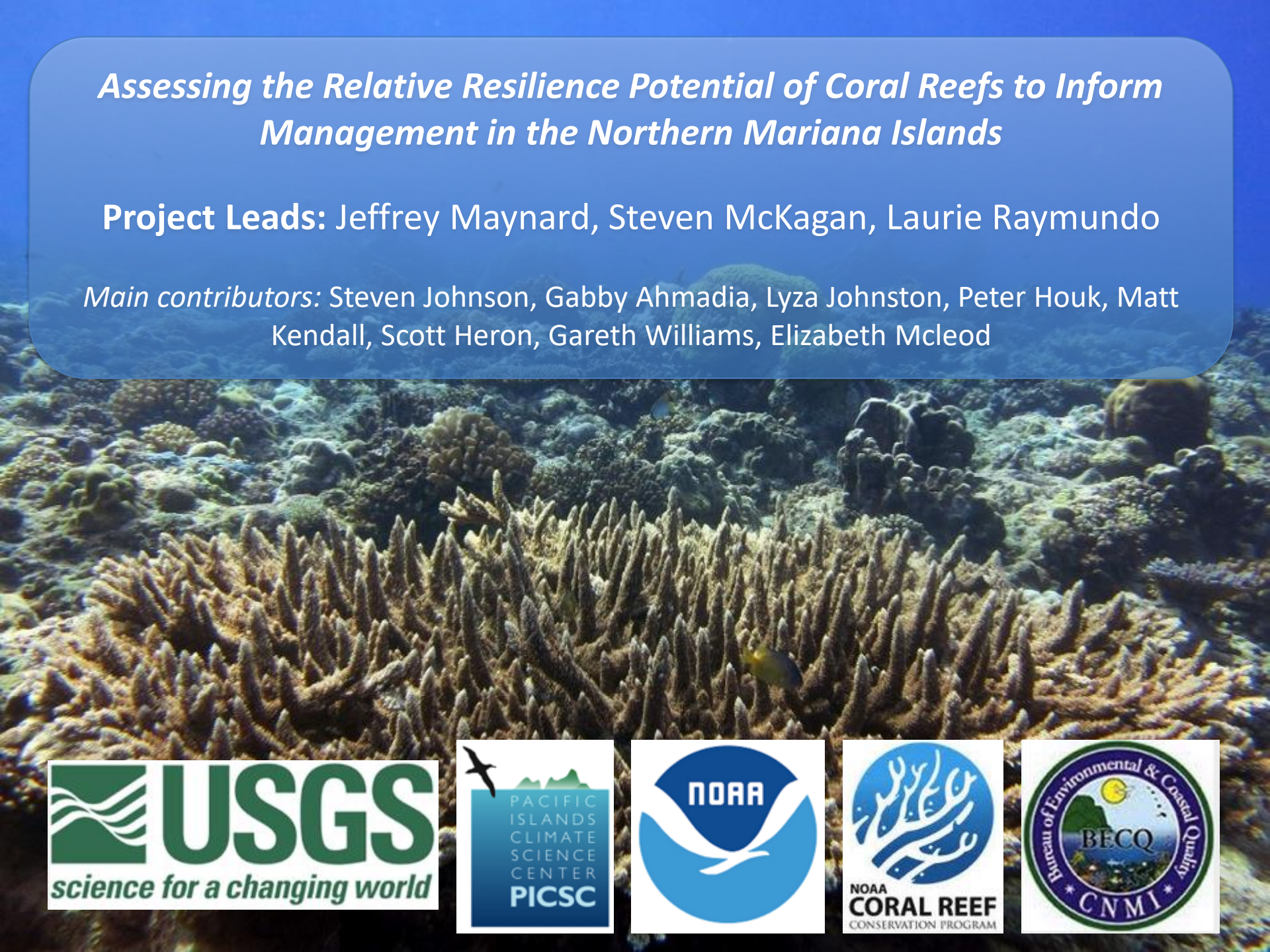
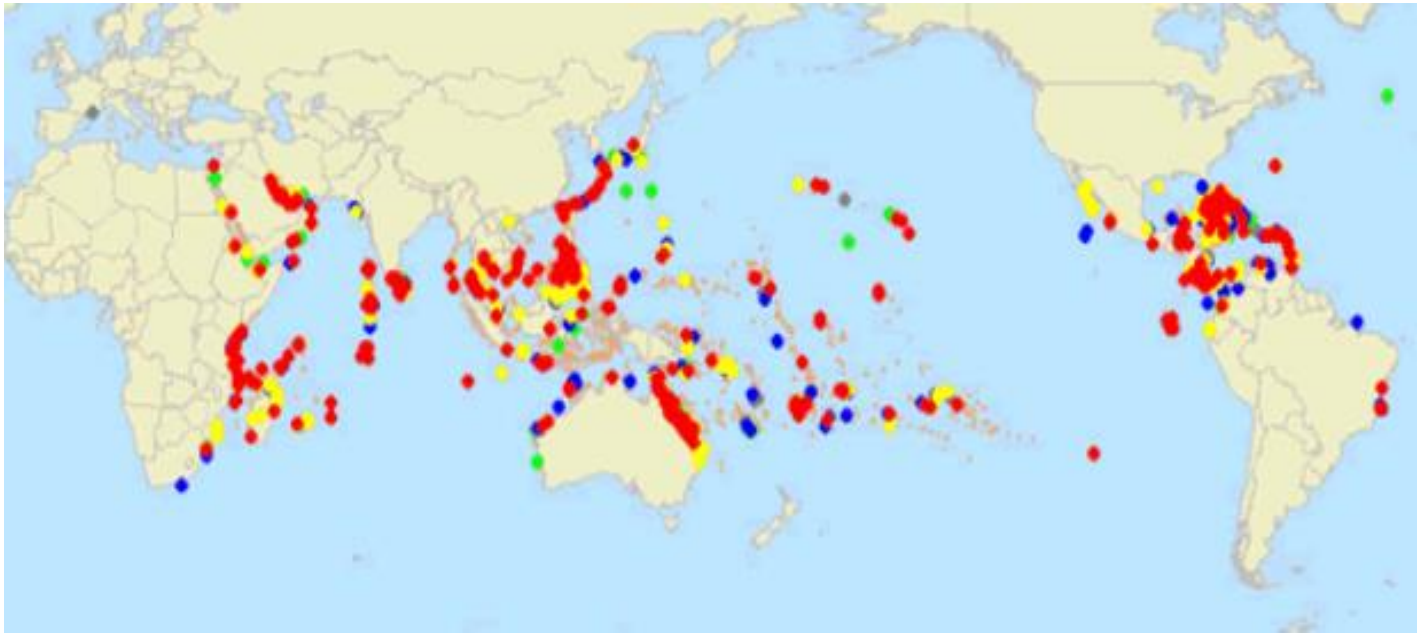


Assessing Resilience

Prior to the early to mid 1980s, bleaching tended to be rare and localized, and corals generally recovered.

There were minor global-scale events in 1987 and 1990.

Then, in 1998…



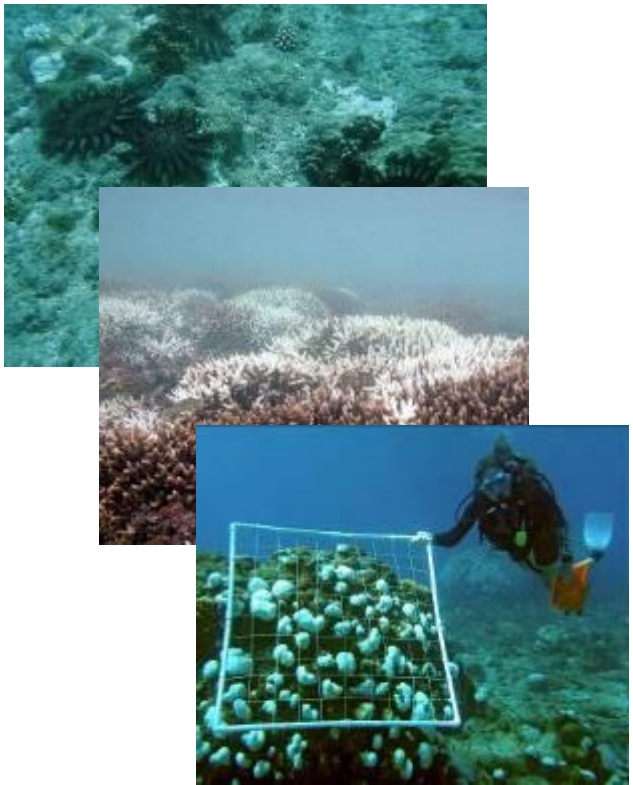
60 countries

Up to 70% mortality

Corals affected as deep as 50 m

16% of the world's corals died

CNMI Bleaching History



Large bleaching event in 2000

- ~ 60-70% mortality

Smaller bleaching event in 2005

- Coincided with large *Acanthaster planci* outbreak

2009 – 2011: NOAA Coral Reef Watch forecasted severe bleaching

- No bleaching thanks to increased rain/cloud cover

Reef sites

Unprecedented coral bleaching across the Marianas Archipelago

In 1998, many reefs around the world experienced severe, widespread bleaching and mortality coinciding with anomalously high sea surface temperatures (SSTs). The Marianas Archipelago was an exception in the Indo-Pacific regionin which SSTs remained withinnormal rangesduring this period (Rayner et al. 2006). Prior to 1998 and during non-El Niño years, surveys across the Marianas reported mild to moderate bleaching (68 % of taxa showed signs of bleaching in 1994; Paulayand Benayahu1999). Since 1998, cumulative evidence from published and anecdotal reports suggests that Marianas reefs have not experienced extensive impacts from coral bleaching over the past two decades (Burdick et al. 2008; P. Houk pers. obs).

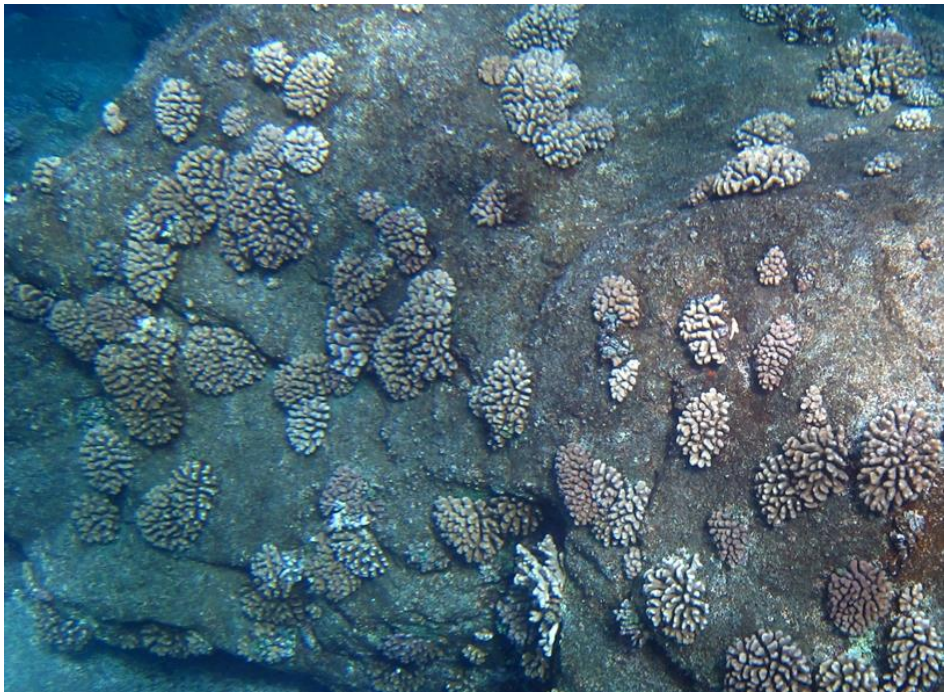
We report the first known severe, widespread bleaching and mortality event across the three largest islands in the lower Marianas Archipelago: Guam, Rota, and Saipan (Fig. 1). In 2013, 85 % of taxa on nearshore reefs showed signs of bleaching. The 2013 bleaching event coincided with local offshore SSTs exceeding the maximum monthly mean by 0.5–1.6 °C, from July 2013 through October 2013, ending after Typhoon Francisco formed southwest of Guam. The National Weather Service monitoring recorded wind speeds −2 m s^{-1} slower than monthly averages in July and August. This produced sustained, low wave energy along the windward (eastern) side of the islands simultaneously with elevated SSTs. As global SSTs continue to increase, reefs worldwide will remain vulnerable to bleaching events. Understanding differential responses among taxa and reefs to better predict bleaching-induced changes is a critical first step to managing for reef resilience and promoting recovery from such events.

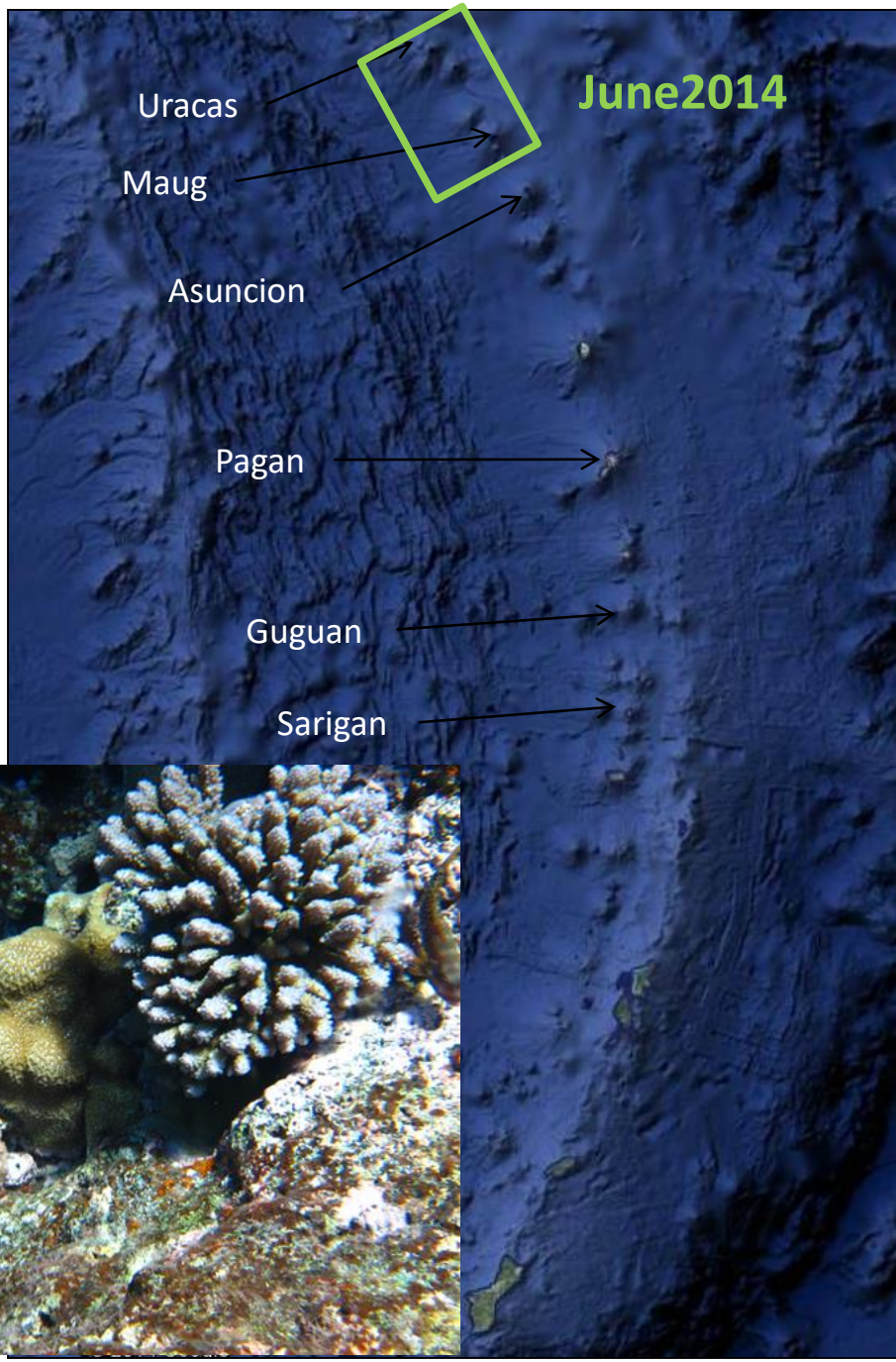
Acknowledgments J. Gault, J. Igud, R. Okano, and J. Miller for field support.

References

Burdick D, Brown V, Asher J, Caballes C, Gawel M, Goldman L, Hall A, Kenyon J, Leberer T, Lundblad E, McIlwain J, Miller J,

2013 bleaching leads to 100% loss in several Saipan Lagoon staghorn beds

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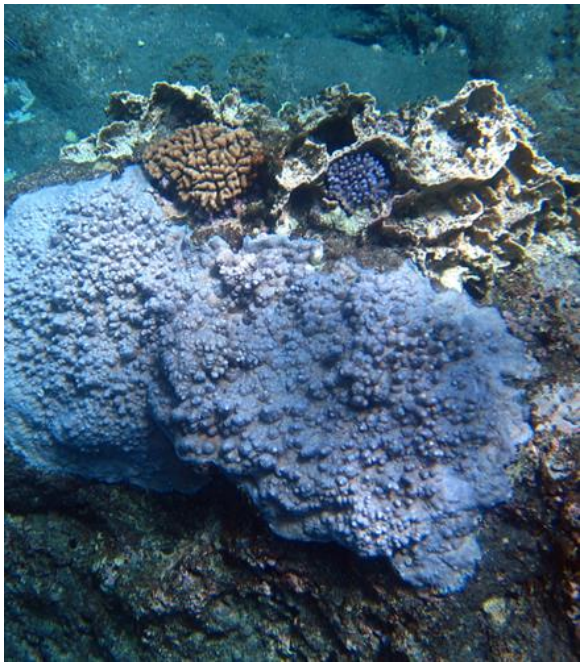

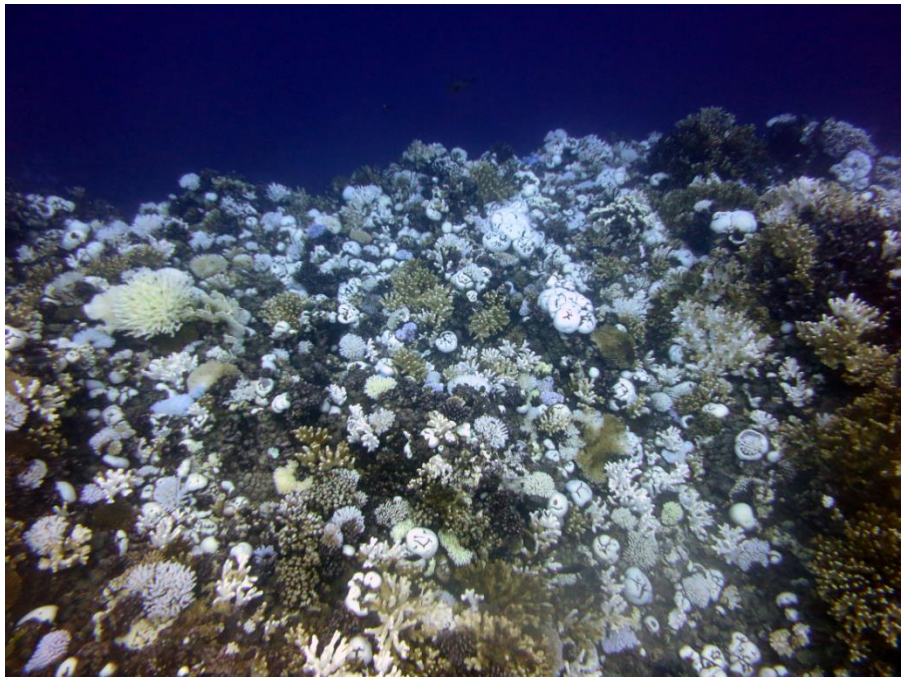

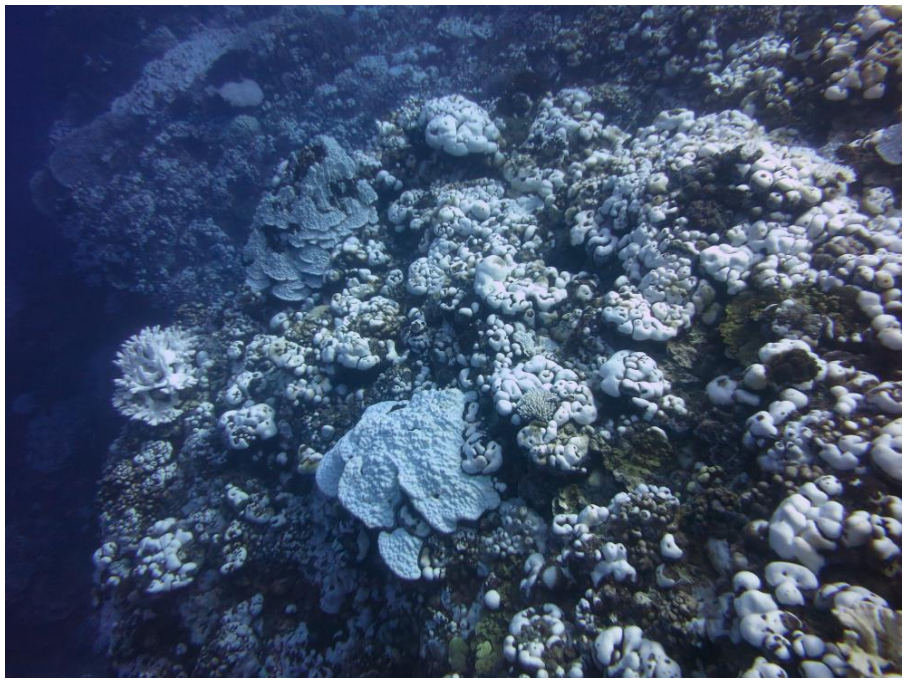

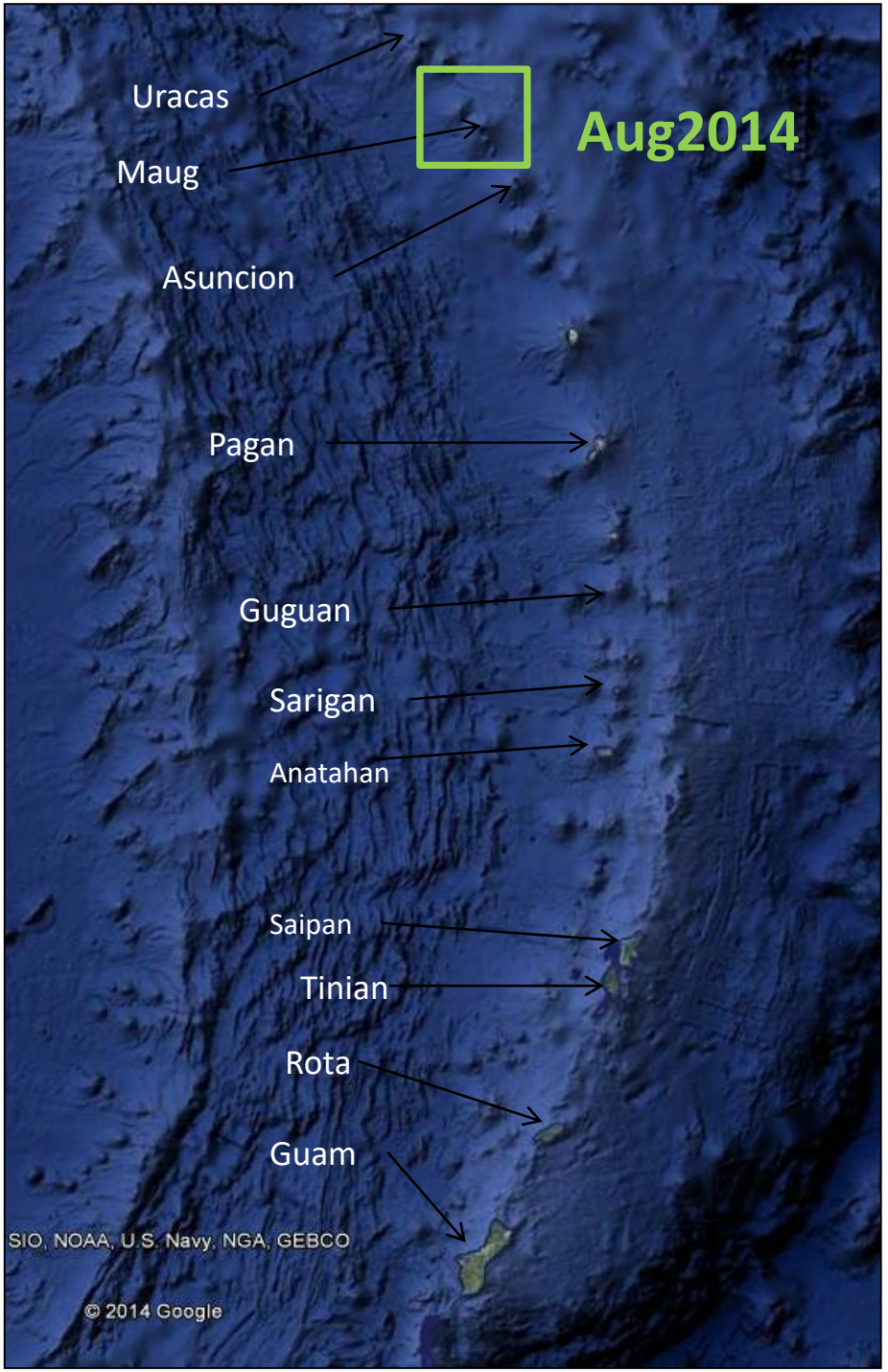
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Anatahan
Saipan
Tinian
Rota
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SIO, NOAA, U.S. Navy, NGA, GEBCO
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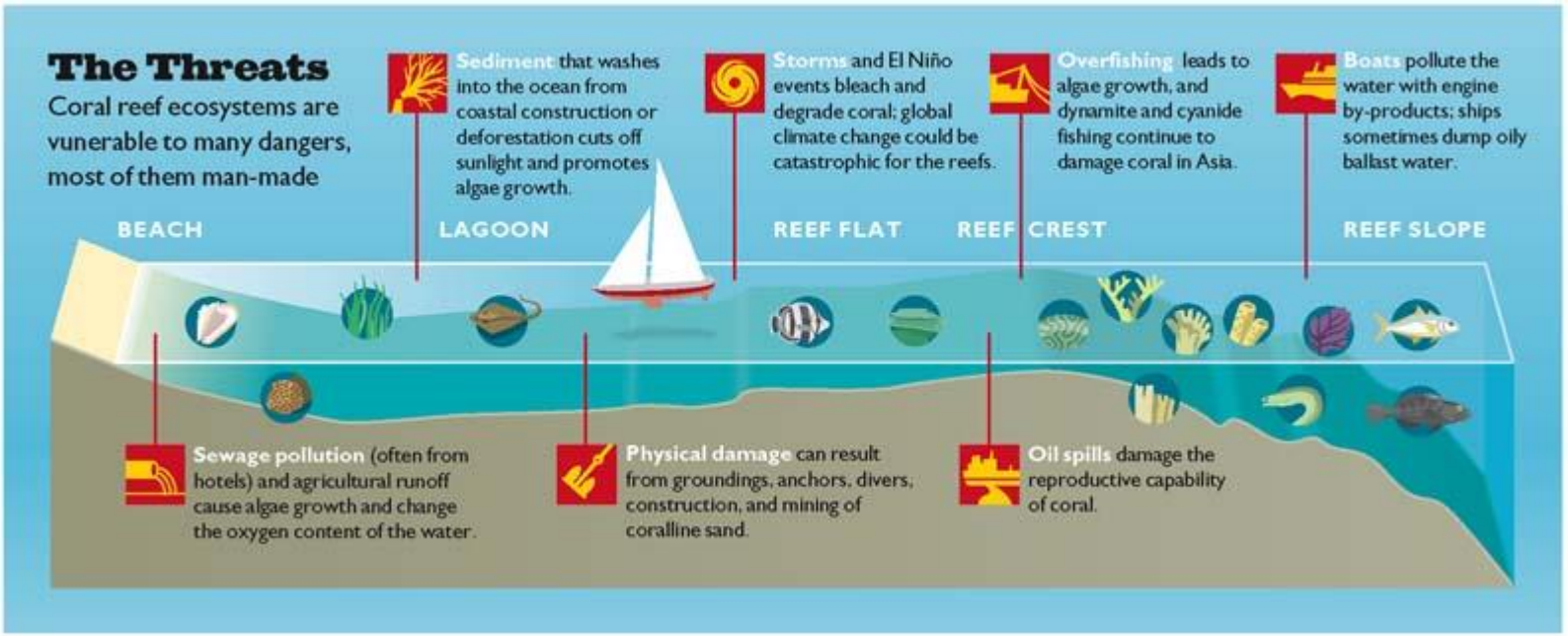
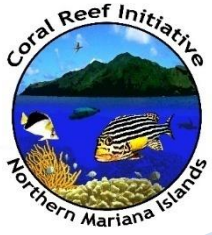
What Can We Do?

- Prioritize management that gives our reefs the best chance to persist (recover & resist)



CNMI Reef Resiliency Project Management



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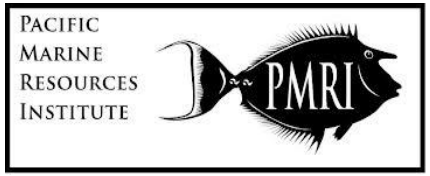


Subcontracted Support
Peter Houk
Coral Ecologist

Prioritizing Key Resilience Indicators to Support Coral Reef Management in a Changing Climate

	Perceived importance (0 to 10)			Scientific evidence (−5 to +5)			Feasibility (0 to 10)
Ecological factor	Resilience	Resistance	Recovery	Resilience	Resistance	Recovery	
(1) Resistant coral species							
(2) Temperature variability							
Stress-resistant symbionts							
(3)Nutrients(pollution)							
(4) Sedimentation							
(5) Coral diversity							
(6) Herbivore biomass							
(7) Physical human impacts **							
(8) Coral disease **							
Tidal mixing							
(9) Macroalgae							
(10) Recruitment							
(11) Fishing pressure							
Herbivore diversity							
Habitat complexity							
Connectivity							
Mature colonies							
Light (stress)							
Coral size class distribution							

Resilience Indicators

(contribute to score)

- Bleaching Resistance
- Temperature Variability
- Coral Diversity
- Herbivore Biomass & Diversity
- Macroalgae Cover
- Coral Recruitment

System Stressors

(Incorporated as Management Queries}

- Sediment and Nutrient Loading
- Fishing Pressure/Access

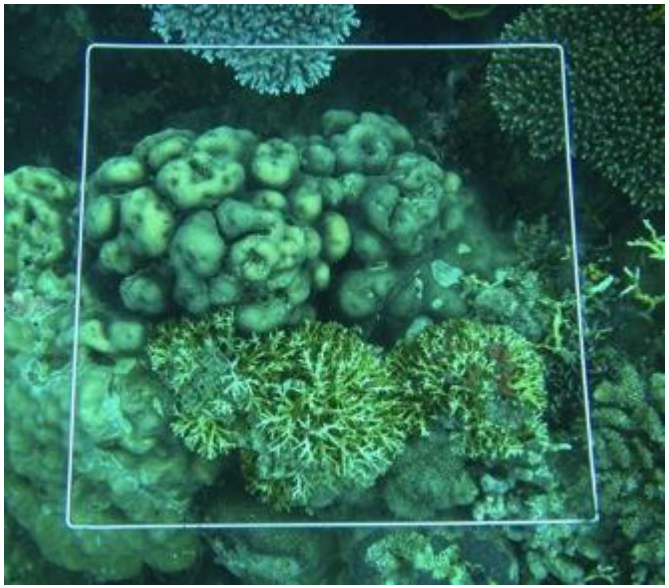
- & Connectivity at Island Scale

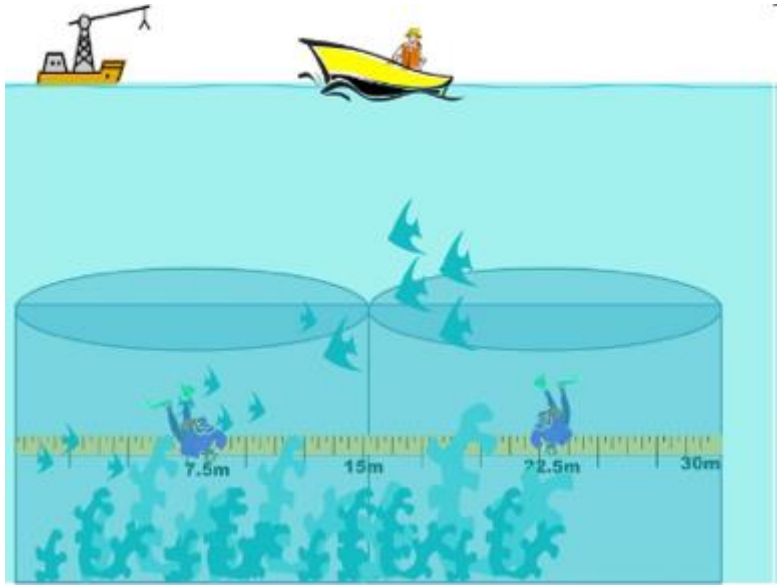
Methods Highlights

78 Forereef sites at ~30ft around Saipan (2012), Tinian and Rota (2014)

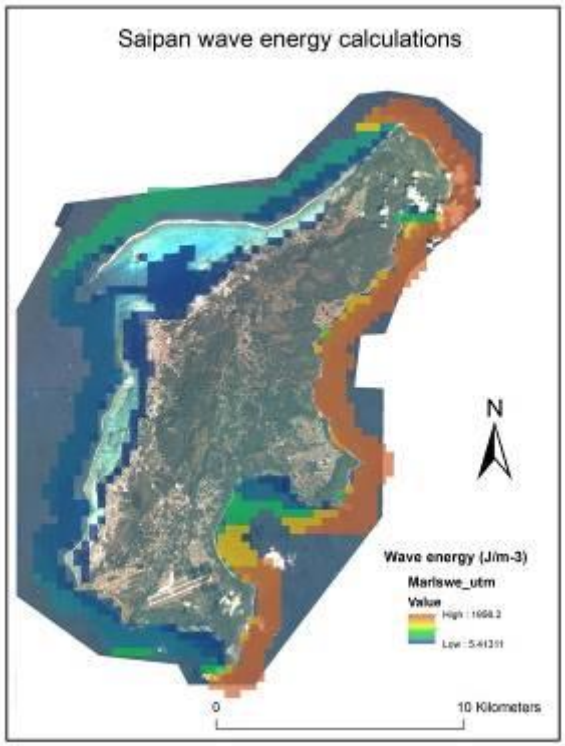
Coral community – 12-16 quarter metre quadrats, measure longest diameter of each coral, point-intercept transects for percent cover [10,000 corals, ~160 species]

Fish community – 9 stationary point counts, 5 meter x 3 minutes, ID to species level for all fish ≥8 cm [>30,000 fish, ~250 species]



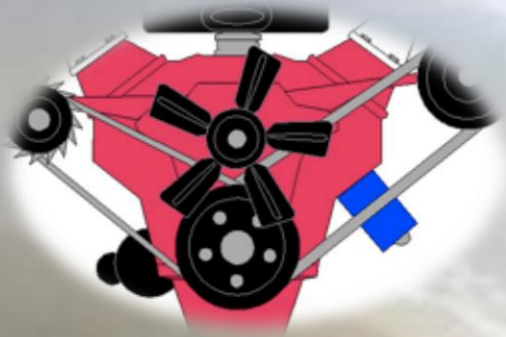


Fishing Access



Several different approaches were considered to establish this metric:

1) Base it off of existing effort data from the creel program and/or night time commercial spear study:
   - Problem, incomplete coverage for 35 sites and/or data unavailable
2) Perform a survey of local fisheries managers regarding pressure:
   - Problem, this is difficult or impossible to duplicate in other locations and introduces bias.
3) Establish access to fishing areas as a function of wind and wave exposure”
   - This approach is a proxy for pressure, but provides relative information for all sites and removes survey issues. MPA’s were set to maximum exposure.

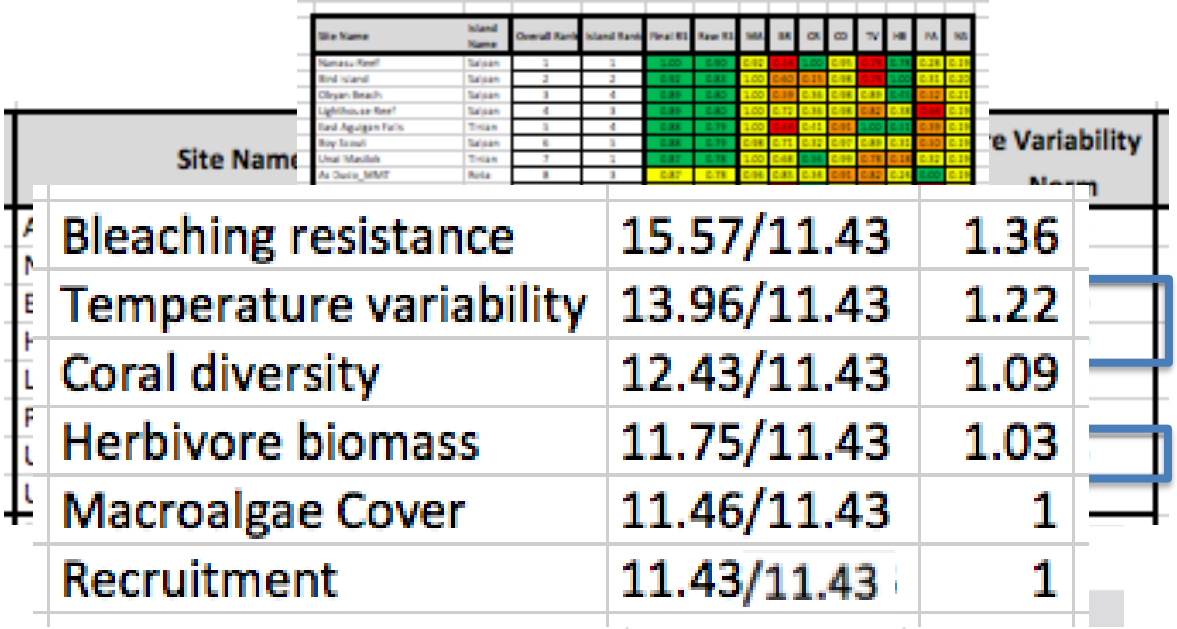


Time for a look under the hood…

Data Analysis

Four steps

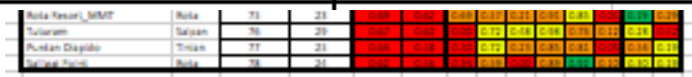
1. Raw data values for all sites normalised by dividing by the max value and standardised to a uni-directional 0-1 scale.
2. Normalised scores are then scaled.
3. Scores are then averaged ***and re-normalised.***
4. Sites are then ranked from highest to lowest score and classified.



Site Name		e Variability Norm
Bleaching resistance	15.57/11.43	1.36
Temperature variability	13.96/11.43	1.22
Coral diversity	12.43/11.43	1.09
Herbivore biomass	11.75/11.43	1.03
Macroalgae Cover	11.46/11.43	1
Recruitment	11.43/11.43	1

Site Name	Final R
Nanasu Reef	1.00
Bird Island	0.92
Obyan Beach	0.89
Lighthouse Reef	0.89
East Aguigan Falls	0.88
Boy Scout	0.88
Unai Masilok	0.87

Site Name	Bleaching Resistance	
	Conv	Norm
Cave Museum_MMT	0.99	0.72
Coconut Village	1.04	0.76
Coral Gardens_MMT	1.31	0.96
Coral Ocean Point	0.70	0.51
Dynasty_MMT	1.20	0.88
East Aguigan Falls	0.60	0.44
East Wedding Cake	1.12	0.82
Elbow Reef	0.87	0.64

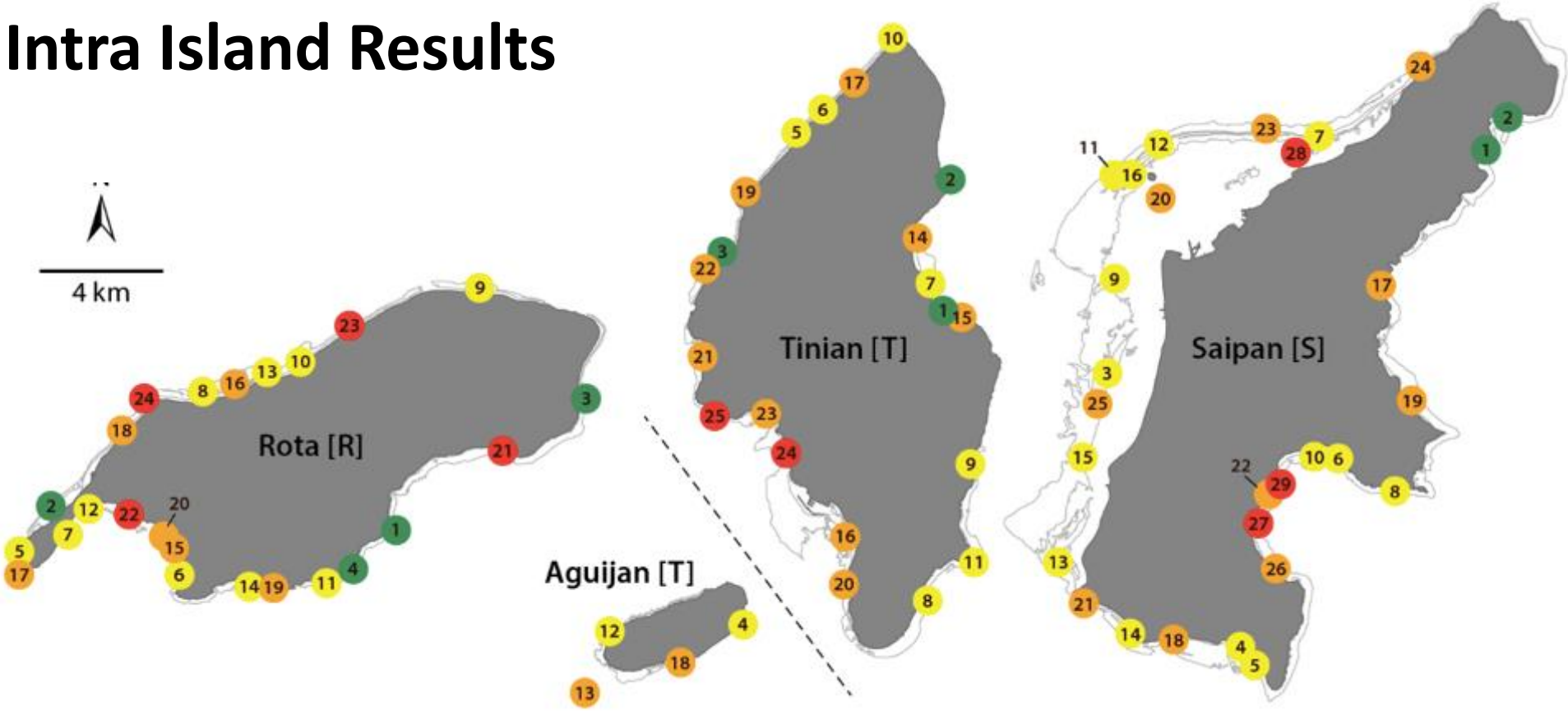


Low (<avg - 1 SD) Med-Low (<avg and >avg - 1 SD) Med-High (>avg and <avg - 1 SD) High (>avg + 1 SD)

Inter Island Results

- Relative resilience potential classes: **7** high, **37** med-high, **24** med-low, **10** low
- All but one of the established MPAs has high or med-high rel. resilience potential
- 5 of the 7 high resilience sites are in Saipan; 7 of the 10 low resilience sites are in Rota

Intra Island Results



Resilience potential most variable at Rota

≥2 high and low resilience sites at all islands

Generally, sites on more exposed sides of the islands (east for S and T and south for R) have higher relative resilience potential

Which indicators most influence the assessment results and site rankings?

Principle Coordinate and Canonical Analysis of Principles

Bleaching resistance	15.57/11.43	1.36
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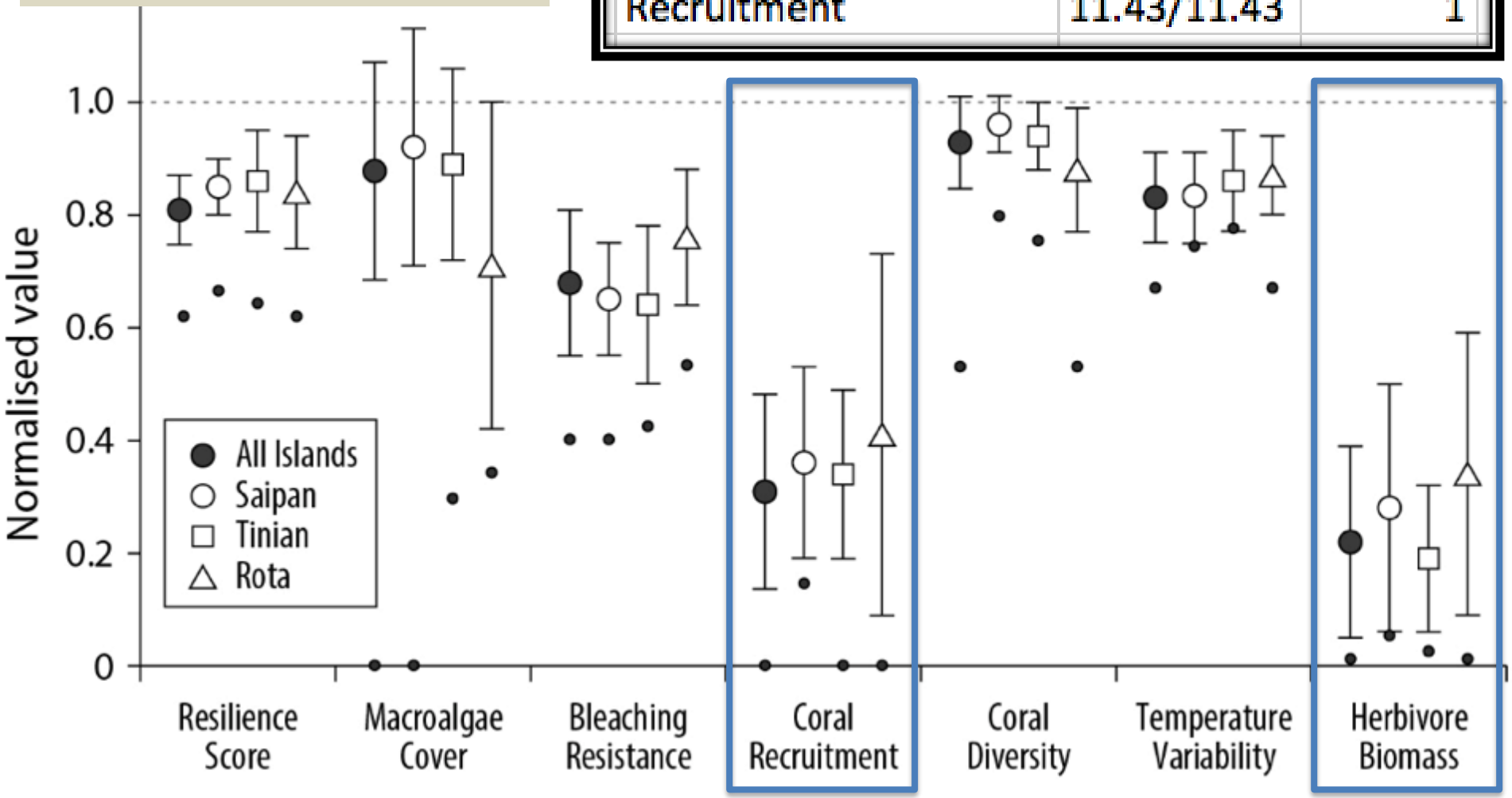
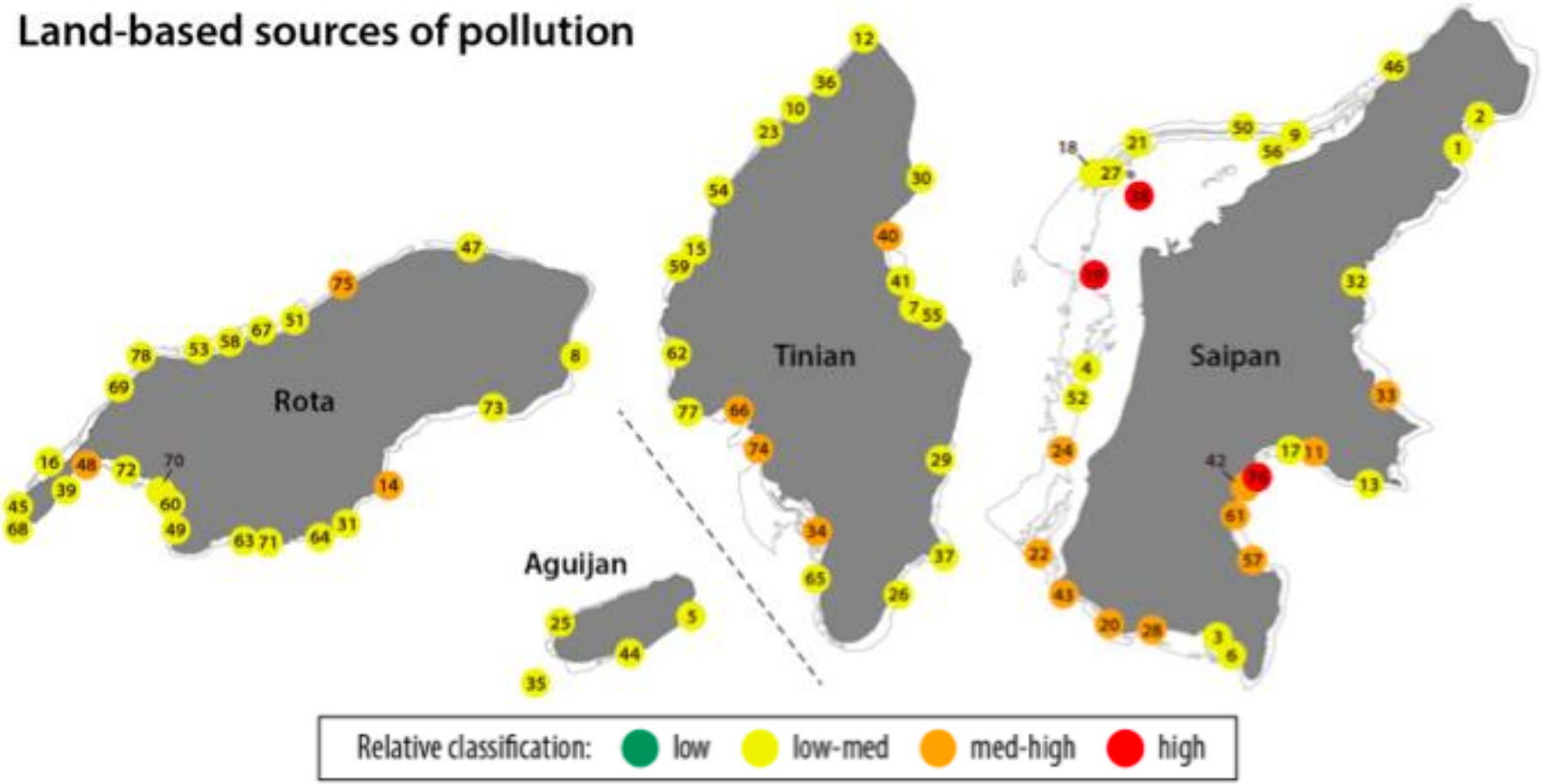
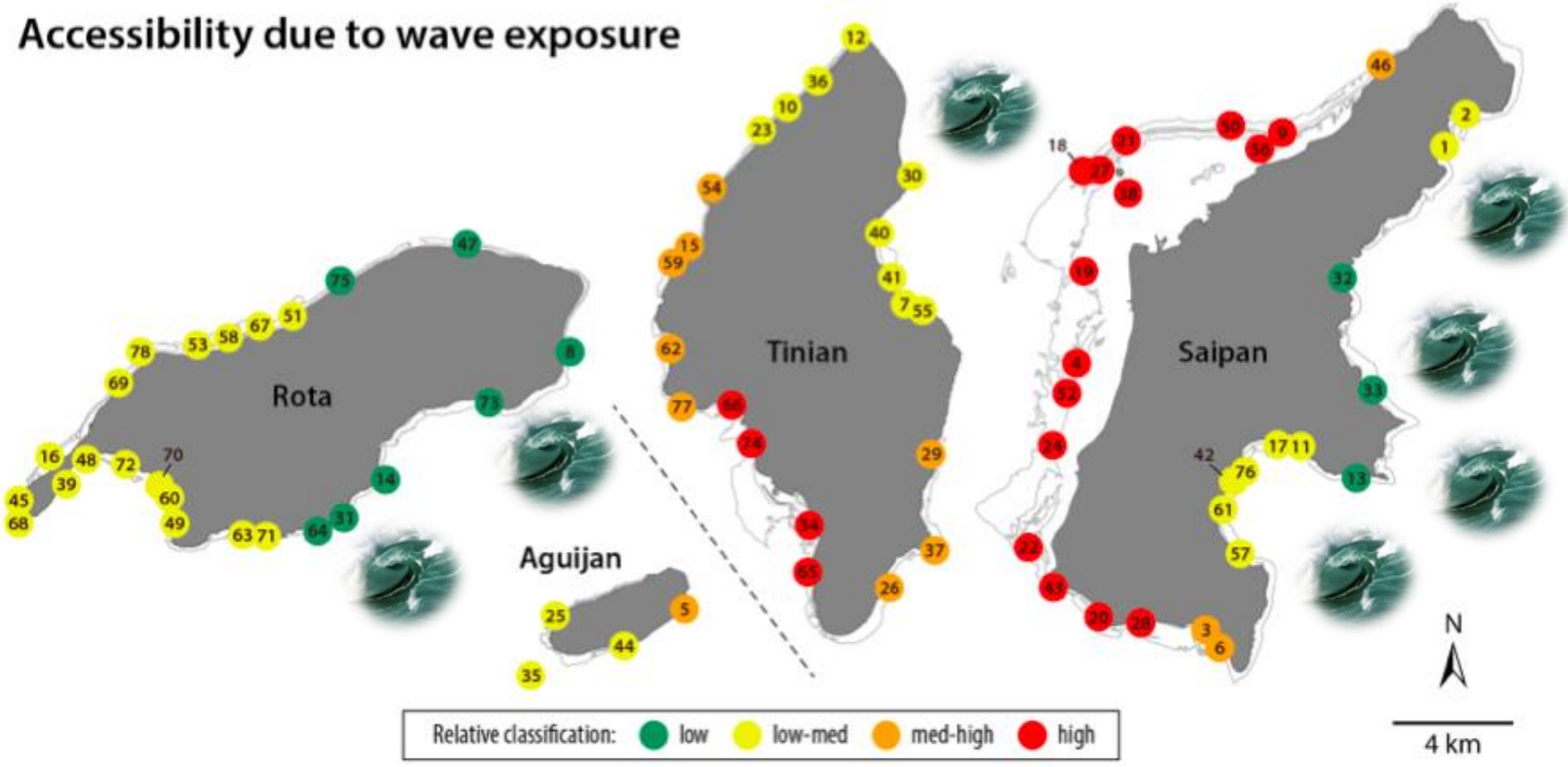


Anthropogenic stressors:
Land-based sources of pollution



Anthropogenic stressors:
Accessibility due to wave exposure
(fishing access)



Targets for:

Conservation
Land-based sources of pollution (LBSP) reduction
Fishery regulations and enforcement
Bleaching monitoring and supporting recovery
Reef restoration/coral translocation
Tourism outreach and stewardship

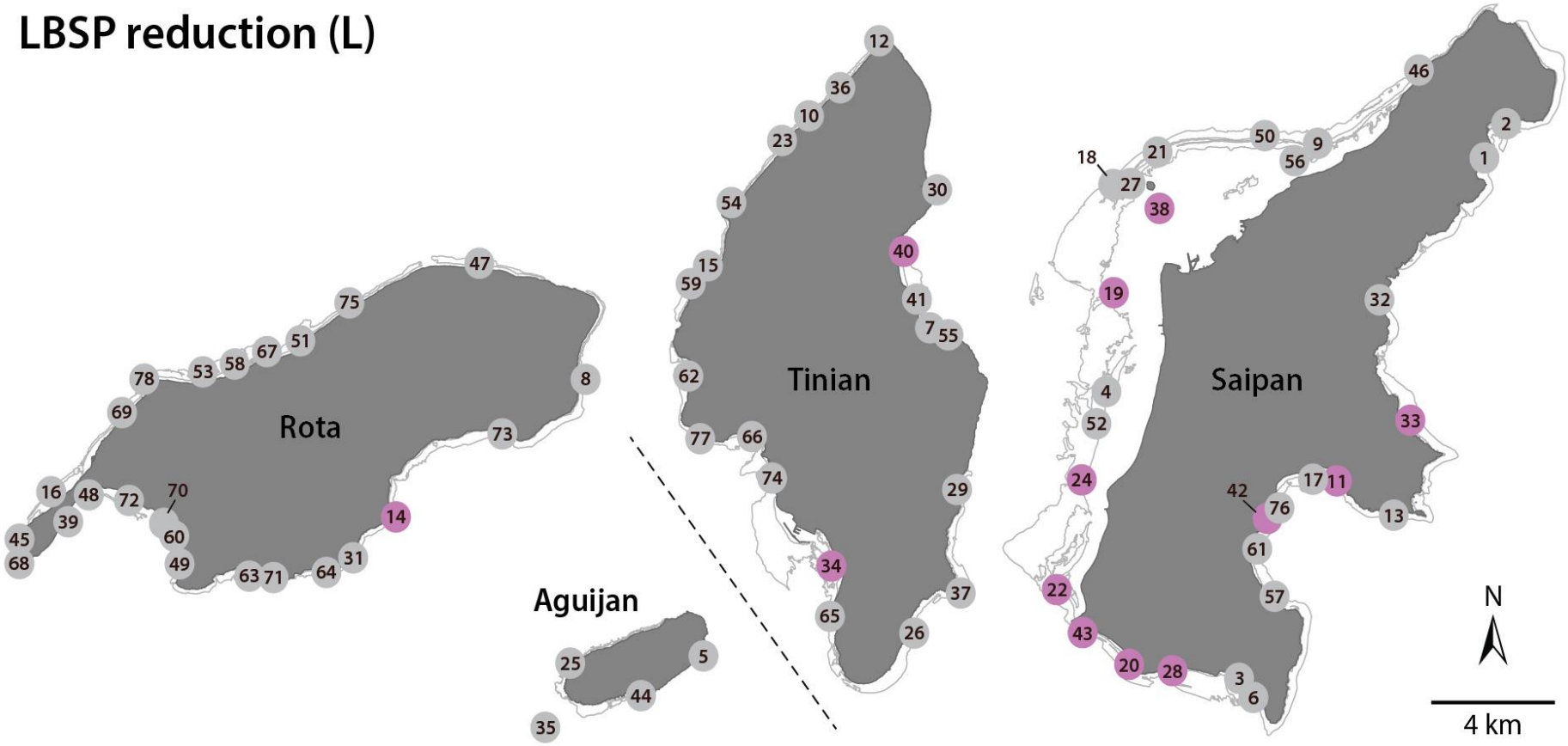
Should We Protect the Strong or the Weak?

Game et al. 2008



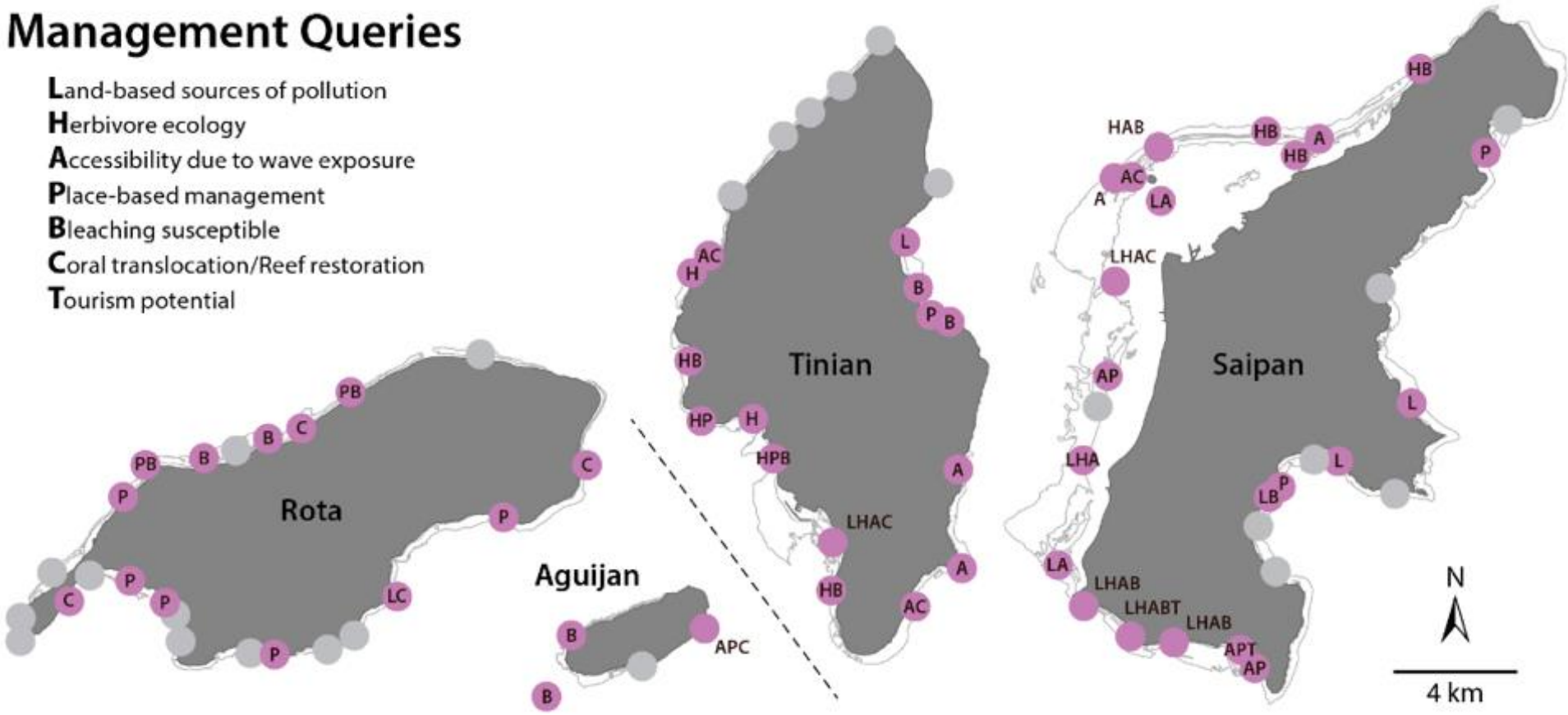

Informing Management: Query Results

LBSP reduction (L)



Criteria (*n* of 78)	Relevant management actions
Above average scores for resilience potential and land-based sources of pollution (13)	Afforestation, stream bank stabilization, riparian restoration, road and storm drain improvement, other erosion control practices, wetland enhancement and sewage treatment upgrades

Informing Management: Query Results



55 of the 78 survey sites meet at least one of the 7 sets of query criteria

List of queries is not exhaustive of all of the possible options!

Relevant management actions are not new; innovation is in the inclusion of resilience as an information layer such that these actions can be targeted to maximise site and system resilience.

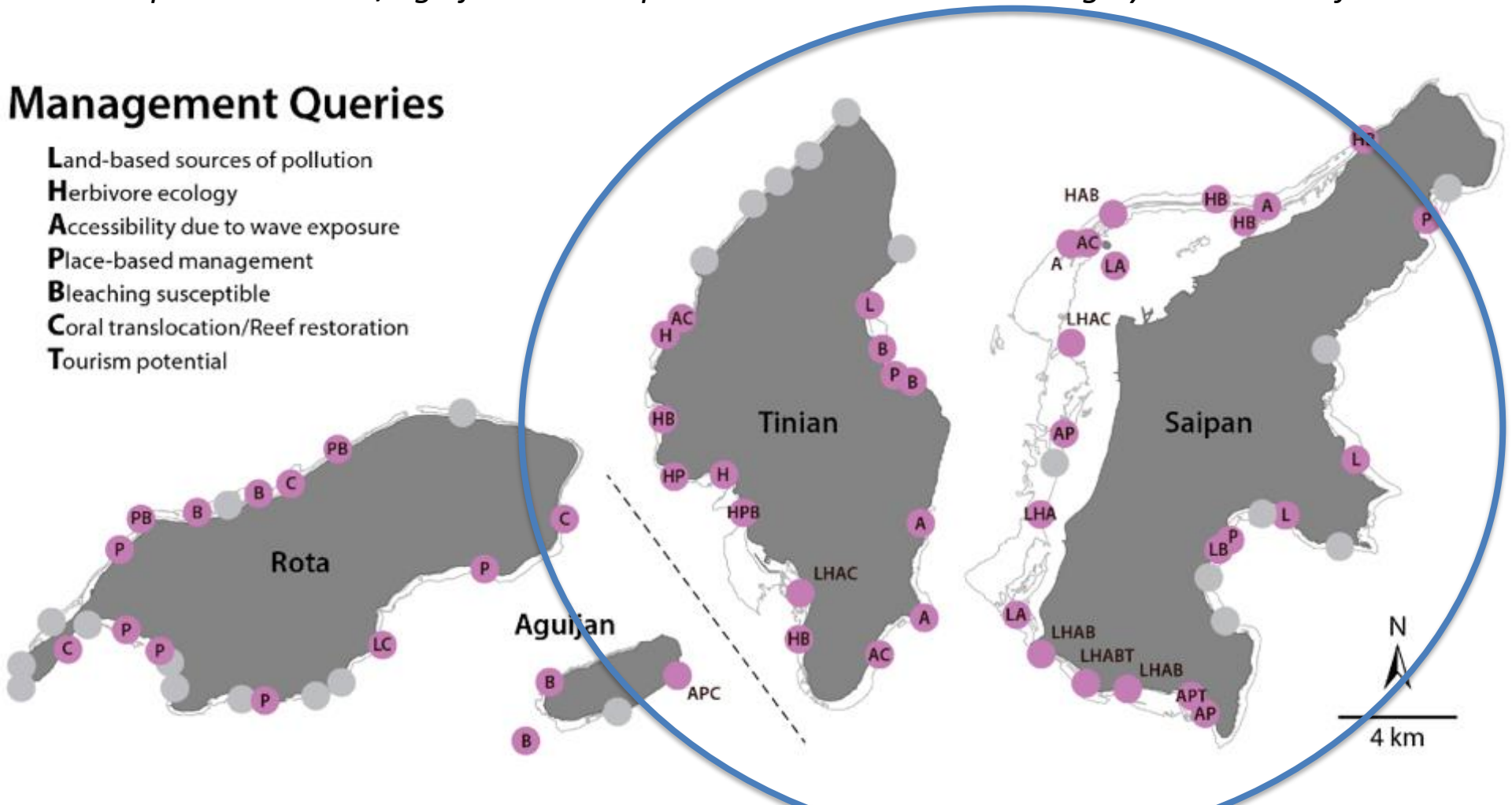
Connectivity and resilience

From Resilience Study -

Rota – lower coral recruitment and coral diversity; 7 of 10 low resilience sites

From Connectivity Study -

1. *Saipan is roughly twice the source that Tinian/Aguijan is and 10x that of Rota.*
2. *Saipan and Tinian/Aguijan are comparable destinations and roughly twice that of Rota*



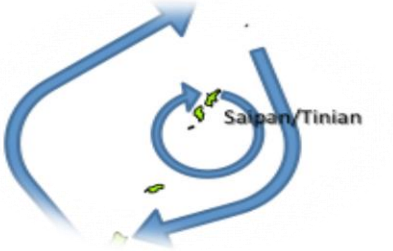
Results highlights

1. Resilience potential varied greatly within and among islands; some sites have high and some have low relative resilience potential.

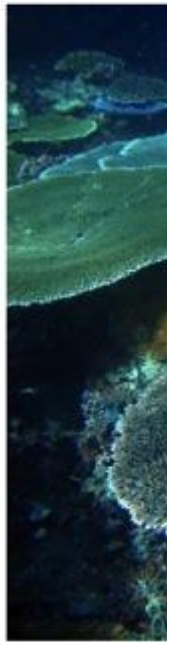
2. Herbivore biomass and coral recruitment are key drivers in CNMI of differences in relative resilience potential (as assessed here)

3. The majority of sites were identified as warranting management attention for at least one reason we can relate to an action that will support resilience

4. Connectivity information helps explain assessment results and prioritize from among the sites that warrant management attention.



RESOURCES



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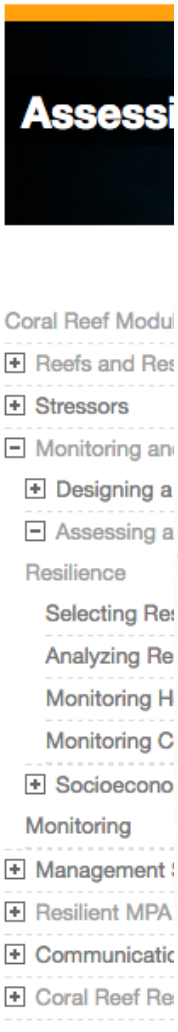

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Assessing relative resilience potential of coral reefs to inform management in the northern Mariana Islands

Running title: *Assessing relative resilience potential of coral reefs*

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2012 report: Search CORIS for Saipan Resilience ; www.reefresilience.org
USGS project summary: NCCWSC website ; send info requests to maynardmarine@gmail.com

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NOAA CORAL REEF CONSERVATION PROGRAM

QUESTIONS??

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