A close-up photograph of a coral reef. The coral has a porous, honeycomb-like texture and is primarily green and brown. On the left side, a portion of a diver's blue and black fin is visible. The background is dark, suggesting an underwater environment.

# Do MPAs facilitate coral reef ecosystem health?

Maya Walton  
University of Hawai'i Mānoa  
Biology Department

# Marine Protected Areas (MPAs) and coral reef health

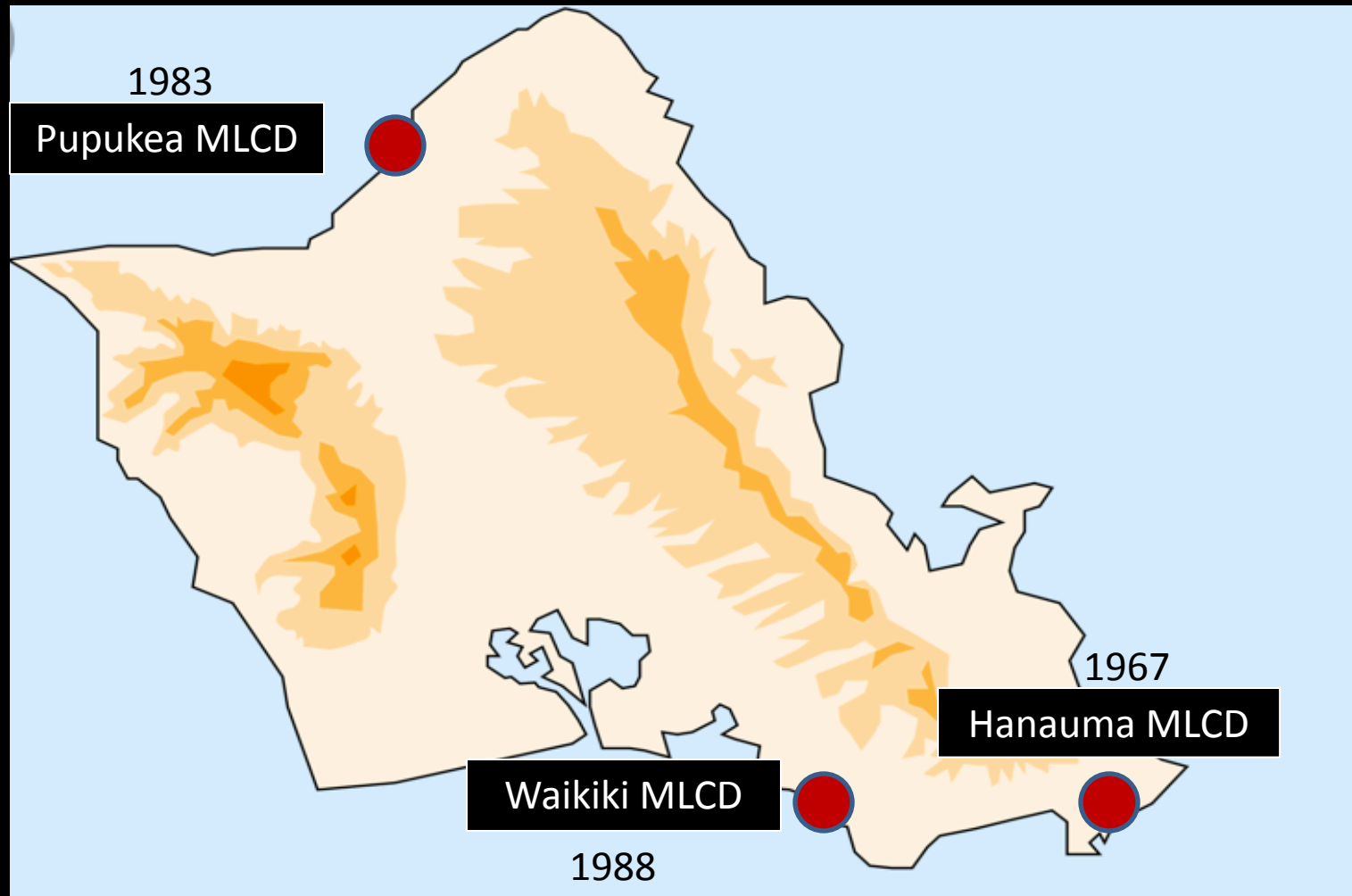




# Marine Life Conservation Districts as MPAs



# Oahu's Marine Life Conservation Districts (MLCDs)



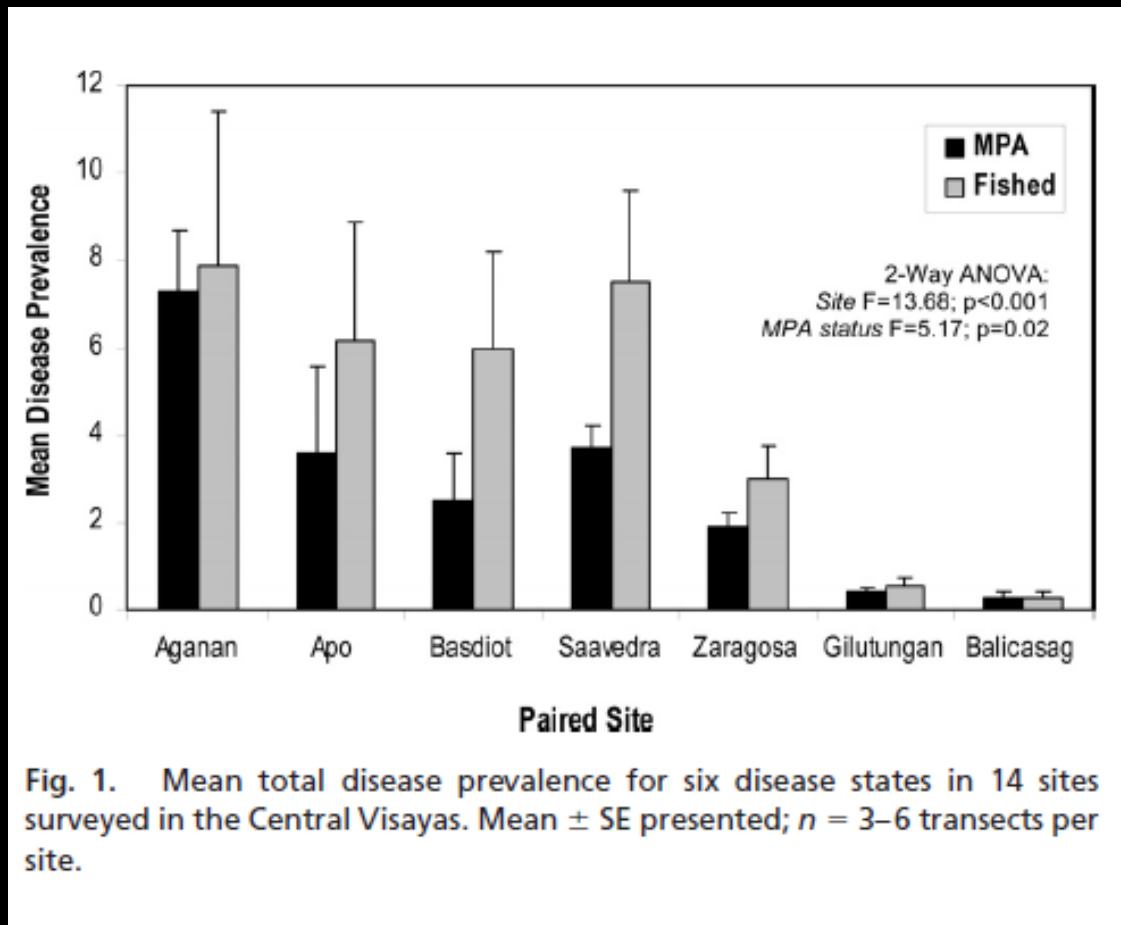
# Benefits of Marine Protected Areas



- Increased fish and invertebrate biomass (Acosta, 2002; Friedlander et al. 2003)
- Reduced macroalgal cover (Mumby et al. 2006)
- Increased coral recruitment (Mumby et al. 2007)

# MPAs and coral disease

- Lower coral disease levels inside protected areas (Raymundo et al. 2009)



# MPAs and coral disease

## **Influence of marine reserves on coral disease prevalence**

**Cathie A. Page<sup>1,\*</sup>, David M. Baker<sup>2</sup>, C. Drew Harvell<sup>2</sup>, Yimnang Golbuu<sup>3</sup>,  
Laurie Raymundo<sup>4,5</sup>, Stephen J. Neale<sup>6,7</sup>, Kathryn B. Rosell<sup>4</sup>, Krystal L. Rypien<sup>2</sup>,  
Jason P. Andras<sup>2</sup>, Bette L. Willis<sup>1</sup>**

- no significant difference in disease levels  
(Page et al. 2009)





Photo: Greta Aeby



# MPAs and coral health

1. Host abundance
2. Water quality
3. Increased fish abundance and downstream impacts on corals



Photo: Charles Lohr

# Coral disease in Oahu

- No studies yet comparing coral disease prevalence inside and outside of Marine Life Conservation Districts on Oahu.

# Research Questions

1. Do disease levels differ across protection boundaries?
2. What biological and environmental factors are the best predictors for the most common diseases?
3. Are there any size-class level differences in disease susceptibility?
4. Which aspects of coral reef ecosystem health are preserved under protective status?



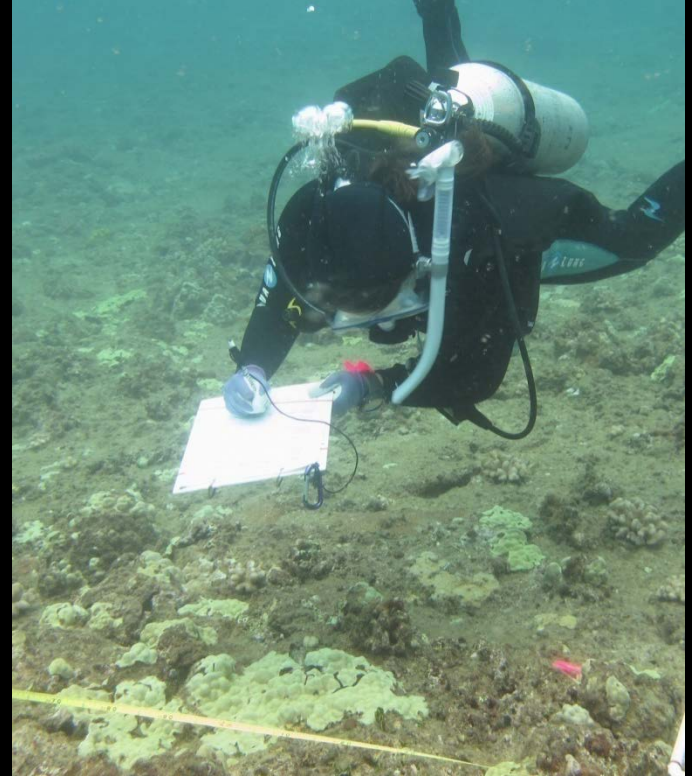
# Investigating indicators of ecosystem health

- Coral disease levels
- Coral cover
- Macroalgal cover
- Coral community size structure
- Sediment grain size
- Sediment composition
- Fish density by trophic guild
  - Herbivores
  - Corallivores
  - Piscivores



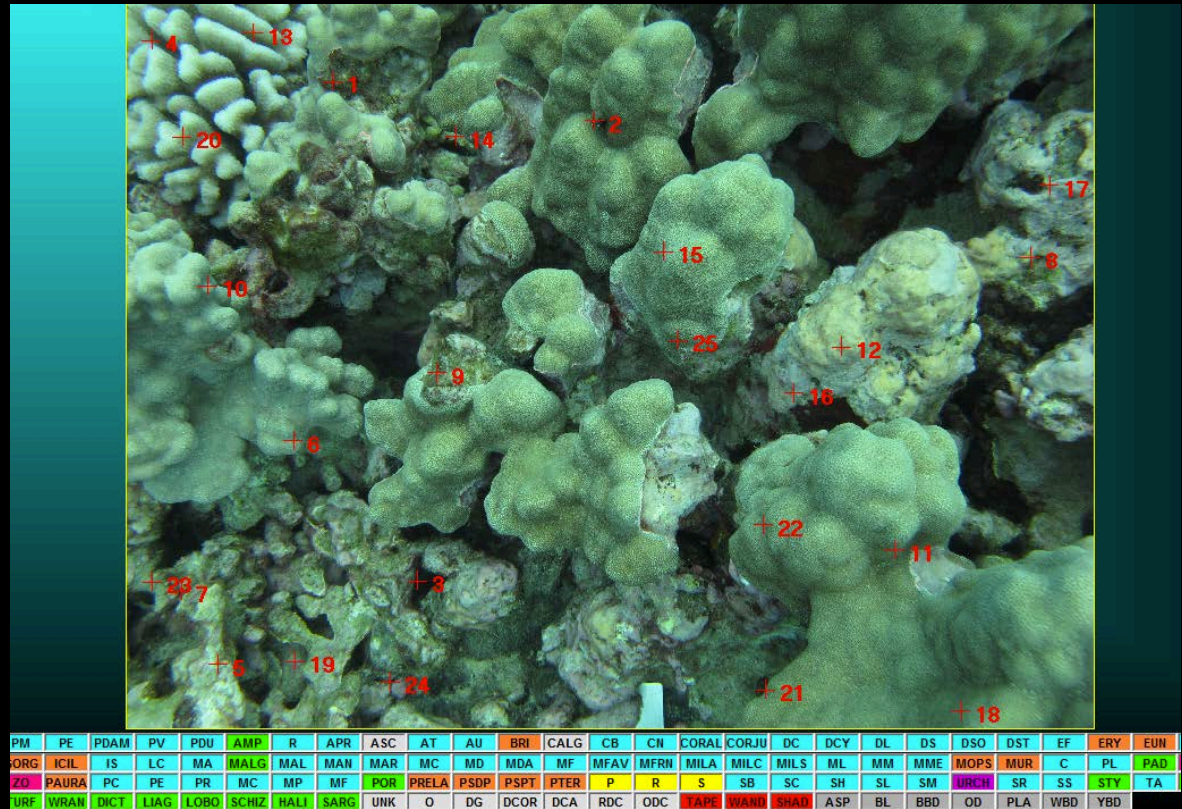
# Methods

- Field surveys at randomly selected points (total of 119 surveys)
- Fish surveys (underwater visual belt transect surveys)
- Coral colony counts



# Methods

- Benthic composition: Photoquadrats
- Sediment composition
- Sediment grain size



PM	PE	PDAM	PV	PDU	AMP	R	APR	ASC	AT	AU	BRI	CALG	CB	CN	CORAL	CORJU	DC	DCY	DL	DS	DSO	DST	EF	ERY	EUN
ORG	ICIL	IS	LC	MA	MALG	MAL	MAN	MAR	MC	MD	MDA	MF	MFAV	MFRN	MILA	MILC	MILS	ML	MM	MME	MOPS	MUR	C	PL	PAD
ZO	PAURA	PC	PE	PR	MC	MP	MF	POR	PRELA	PSDP	PSPT	PTER	P	R	S	SB	SC	SH	SL	SM	URCH	SR	SS	STY	TA
URF	WRAN	DICT	LIAG	LOBO	SCHIZ	HALI	SARG	UNK	O	DG	DCOR	DCA	RDC	ODC	LAP	WAN	SHAD	ASP	BL	BBD	OD	PLA	WBD	YBD	



# Calculating disease prevalence

$$\text{Prevalence (\%)} = \frac{\text{number of colonies with signs of lesions}}{\text{Total number of colonies}}$$

# Prevalence across protection boundaries

	Hanauma		Pupukea		Waikiki	
Lesion type	P	U	P	U	P	U
<b>P. lobata growth anomaly</b>	16.47% (1.79)	0.85% (0.36)	2.89% (0.90)	0.77% (0.29)	8.55% (4.64)	0.42% (0.42)
<b>P. lobata trematodiasis</b>	10.83% (2.62)	2.77% (0.72)	3.47% (0.77)	0.94% (0.34)	19.69% (4.35)	20.44% (5.89)
<b>P. lobata tissue loss</b>	1.72% (0.50)	0.07% (0.04)	1.33% (0.47)	0.41% (0.17)	0	0.35% (0.35)
<b>P. lobata lesion with red filamentous alga</b>	3.64% (0.94)	5.67% (4.97)	1.86% (0.13)	0	0	0.56% (0.56)
<b>P. meandrina tissue loss</b>	3.04% (1.37)	3.62% (0.91)	1.48% (0.54)	0.25% (0.25)	0	2.00% (2.00)

Mean prevalence with standard error in parentheses, red indicates significantly higher prevalence in MLCD, blue indicates significantly higher prevalence in unprotected area (Kruskal-Wallis,  $p < 0.05$ )

# Explanatory variables used in multivariate analysis

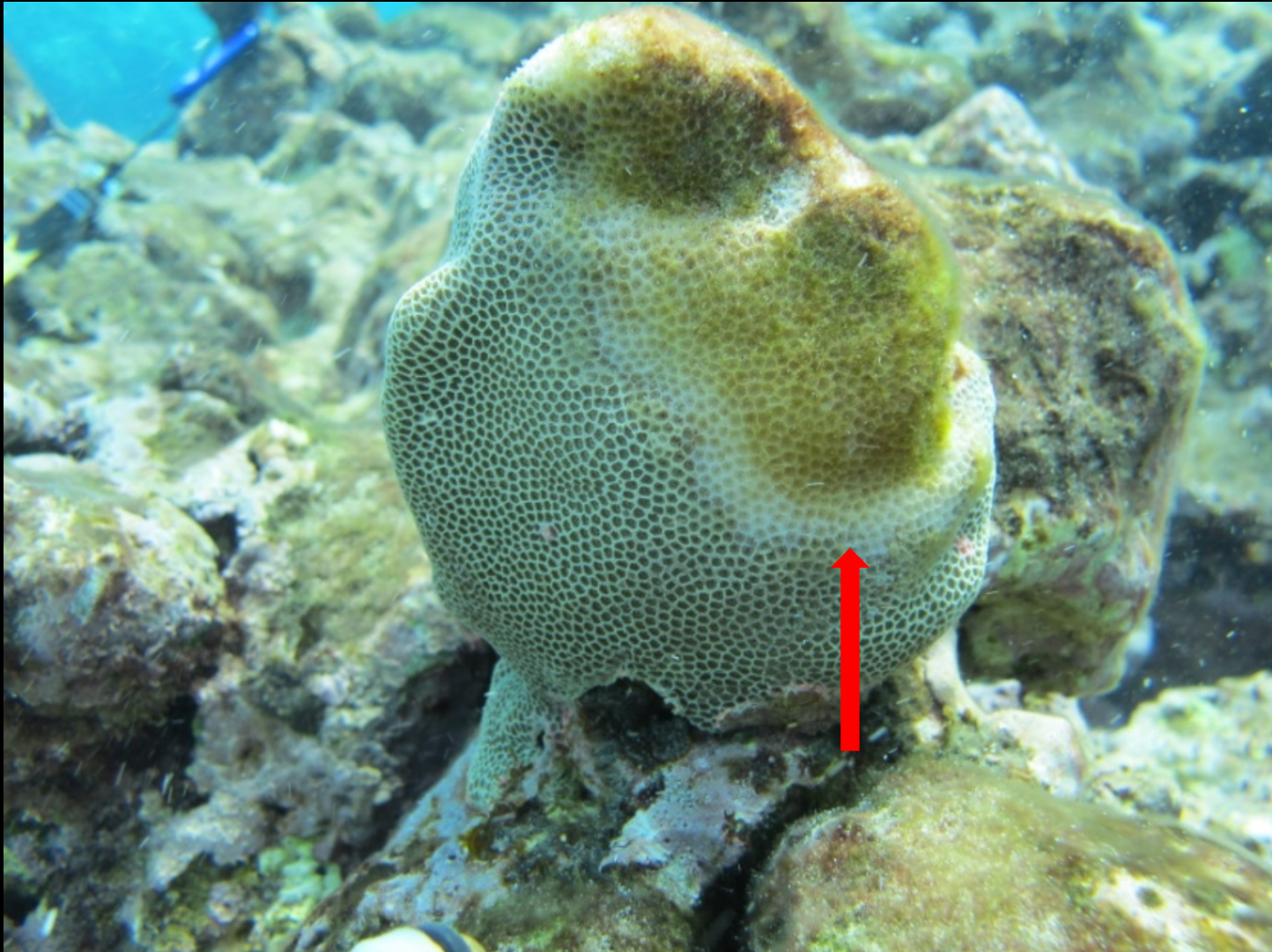
1. Depth
2. Corallivore density
3. Detritivore density
4. Herbivore density
5. Invertivore density (mobile prey)
6. Invertivore density (sessile prey)
7. Piscivore density
8. Zooplanktivore density
9. Macroalgal % cover
10. Host species % cover
11. Host species density
12. Most common size class of host species in survey
13. % organic
14. % carbonate
15. Coarse sediment %
16. Rubble %
17. Silt %

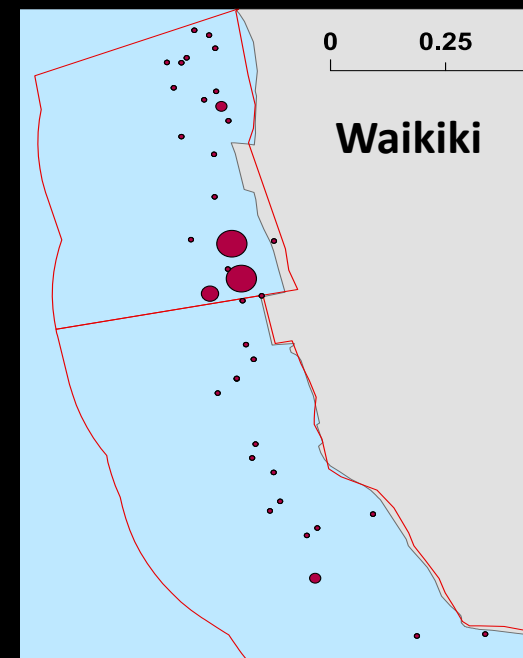
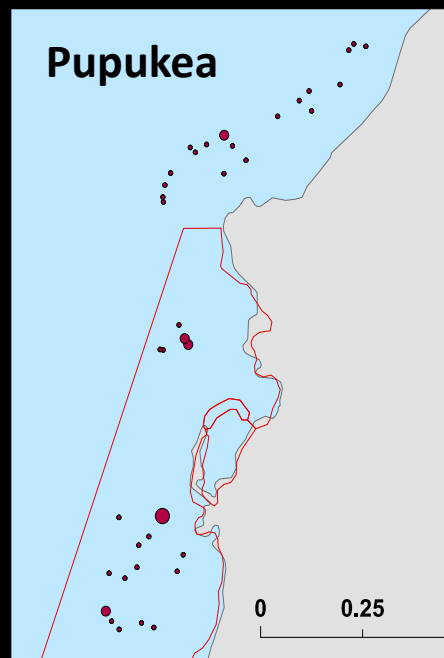
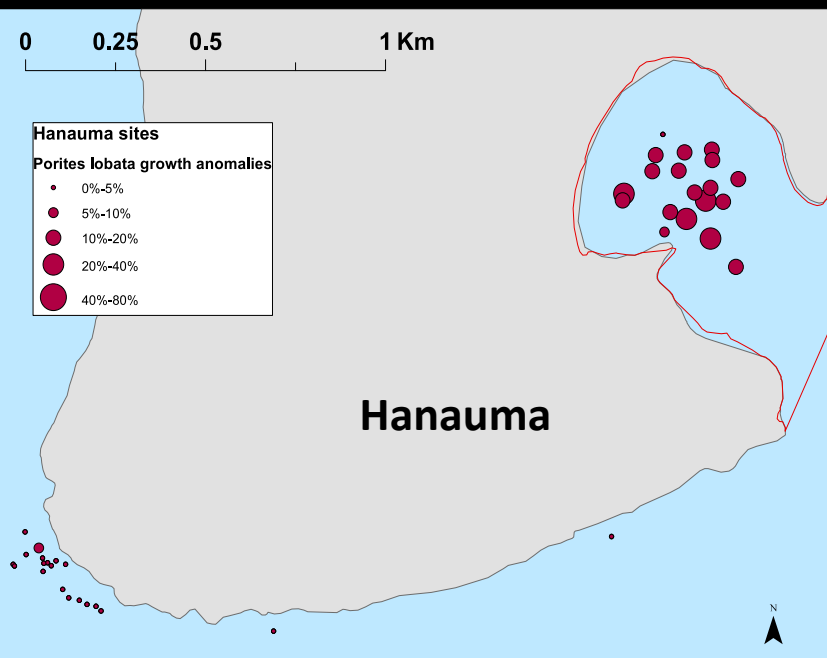


# *Porites lobata* Growth Anomalies



# *Porites lobata* tissue loss

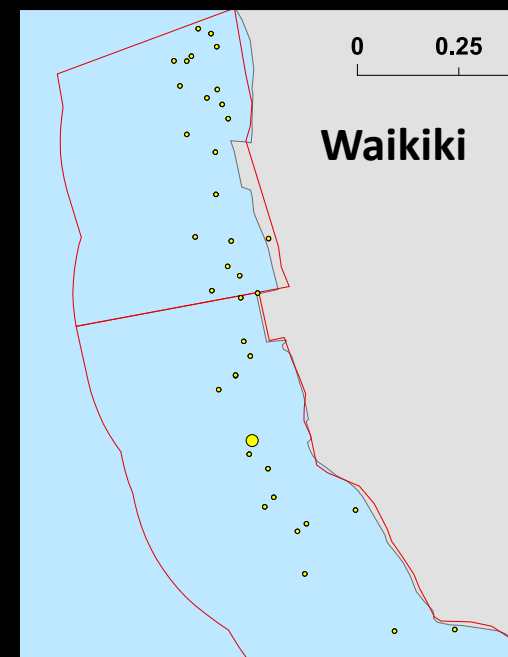
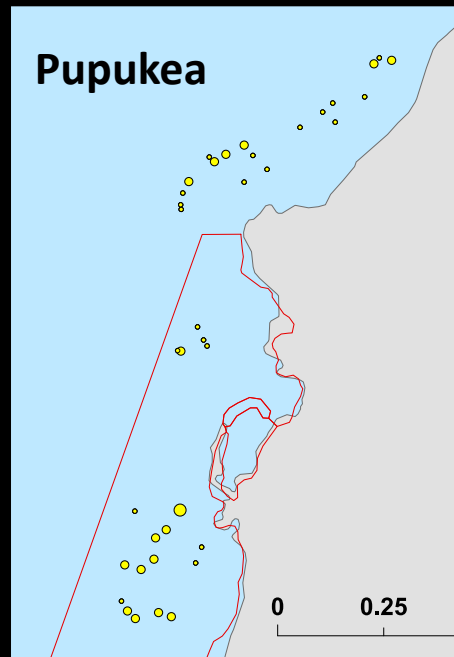
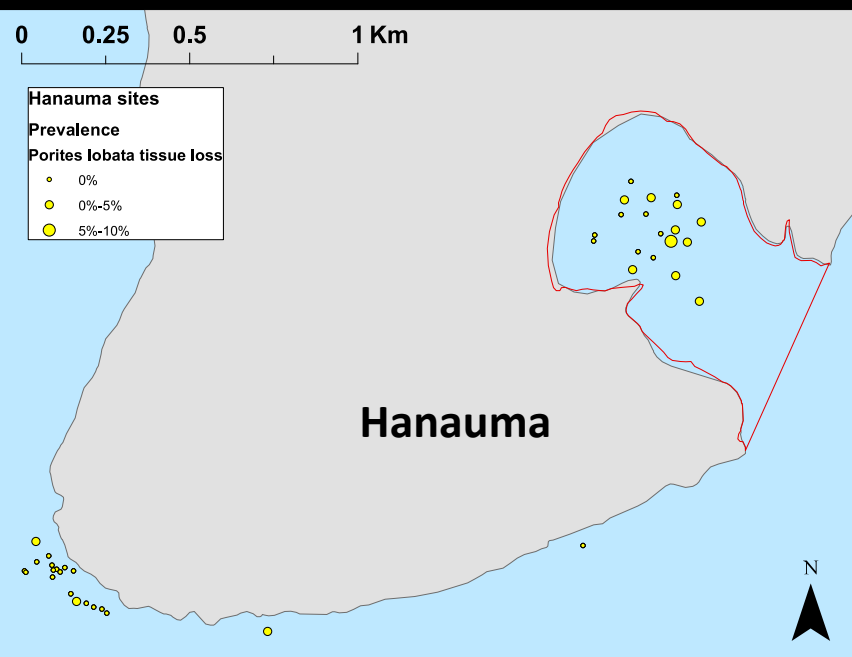




## Prevalence of *Porites lobata* growth anomalies

Predictor	AICc	Pseudo-F	P value	% variability	% total
Silt %	341.47	14.299	0.0023	10.89%	
<i>P. lobata</i> cover	327.76	12.951	0.0020	8.63%	
Corallivore density	321.48	6.3427	0.0262	3.93%	
<i>P. lobata</i> density	338.32	5.2365	0.0277	3.85%	
Rubble %	318.81	4.7382	0.0318	2.84%	
Macroalgal cover	325.76	4.0743	0.0459	2.64%	32.79%

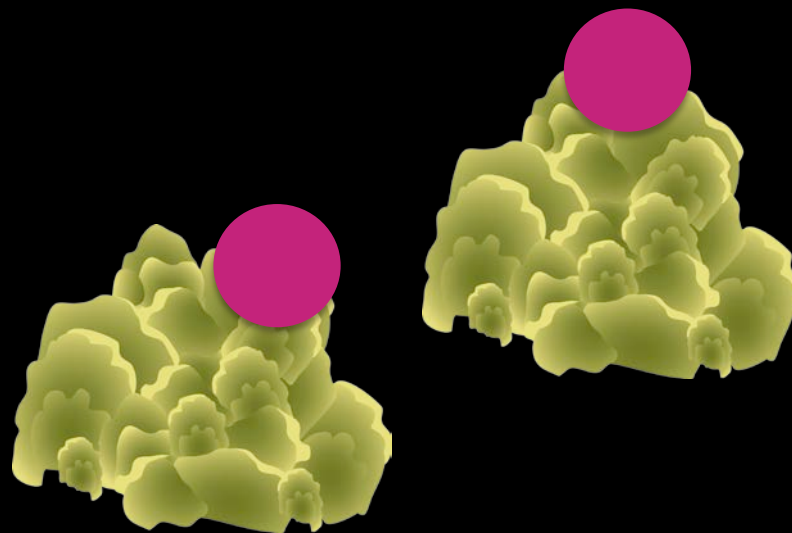
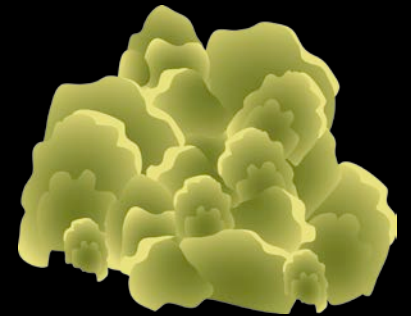




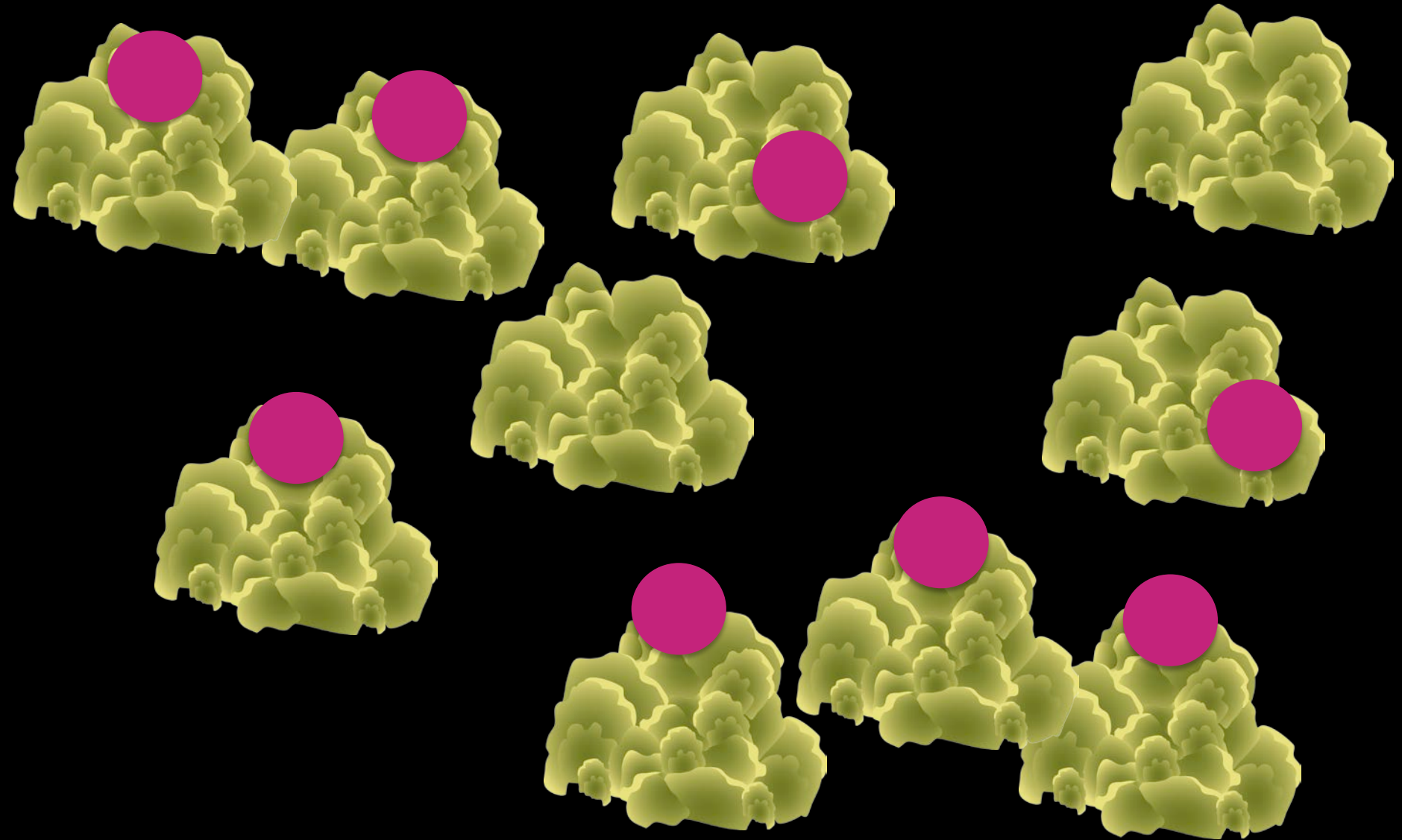
## Prevalence of *Porites lobata* tissue loss

<i>Porites lobata</i> tissue loss						
Response	Predictor	AICc	Pseudo-F	P value	% variability	% total
Prevalence	<i>Porites lobata</i> cover	-95.346	29.046	0.0001	19.89%	
	Sediment rubble	-106.84	6.6876	0.0120	4.04%	
	Organics %	-99.035	5.7879	0.0234	3.81%	
	<i>Porites lobata</i> density	-102.24	5.2848	0.0272	3.35%	
	Detritivore density	-110.25	4.4752	0.0439	2.58%	
	Zooplanktivore density	-107.85	3.1019	0.0733	1.84%	35.51%

# MPAs and host density



# MPAs and host density

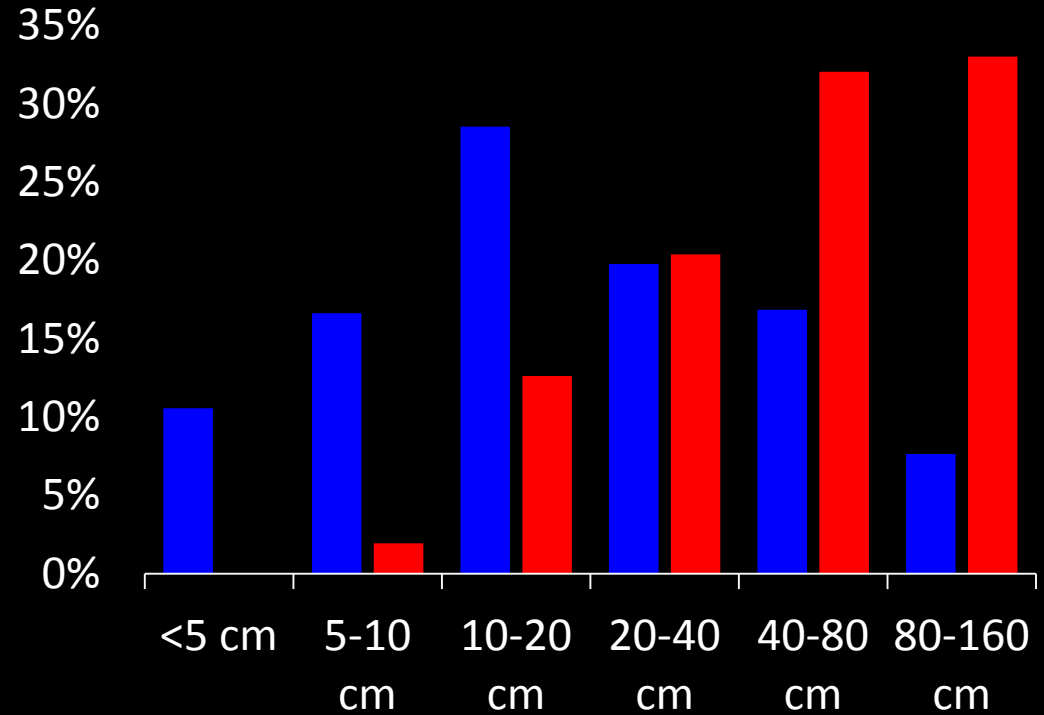


# *Porites lobata* growth anomaly



Chi-Square test  
 $p < 0.01$

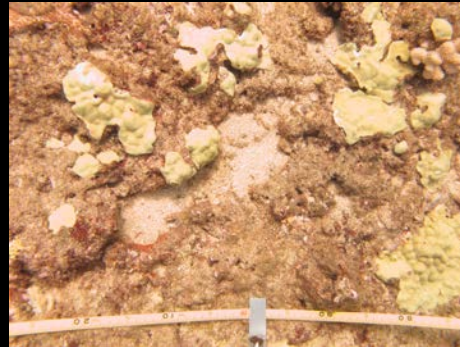
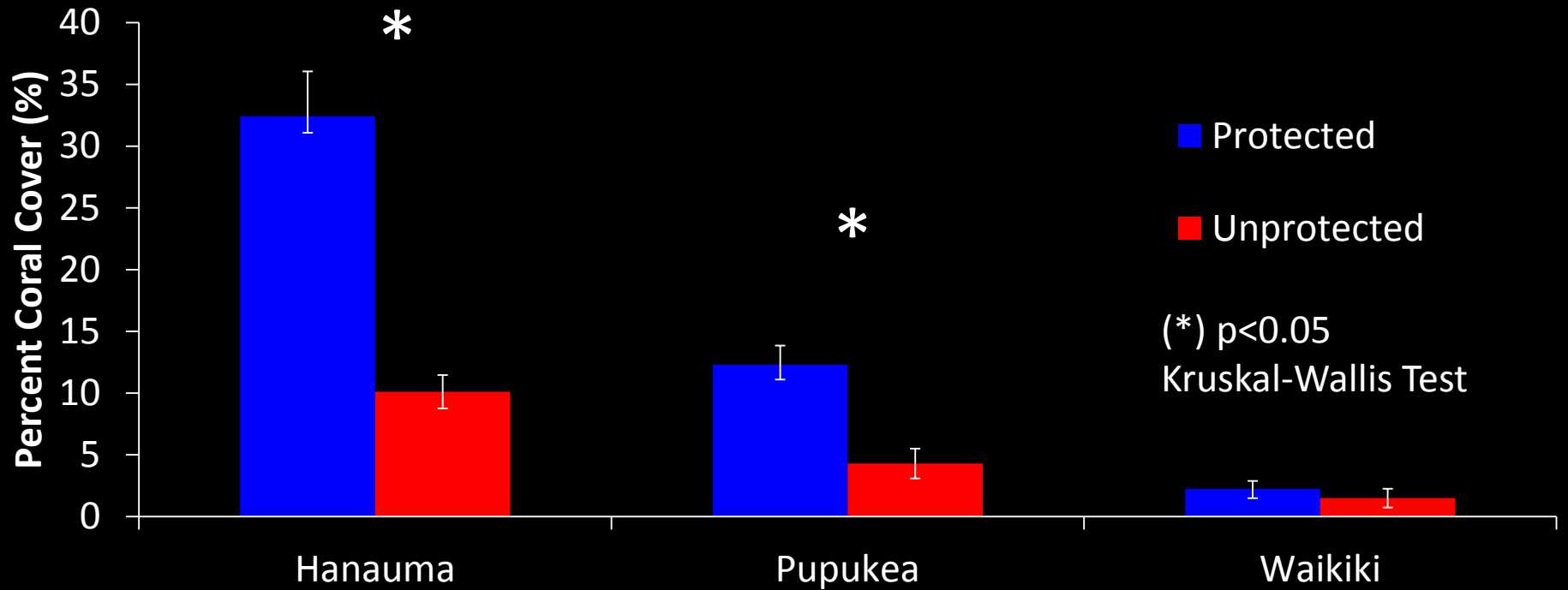
## Hanauma Bay MLCD



■ *P. lobata* healthy

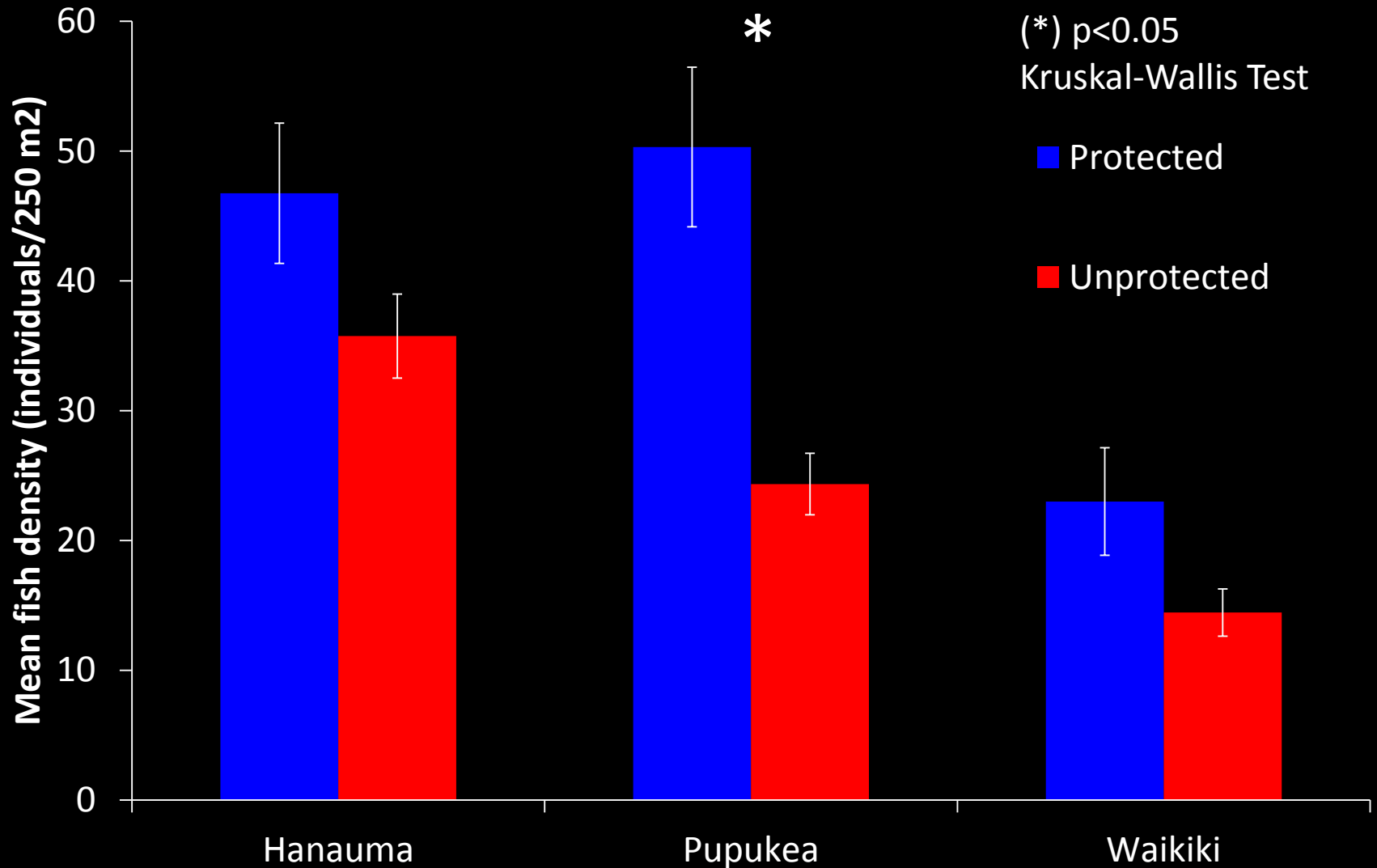
■ *P. lobata* growth anomaly

# Mean Coral Cover

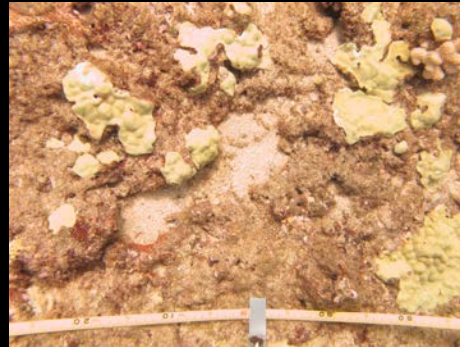
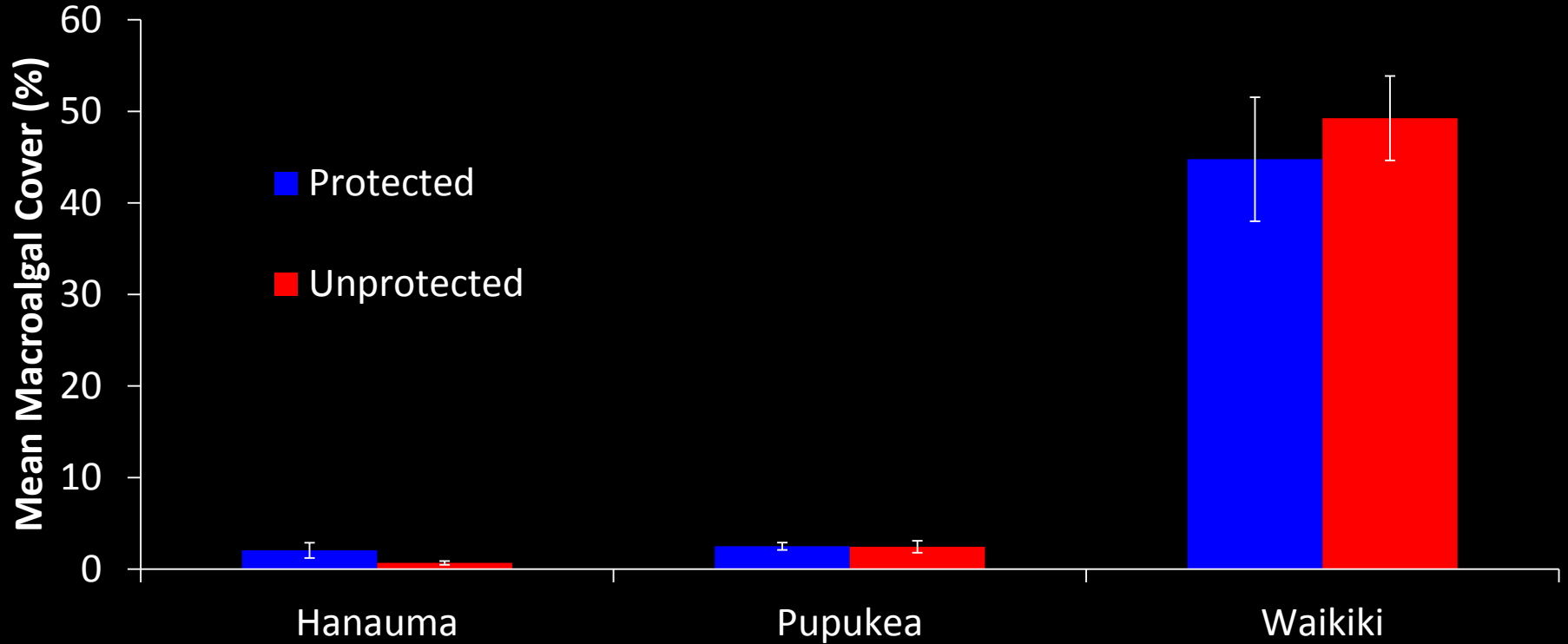




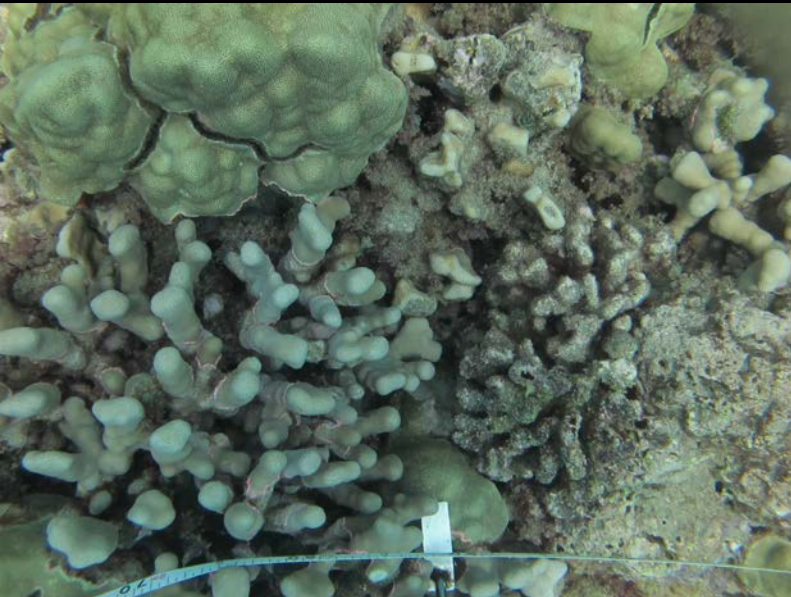
# Fish density



# Mean Macroalgal Cover



# Discussion: MLCDs and high host density



- Percent cover of host species was a strong predictor
- Decreased distance between individuals and potentially higher levels of transmission in dense populations



# Discussion: MPAs and Water quality







# Recommendations

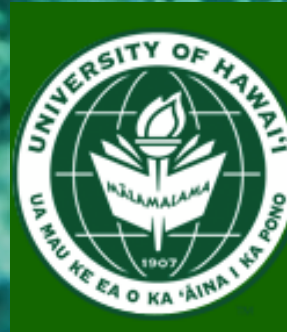
- Integration of watershed management with MLCD regulations
- Continuation of regular monitoring





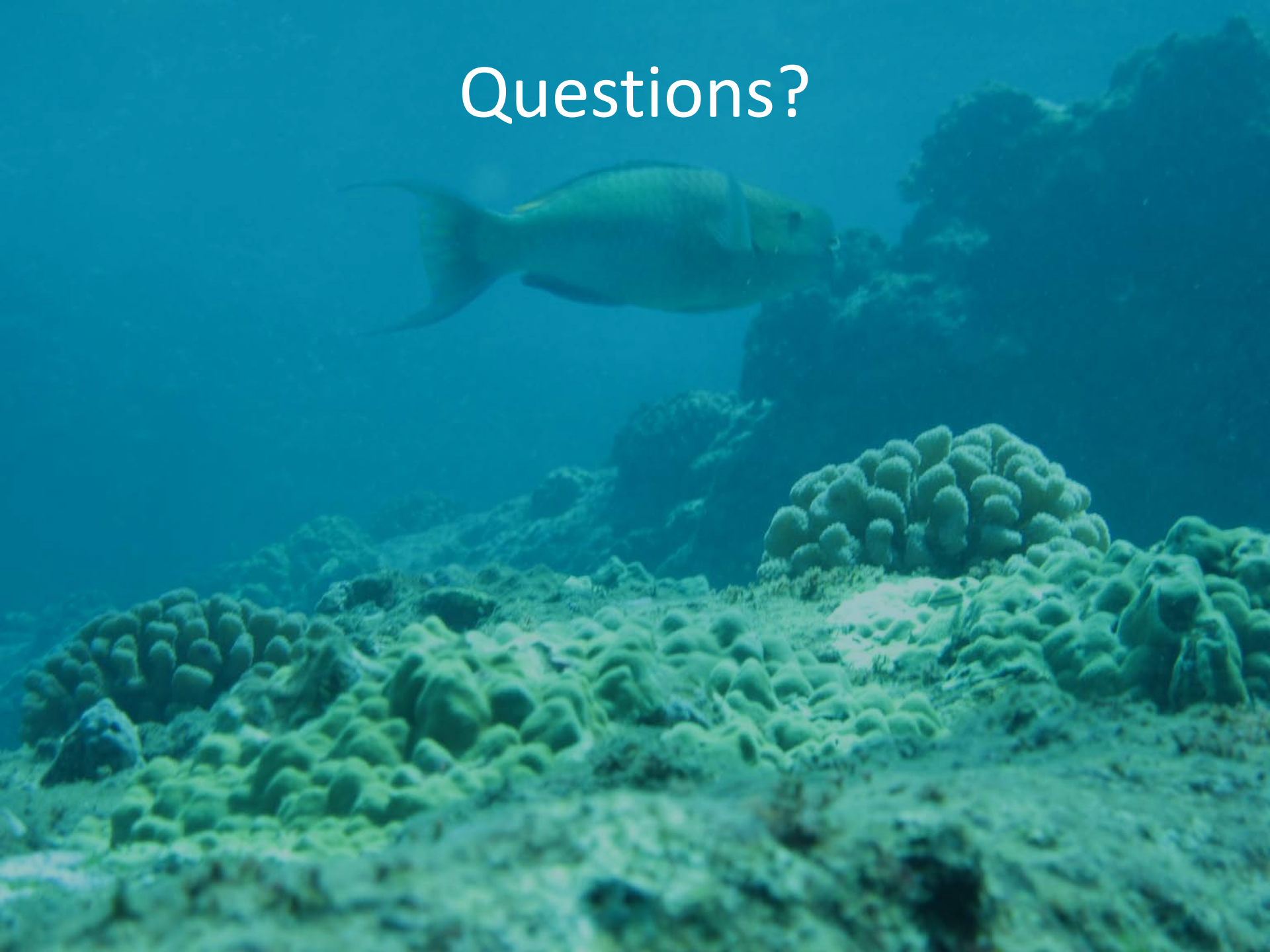
# Acknowledgements

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- Richard Coleman
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- Chris Runyon
- Camille Del Fierro
- Liana Roberson
- Keoki Stender
- Paolo Usseglio
- Kosta Stamoulis
- Dr. Cynthia Hunter
- Dr. Greta Aeby
- Dr. Les Watling
- Funding
  - UH Sea Grant
  - Edmondson Award UH Zoology department
  - UH Manoa Graduate Student Organization

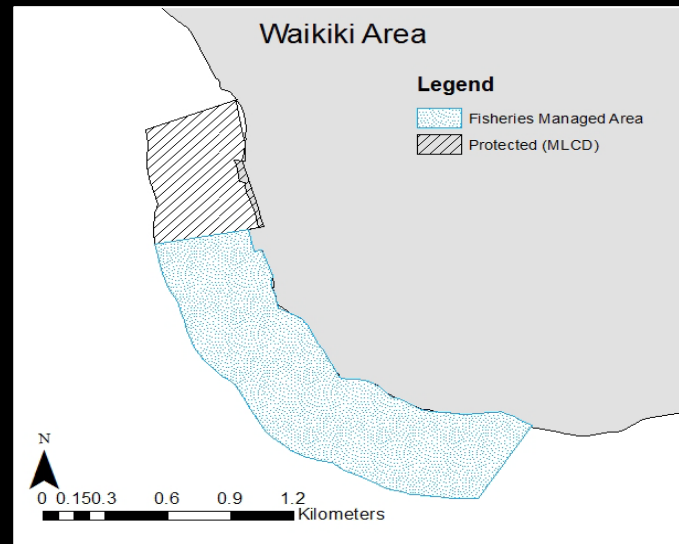
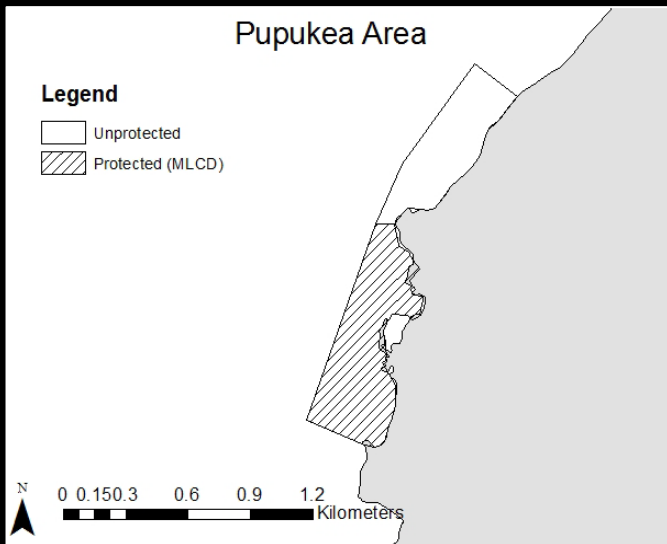
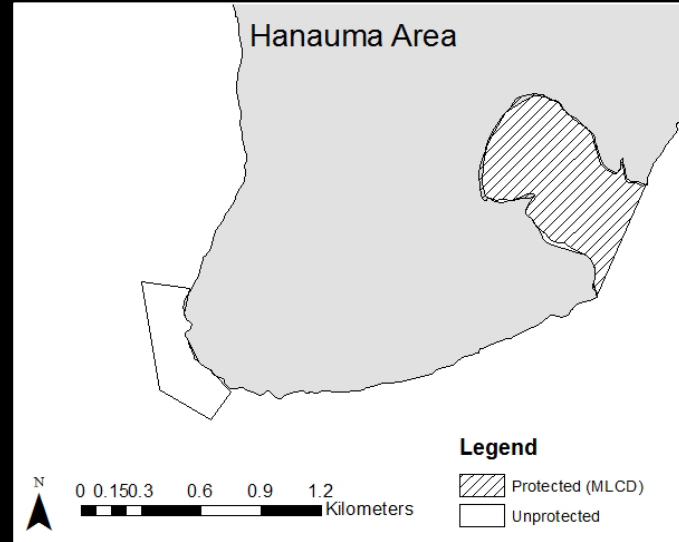
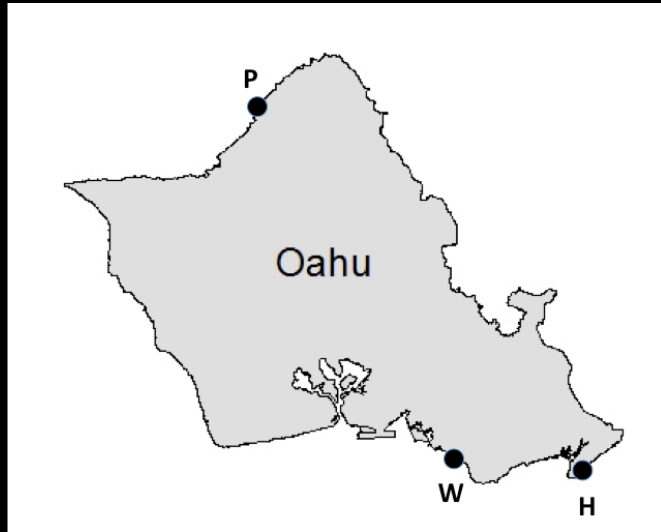


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Questions?

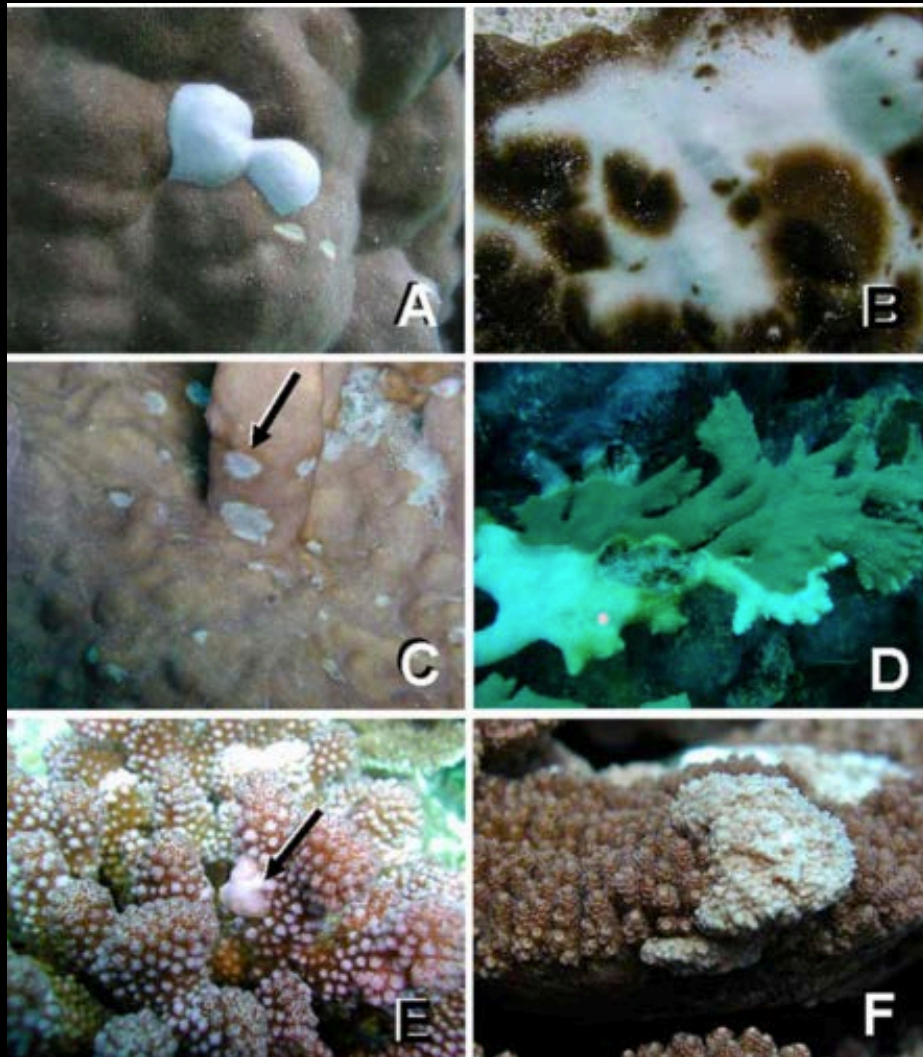


# Study sites





# Identifying lesions in the field

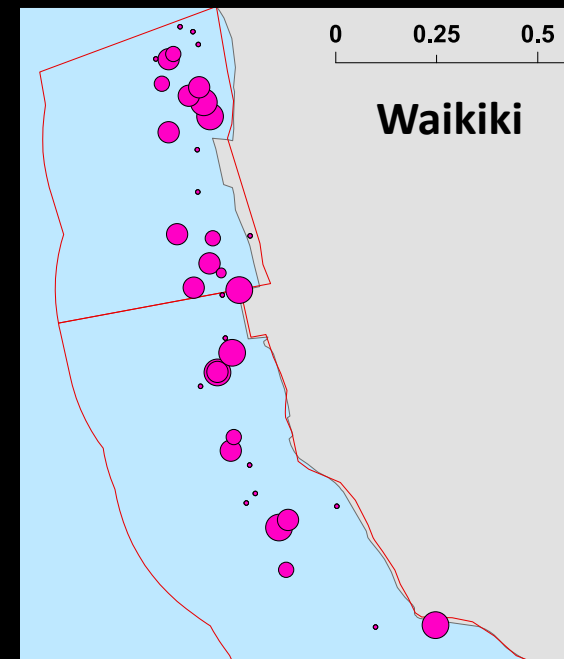
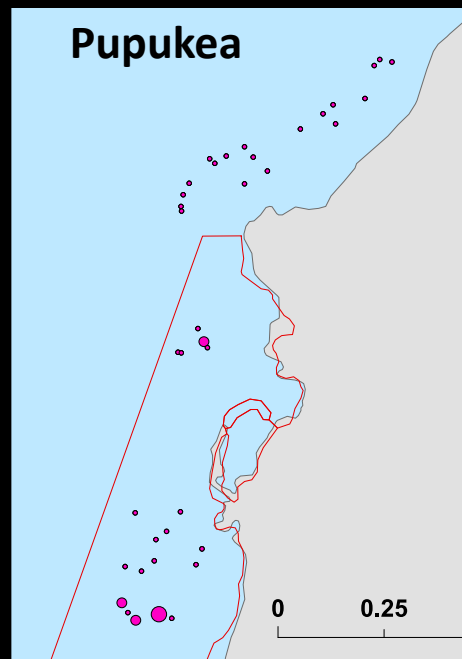
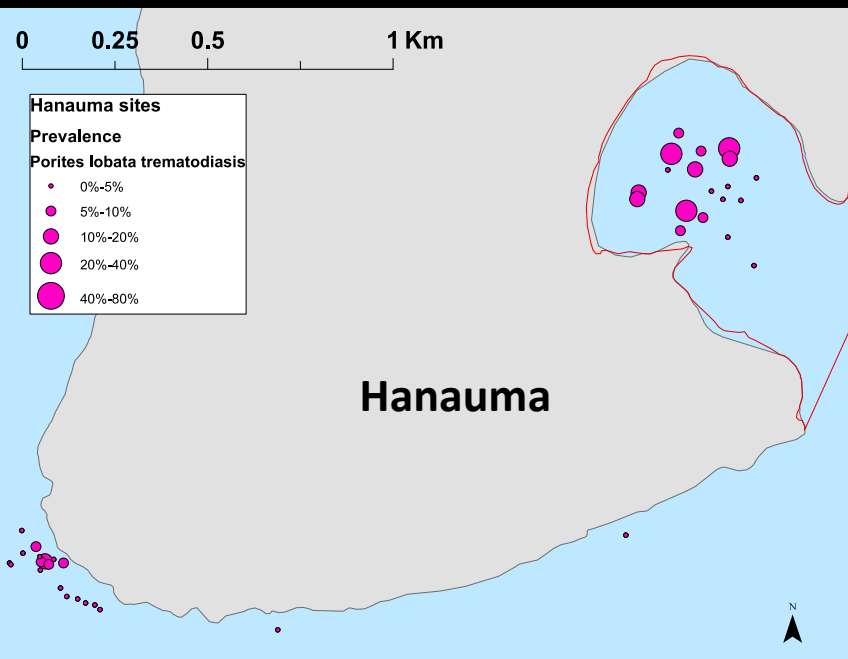


## Lesion types

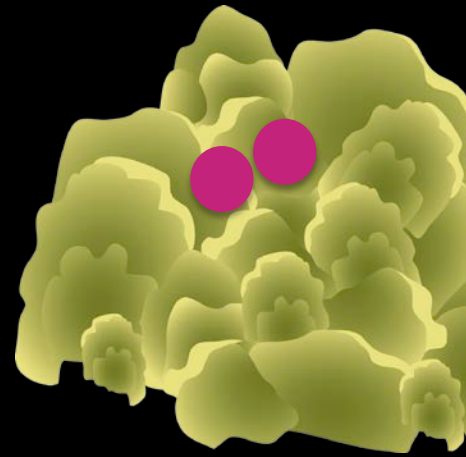
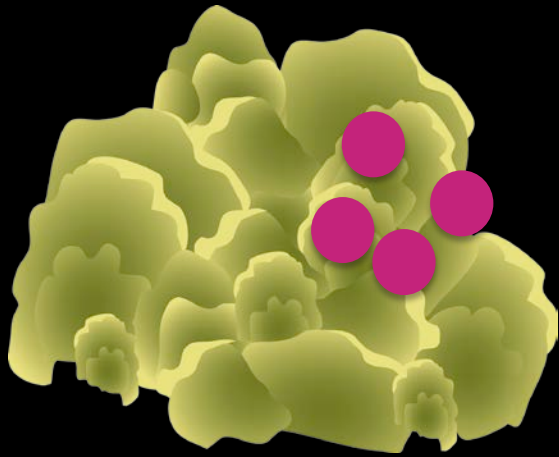
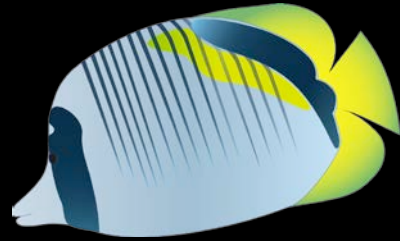
1. Discoloration
2. Tissue loss
3. Growth anomalies

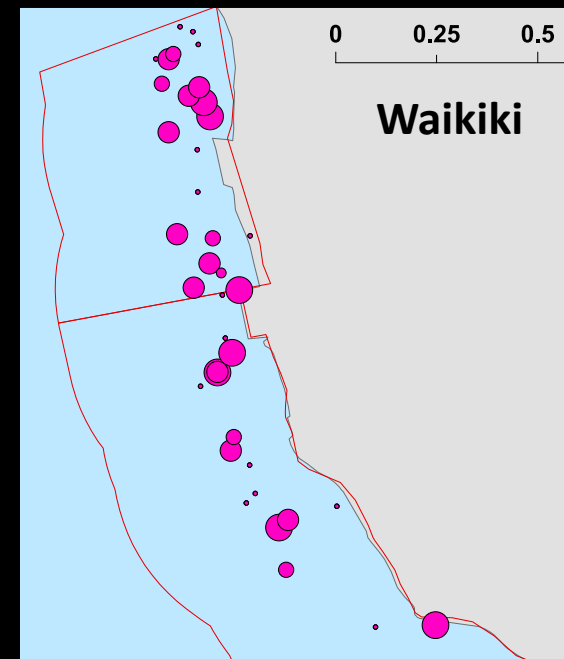
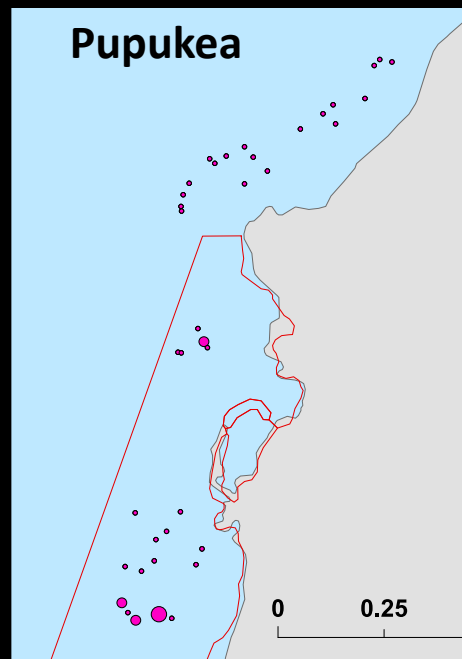
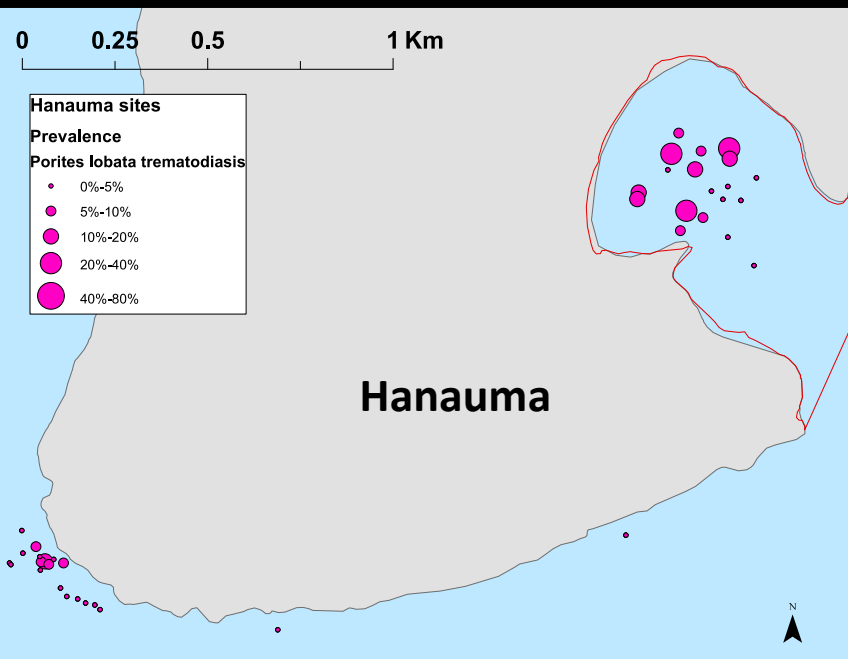
(Work and Rameyer 2005)





Prevalence of *Porites lobata* trematodiasis





## Prevalence of *Porites lobata* trematodiasis

Predictor	AICc	Pseudo-F	P value	% variability	% total
Macroalgal cover	423.44	24.441	0.0002	17.28%	
Depth	421.32	4.1898	0.0422	2.88%	
Most common size class <i>P. lobata</i> colonies	419.24	4.1506	0.0421	2.78%	
Detritivore density	418.75	2.5866	0.1066	1.71%	24.65%

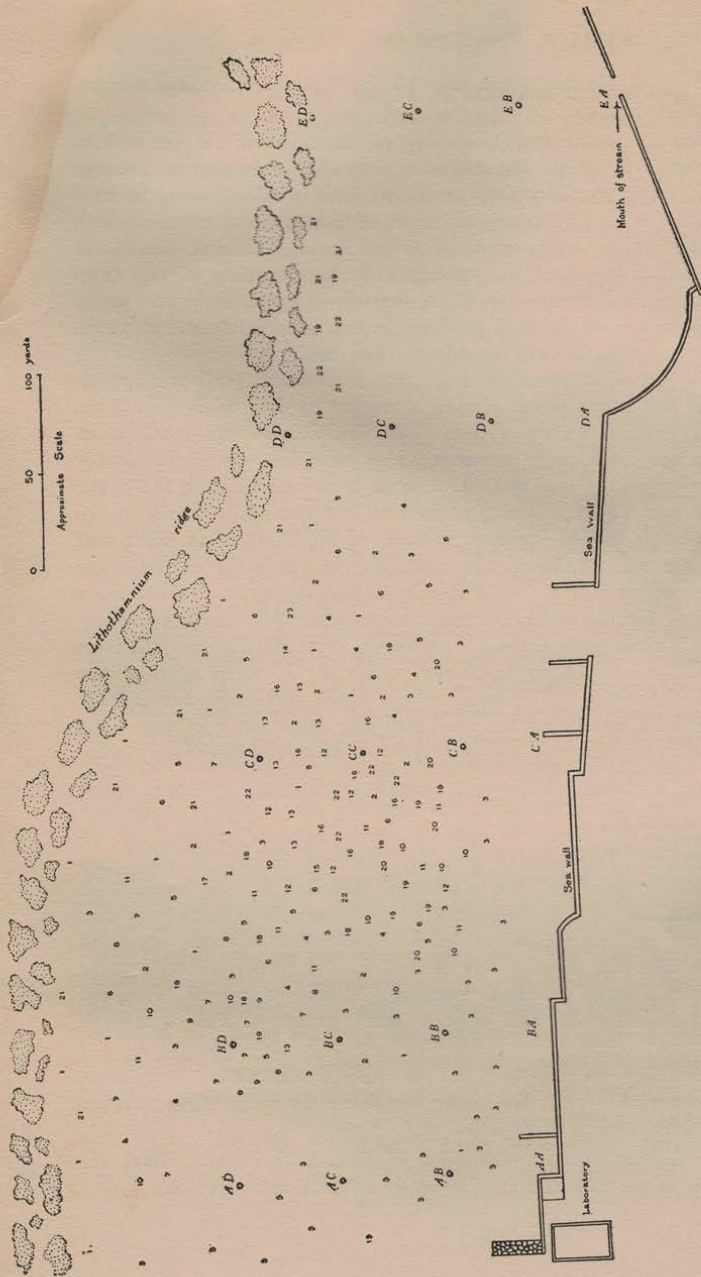


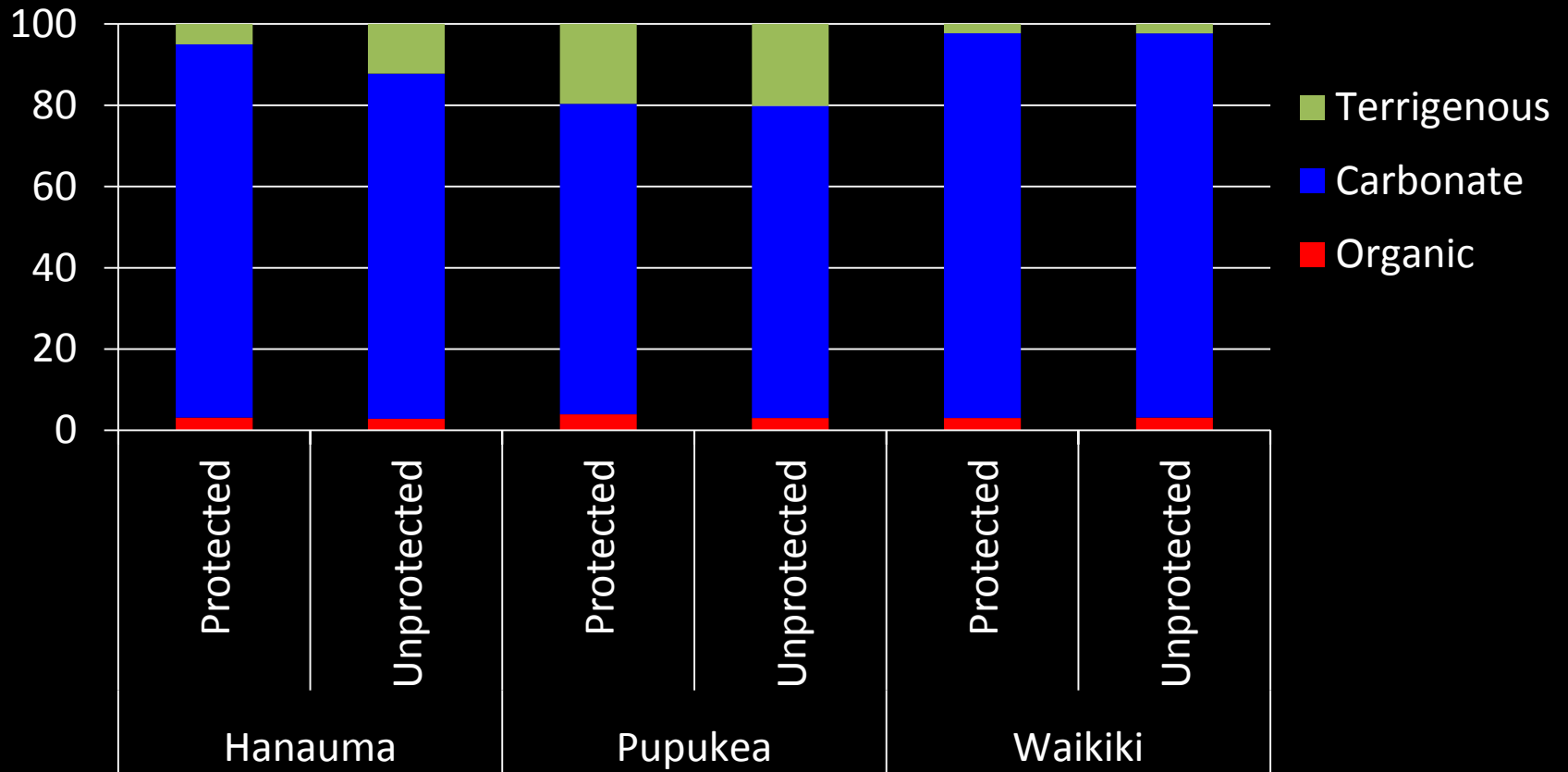
FIGURE 1.—Map of a section of Waikeiki Beach showing general distribution of corals. AA, AB, and other paired letters indicate stations of observation. The numbers show the location of the species of corals as follows: 1, *Pocillopora meandrina* var. *nobilis* Verrill; 2, *Pocillopora ligulata* Dana; 3, *Pocillopora cespitosa* Dana; 4, *Porites evermanni* Vaughan; 5, *Porites lobata* f. *lacera* Vaughan; 6, *Porites lobata* f. *infundibulum* Vaughan; 7, *Porites lobata* f. *centralis* s. f. *alpha* Vaughan; 8, *Porites lobata* f. *centralis* s. f. *beta* Vaughan; 9, *Porites lobata* f. *centralis* s. f. *gamma* Vaughan; 10, *Porites compressa* f. *granimurata* Vaughan; 11, *Porites compressa* f. *angustisepta* Vaughan; 12, *Montipora verrucosa* (Lamarck); 13, *Montipora flabellata* Studer; 14, *Montipora patula* Verrill; 15, *Montipora verrilli* Vaughan; 16, *Pazona varians* Verrill; 17, *Pazona thierdemi* Vaughan; 18, *Cyphastrea ocellina* (Dana); 19, *Stephanaria stellata* Verrill; 20, *Stephanaria brighami* Vaughan; 21, *Favia hawaiiensis* Vaughan; 22, *Lepidastrea agassizi* Vaughan; 23, *Fungia scutaria* Lamarck.



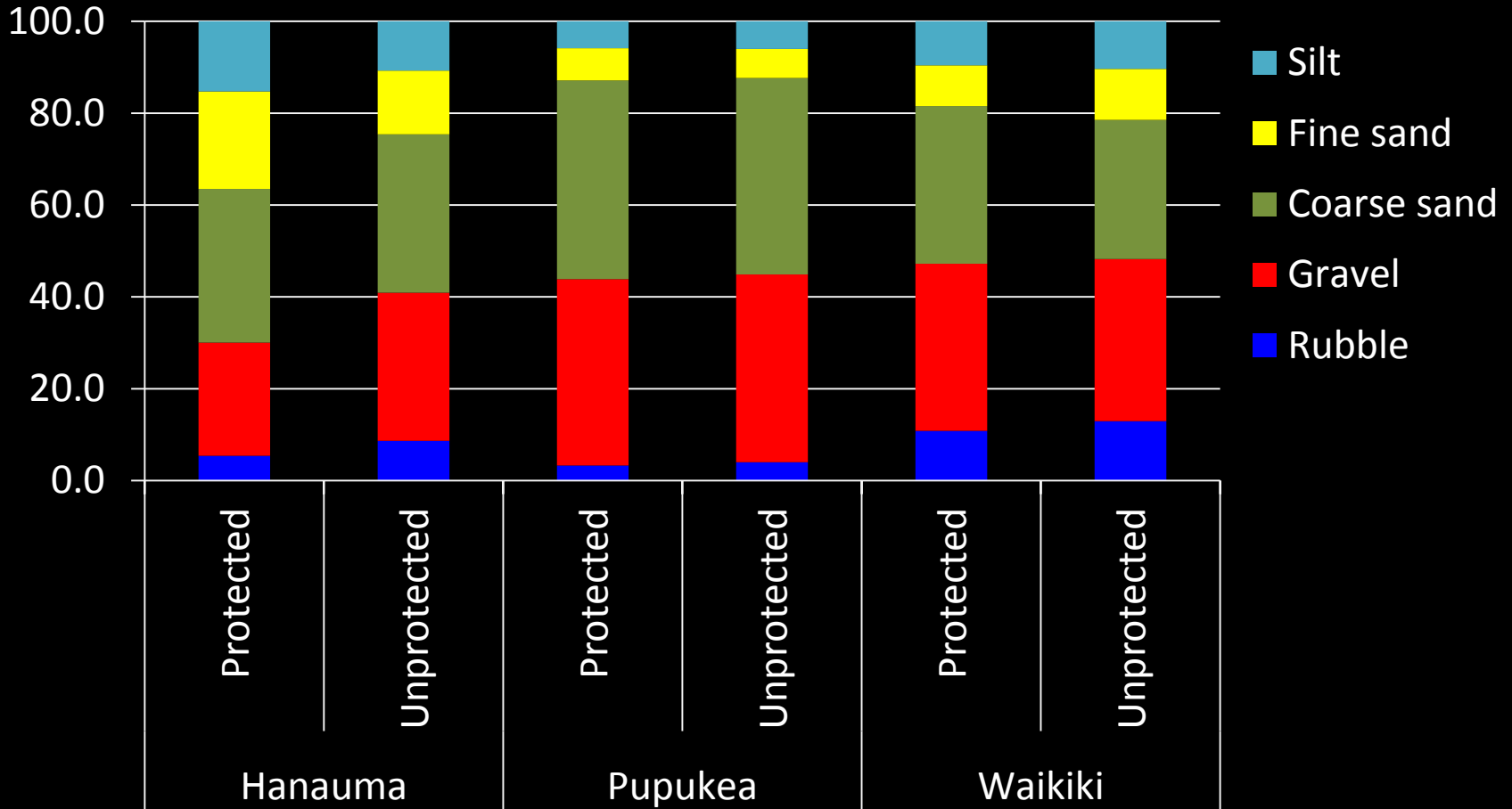


FIGURE 1.—Map of a section of Waikiki Beach showing general distribution of corals. A, B, and other paired letters indicate stations of observation. The numbers show the location of the species of corals as follows: 1, *Pocillopora meandrina* var. *nobilis* Verrill; 2, *Pocillopora ligulata* Dana; 3, *Pocillopora lobata* f. *lacera* Vaughan; 4, *Porites evermanni* Vaughan; 5, *Porites lobata* f. *lacera* Vaughan; 6, *Porites lobata* f. *infundibulum* Vaughan; 7, *Porites lobata* f. *centralis* s. f. *beta* Vaughan; 8, *Porites lobata* f. *centralis* s. f. *alpha* Vaughan; 9, *Porites lobata* f. *centralis* s. f. *gamma* Vaughan; 10, *Porites compressa* f. *granimurata* Vaughan; 11, *Porites compressa* f. *bigustis* Vaughan; 12, *Montipora varians* Verrill; 13, *Montipora stellata* Studer; 14, *Montipora patula* Verrill; 15, *Montipora verrilli* Vaughan; 16, *Pavona varians* Verrill; 17, *Pavona theodoni* Vaughan; 18, *Cyphastrea oculina* (Dana); 19, *Stephanaria brighami* Vaughan; 20, *Stephanaria stellata* Verrill; 21, *Favia hawaiiensis* Vaughan; 22, *Lepasitrea agassizi* Vaughan; 23, *Fungia scutaria* Lamarck.

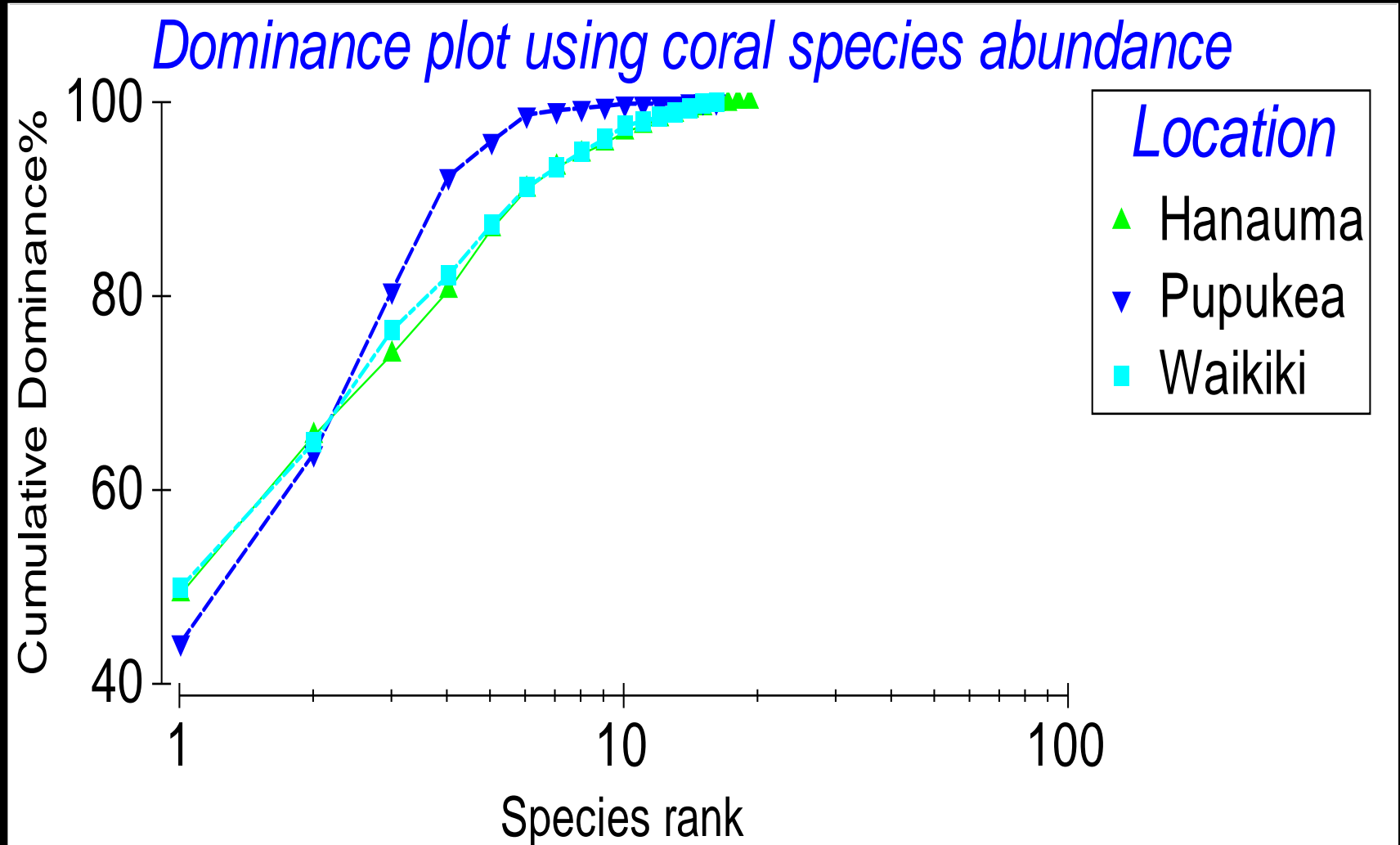
# Sediment composition



# Sediment grain size

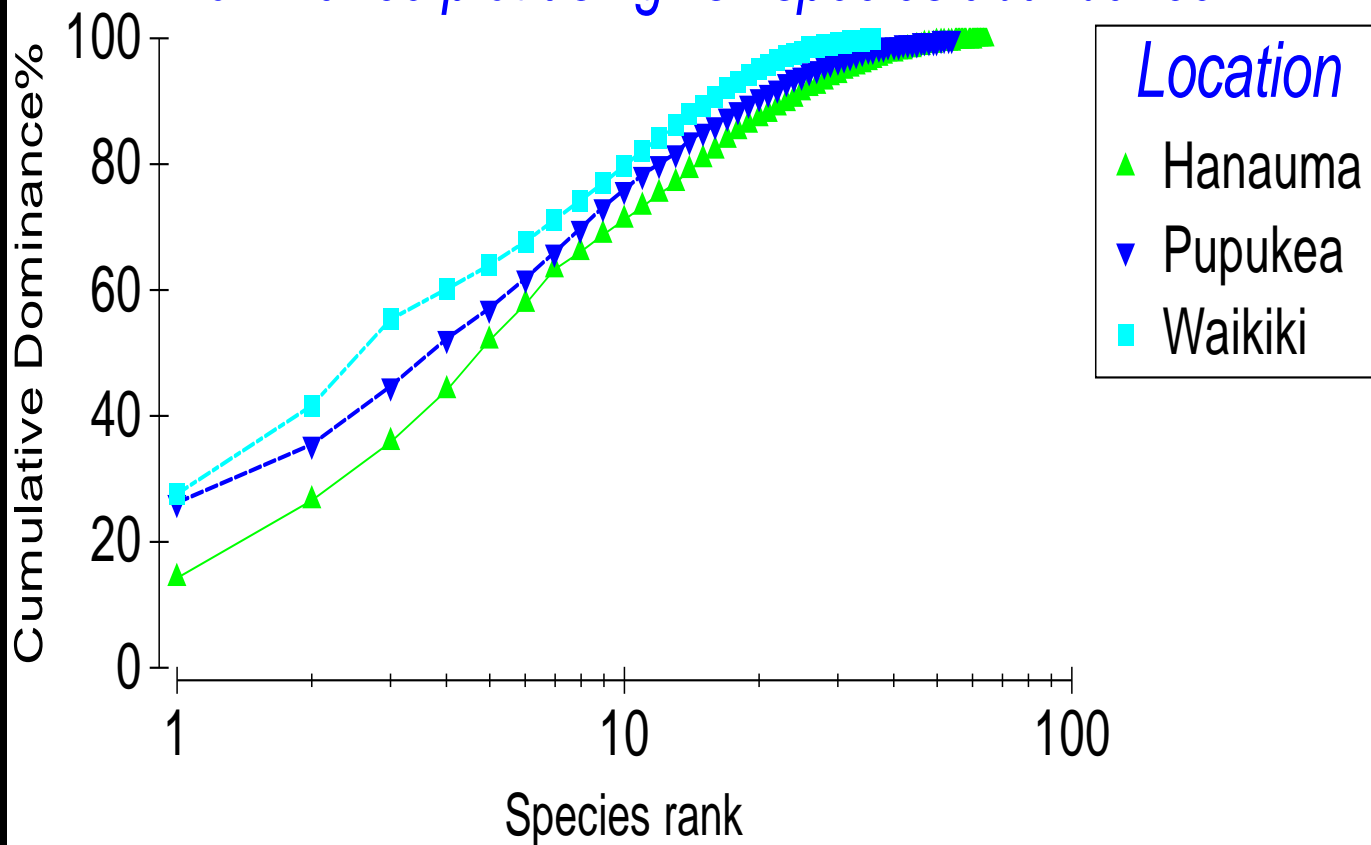


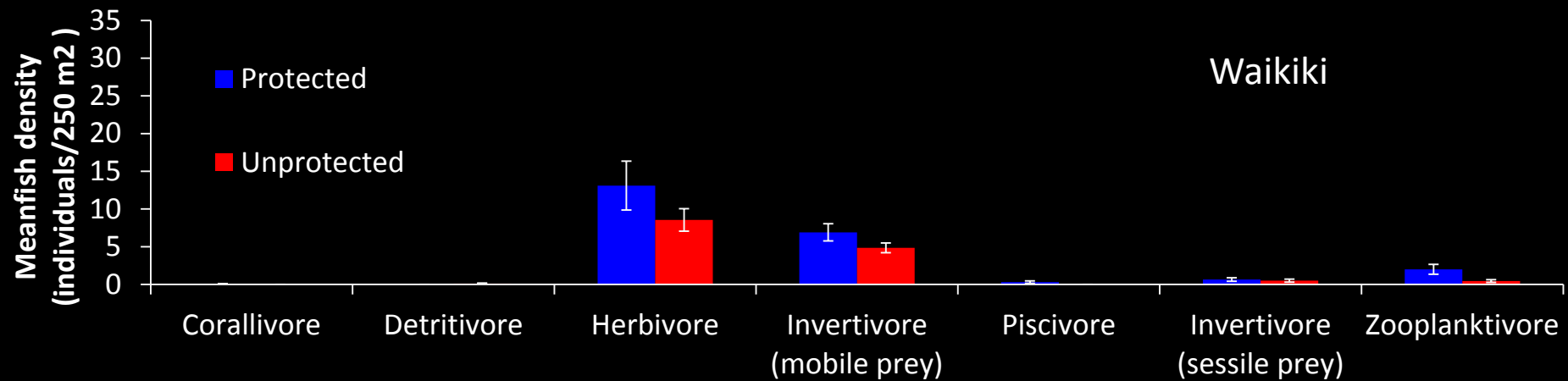
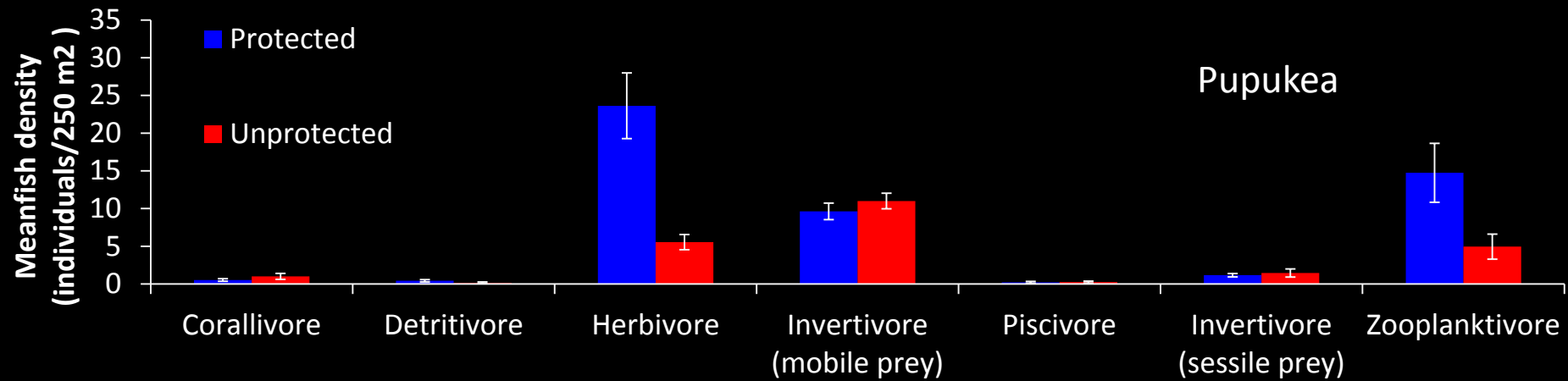
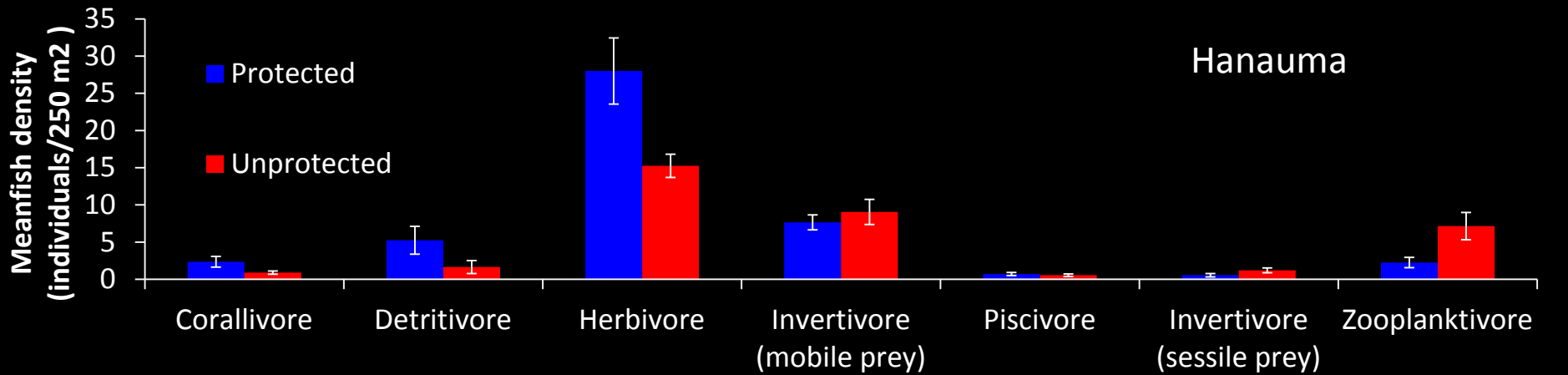
# Species richness among locations





## Dominance plot using fish species abundance





# 7 species of coral affected by lesions

*Montipora capitata*



Photo: Keoki Stender

# 7 species of coral affected by lesions

*Montipora patula*



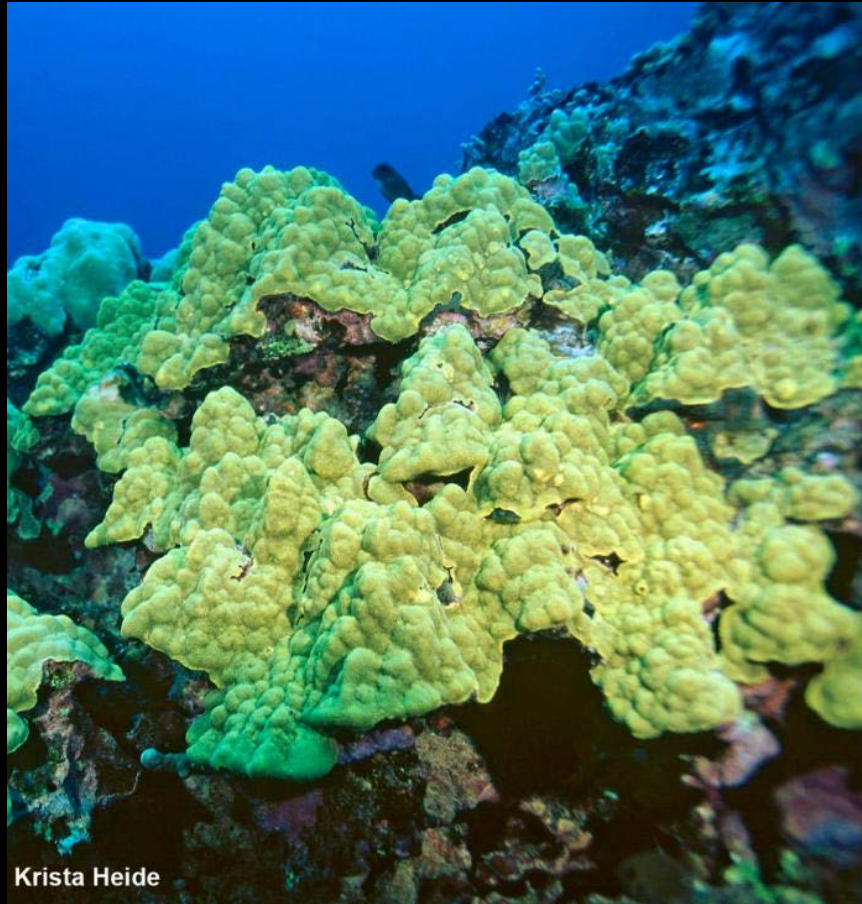
Photo: Linda Preskitt

© LINDA PRESKITT



# 7 species of coral affected by lesions

*Porites lobata*



Krista Heide

Photo: Krista Heide

# 7 species of coral affected by lesions

*Porites evermanni*



Photo: Linda Preskitt

# 7 species of coral affected by lesions

*Porites compressa*

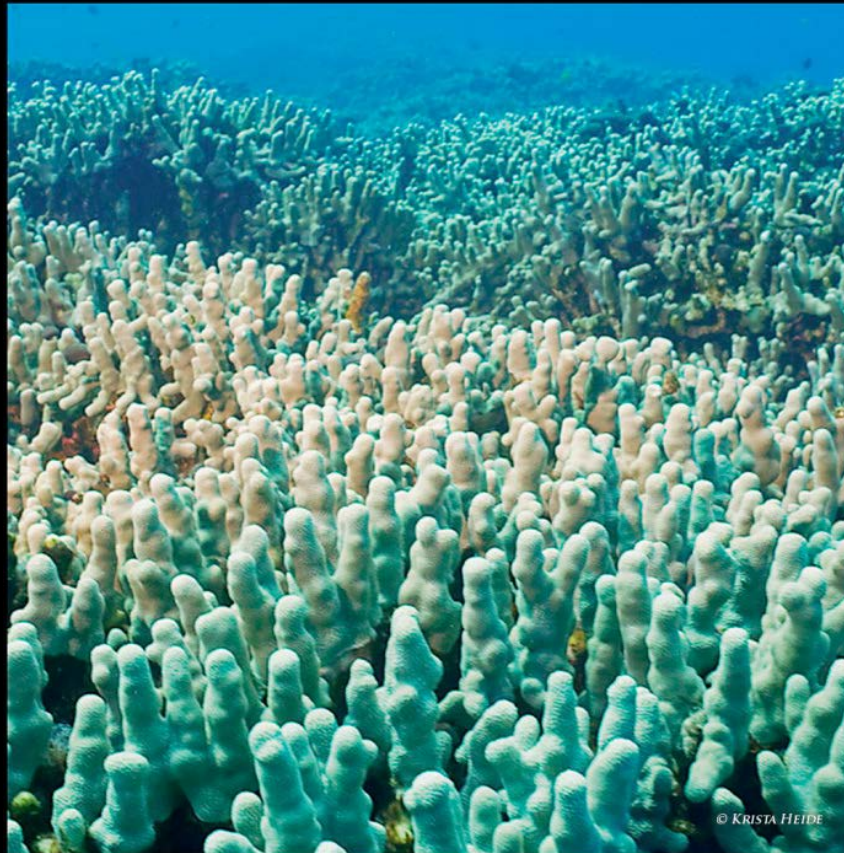


Photo: Krista Heide



# 7 species of coral affected by lesions

*Pocillopora meandrina*



Photo: Linda Preskitt



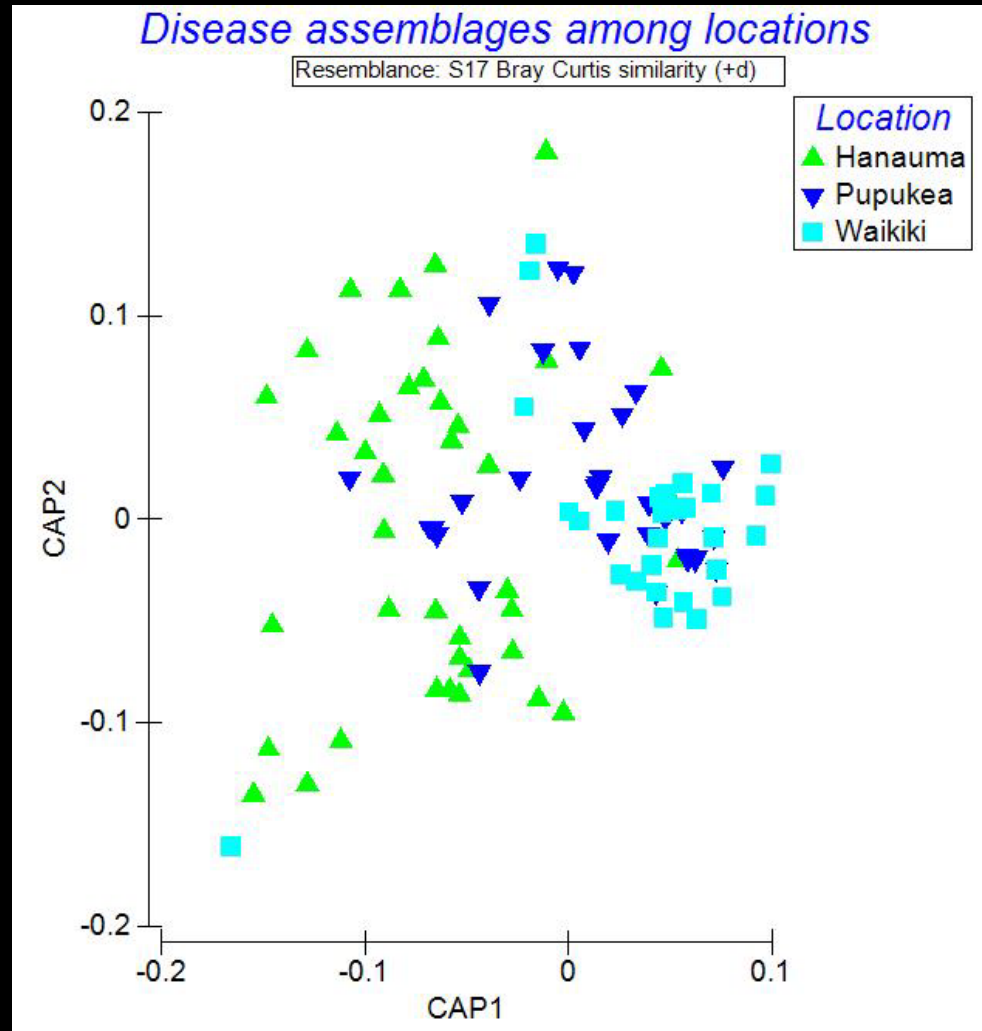
# 7 species of coral affected by lesions

*Pavona varians*



Photo: Linda Preskitt

# Differences in disease assemblages among sites




Disease assemblages were significantly different between the three locations studied on Oahu (PERMANOVA,  $P < 0.0001$ ).


# Random points in areas with greater than 10% coral cover


## Legend

### Hanauma In


 <all other values>


### COVER


 Coral 10%-<50%


 Coral 50%-<90%

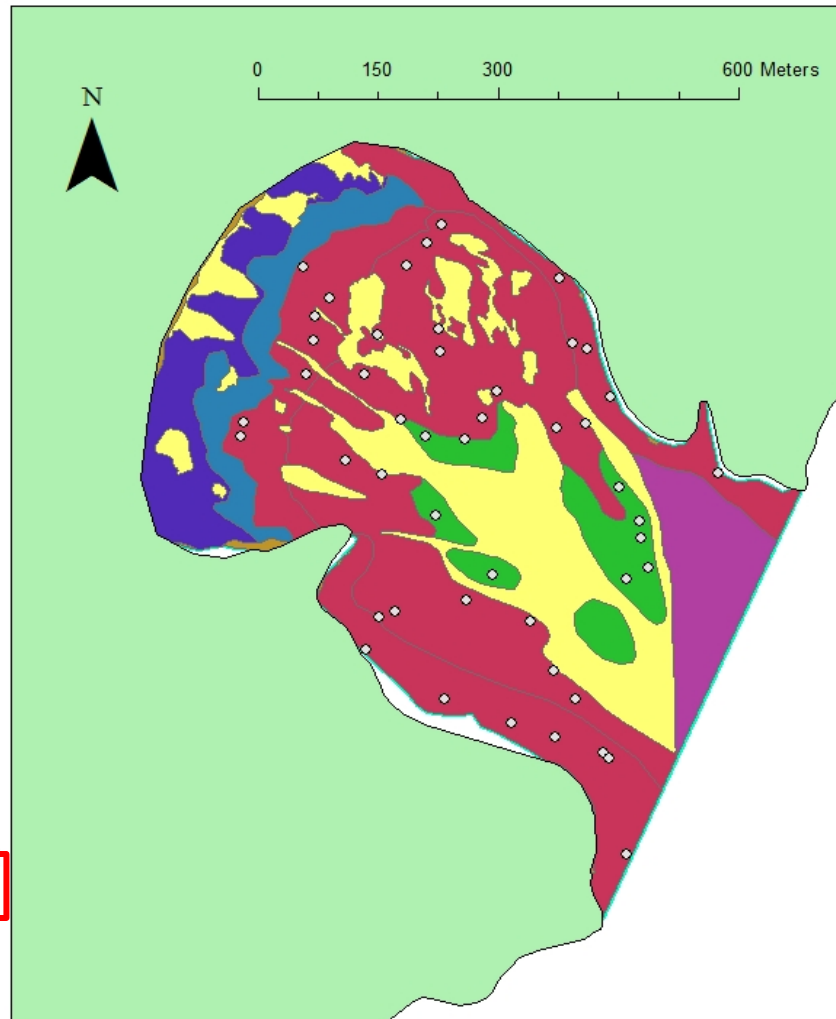
 Coralline Algae 50%-<90%

 Turf 50%-<90%

 Unclassified

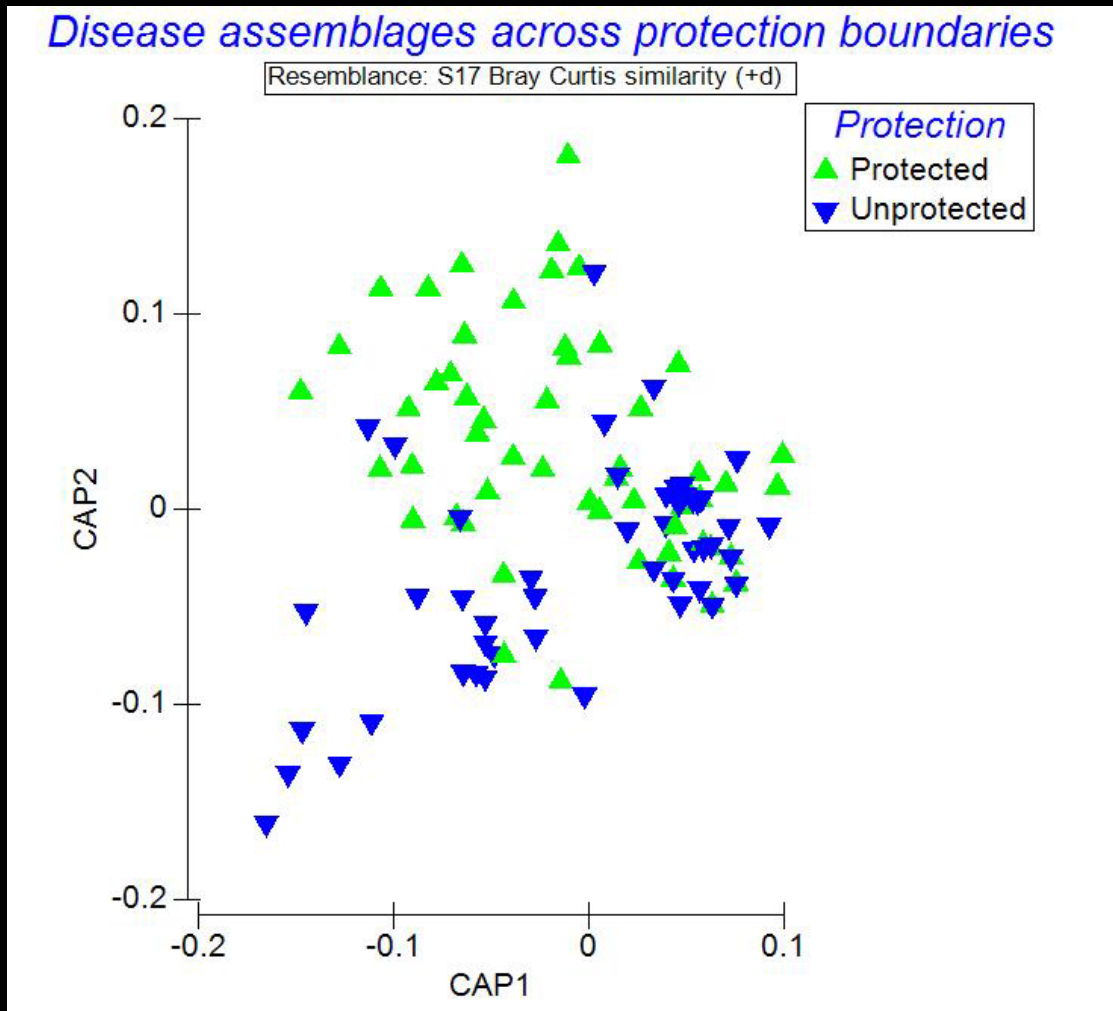
 Uncolonized 90%-100%

 Unknown Unknown



Benthic habitat maps from NOAA

# Differences in disease assemblages across protective boundaries



Disease assemblages were significantly different across protective boundaries (PERMANOVA,  $P < 0.0001$ ).