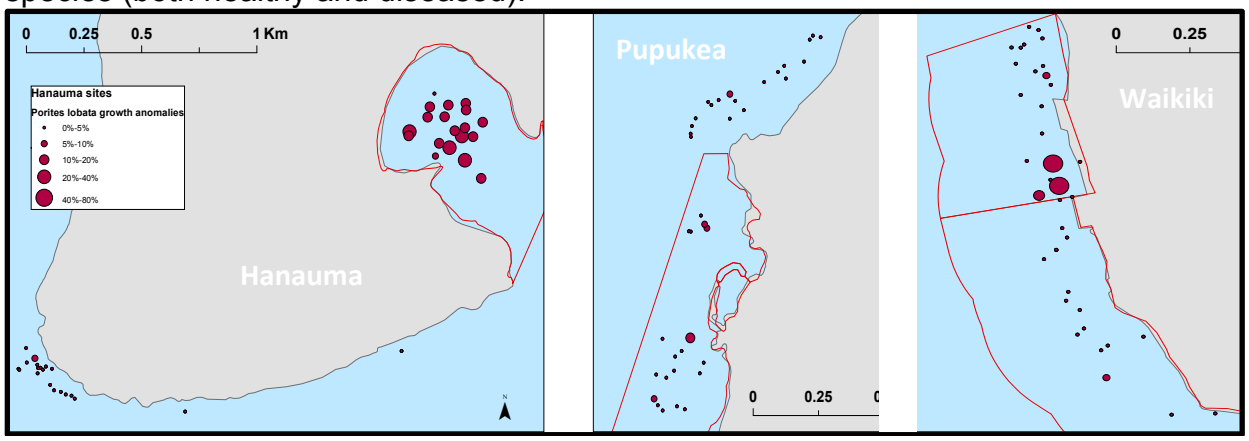
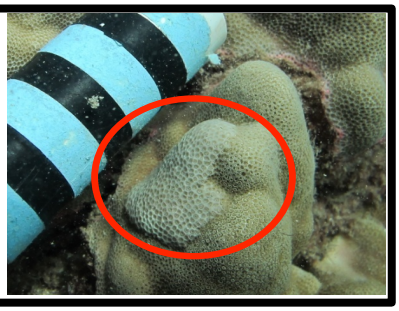
Comparing coral reef ecosystem health inside and outside of Oahu's MLCDs

The study

Management actions, such as the use of Marine Life Conservation Districts (MLCDs), which enhance fish abundance and diversity, could have important downstream impacts on coral reef ecosystem health and coral reef resilience. We investigated coral reef health in Oahu's three MLCDs compared to three comparable nearby unprotected reefs through indicators of ecosystem health including coral disease levels, coral cover, macroalgal cover, coral community size structure, sediment grain size and composition, and fish density (herbivores, corallivores, and piscivores). Prevalence was standardized against coral density and was calculated as the total number of colonies of a specific coral species with a specific lesion type divided by the total number of colonies of that species (both healthy and diseased).



Prevalence maps for *Porites* growth anomalies: Red lines mark the boundary of the Hanauma, Pupukea, and Waikiki MLCDs. Each circle represents a survey site and the size of the circle corresponds to prevalence levels (larger circles indicate higher disease prevalence). Additional "prevalence maps" are provided at the end of this report.



Major findings

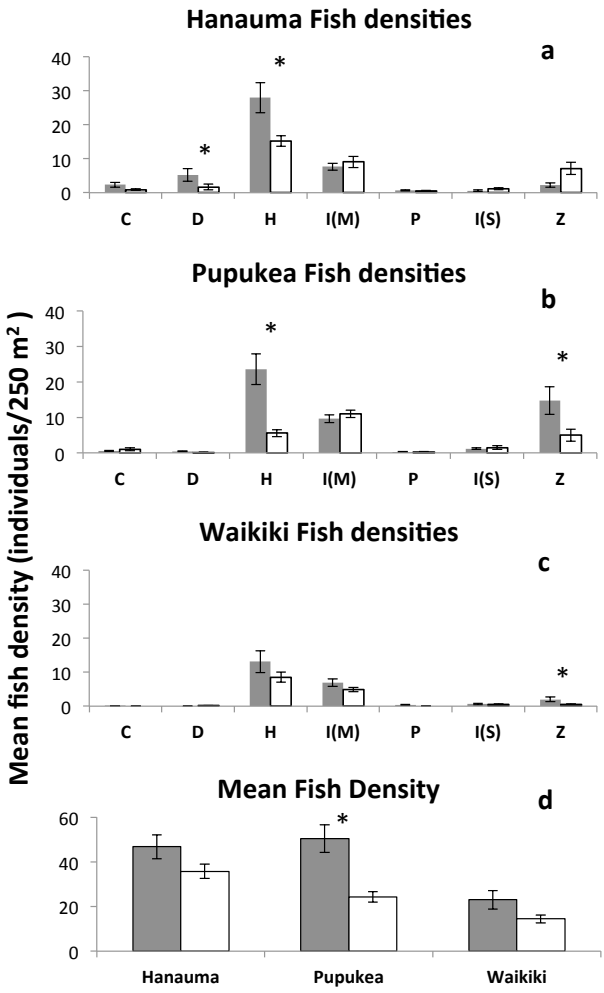
- Percent cover of host species of coral was a strong predictor in statistical models. In other words, for certain types of coral diseases, disease levels were correlated with coral cover.
- MLCDs may act as a refuge for fish but their high coral cover may potentially make them vulnerable to disease outbreaks compared to other locations. For certain types of diseases this could potentially be due to decreased distance between host colonies.
- Fish populations showed a trend of higher densities in MLCDs compared to adjacent unprotected sites.

Major findings continued

- Comparisons of macroalgae levels showed higher levels of macroalgae at the Waikiki MLCD compared to the Pupukea MLCD and Hanauma MLCD. When Macroalgae levels were compared across protection boundaries (protected vs. unprotected) no significant differences were found.
- Water quality, indicated by higher fractions of silt in sediment samples, may play an important role in disease dynamics.

Recommendations

- ***Continued long term monitoring of coral reef ecosystem health*** –Our models showed host cover as one of the strongest predictors of coral disease prevalence. MLCDs are sites with dense coral populations and should continue to be regularly monitored for disease and other signs of reduced coral reef ecosystem health.
- ***Integration of watershed management*** **-** Multivariate analyses showed that silt sediment fractions were the best predictor for prevalence of *Porites lobata* growth anomalies. Higher fractions of silt in sediment samples may be linked to lower rates of sediment removal and longer residence times of land-based pollutants. The potential connection between silt levels, length of exposure to potential contaminants, and prevalence of growth anomalies should be further explored to clarify the role that water quality plays in this disease process.
- ***Community involvement through Makai Watch Programs -*** Pupukea was the only location to have statistically significant higher fish densities in the MLCD compared to adjacent unprotected sites. This site is unique in the high level of community involvement in the MLCD from the Makai Watch program, Malama Pupukea Waimea. It is possible that educational outreach and reporting of poaching through the organization has translated into greater compliance within the MLCD and in turn higher densities of fish within the MLCD.

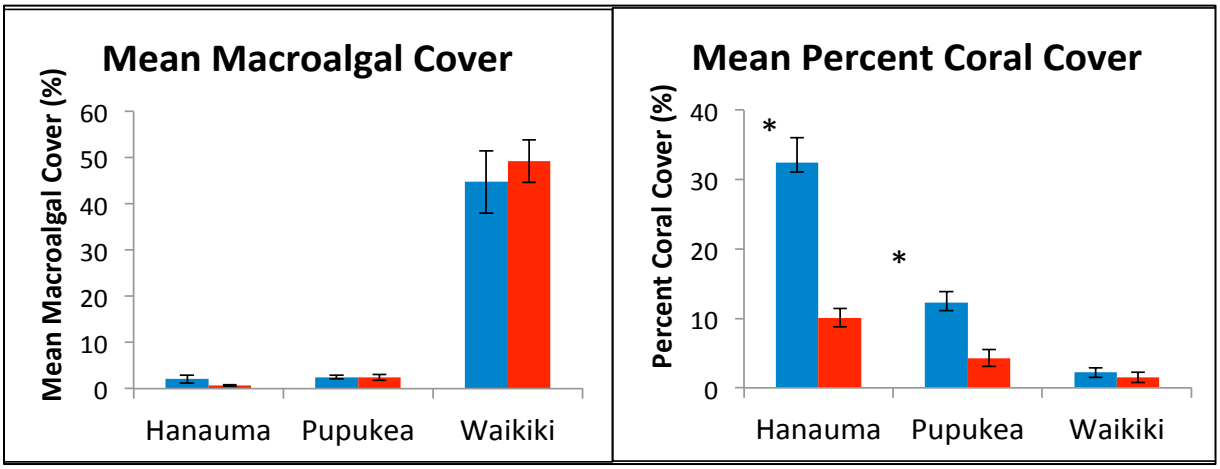


Mean fish density: Grey (MLCD) and white (unprotected) bars represent mean fish density at each of the locations. Black lines indicate standard error and * indicates significant difference (Kruskal-Wallis test, $p<0.0001$). Fish trophic guilds are abbreviated along the x-axis for **a-c**: Corallivore (C), Detritivore (D), Herbivore (H), Invertivore-mobile prey (I(M)), Piscivore (P), Invertivore-sessile prey (I(S)), and Zooplanktivore (Z).

Additional tables and figures

Mean prevalence of five common diseases across protection boundaries: Standard errors in parentheses. MLCDs are represented under columns marked as Protected. Red indicates significantly higher prevalence in MLCD, and blue indicates significantly higher prevalence in unprotected area based on a Kruskal-Wallis test ($p<0.05$).

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



Mean macroalgal and percent coral cover: Blue (MLCD) and red (unprotected) bars represent mean macroalgal or percent coral cover. Black lines show standard error and * indicates significant difference between protected and unprotected sites for that location (Kruskal-Wallis test, $p<0.05$).

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Disease Prevalence Maps

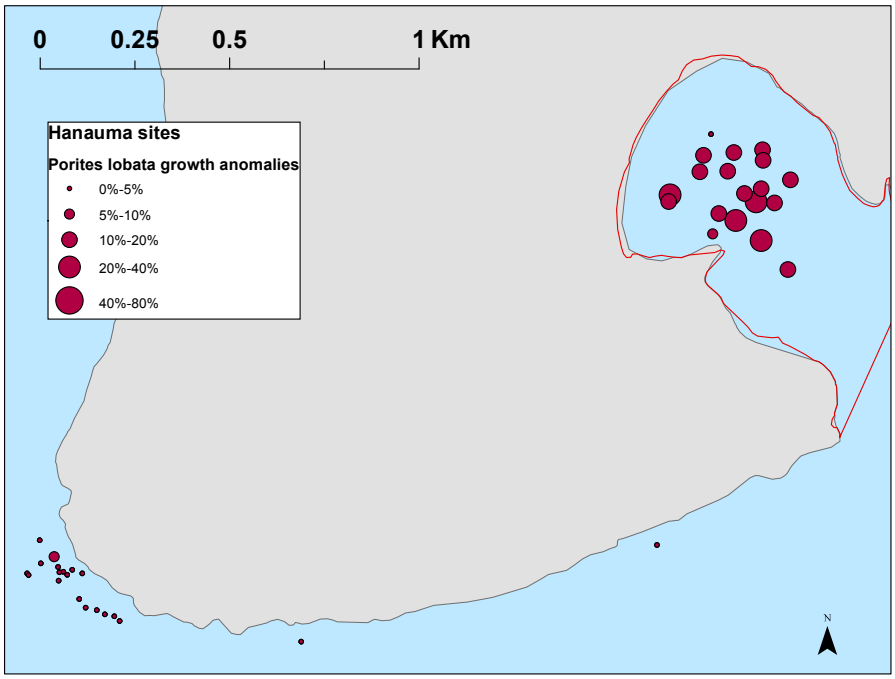

Figure 1. Prevalence of *Porites lobata* growth anomalies at the Hanauma sites. Red lines mark the boundary of the MLCD.

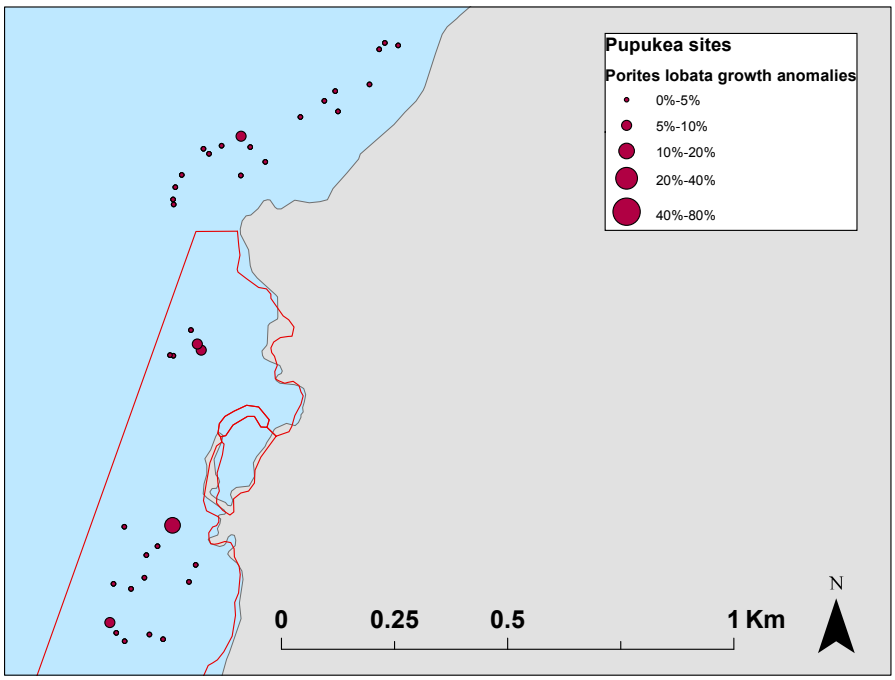

Figure 2. Prevalence of *Porites lobata* growth anomalies at the Pupukea sites. Red lines mark the boundary of the MLCD.

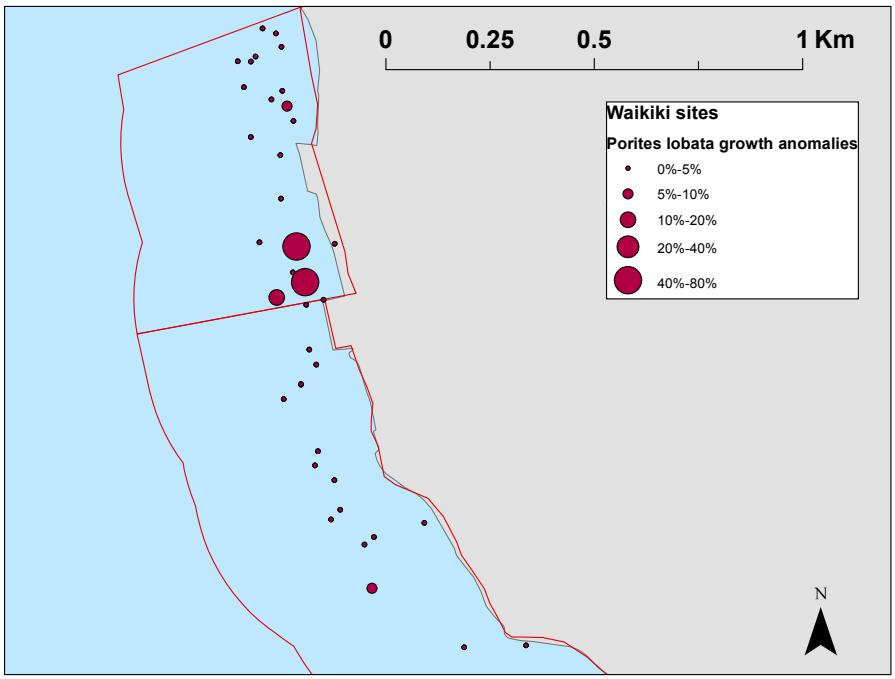

Figure 3. Prevalence of *Porites lobata* growth anomalies at the Waikiki sites. Red lines mark the boundary of the MLCD.

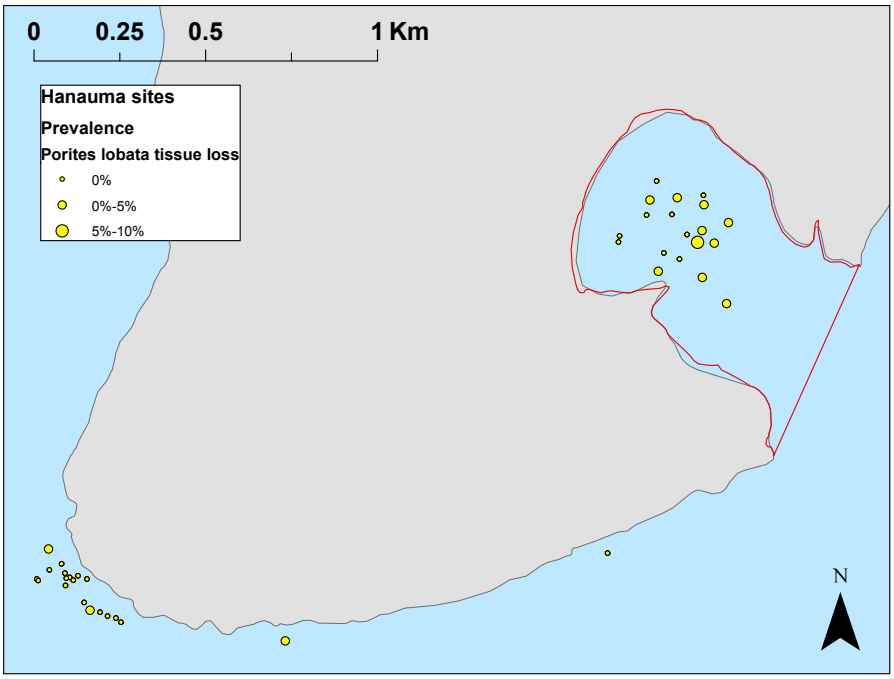

Figure 4. Prevalence of *Porites lobata* tissue loss at the Hanauma sites. Red lines mark the boundary of the MLCD.

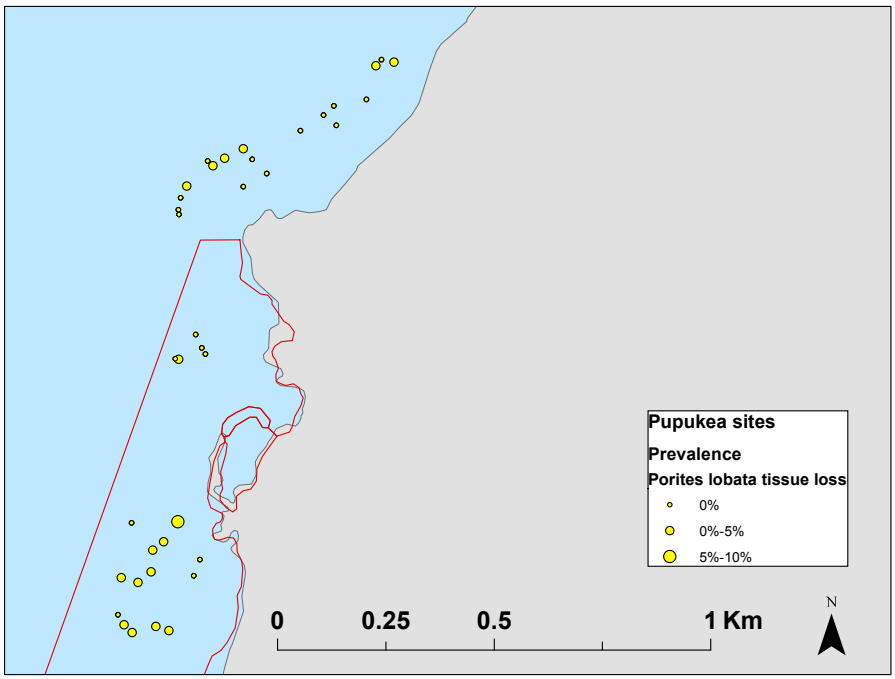

Figure 5. Prevalence of *Porites lobata* tissue loss at the Pupukea sites. Red lines mark the boundary of the MLCD.

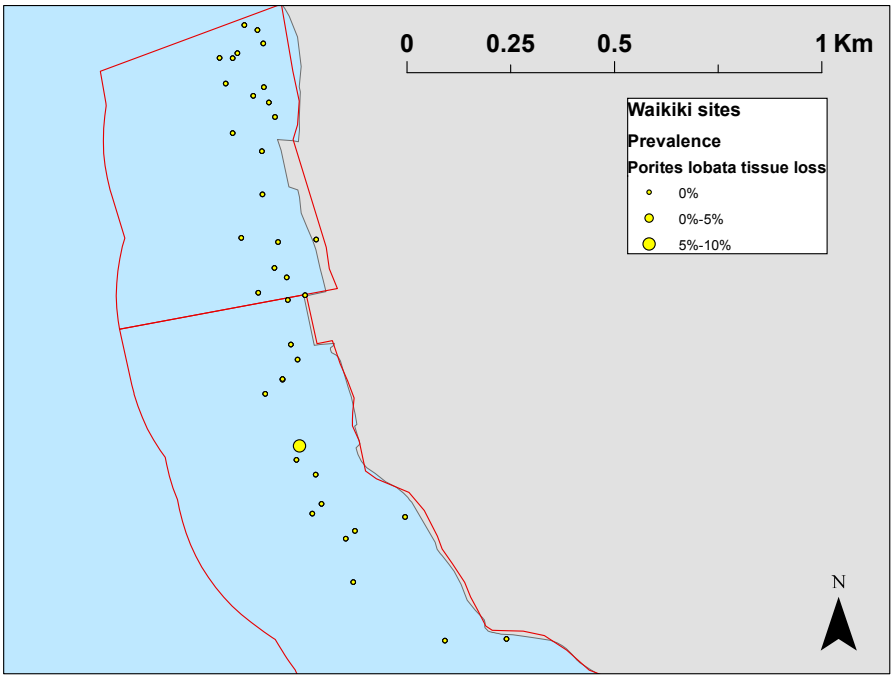

Figure 6. Prevalence of *Porites lobata* tissue loss at the Waikiki sites. Red lines mark the boundary of the MLCD.

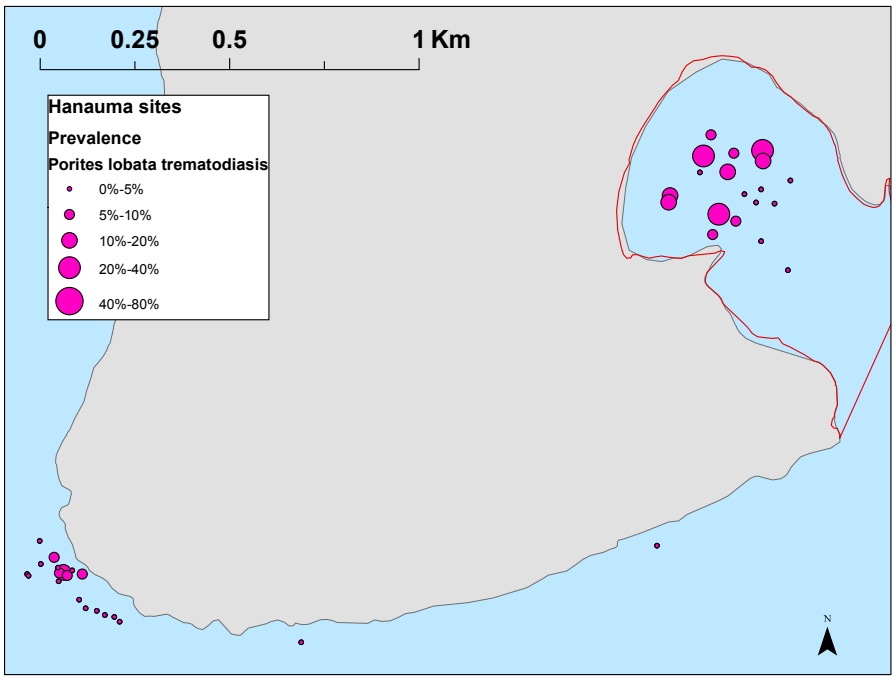

Figure 7. Prevalence of *Porites lobata* trematodiasis at the Hanauma sites. Red lines mark the boundary of the MLCD.

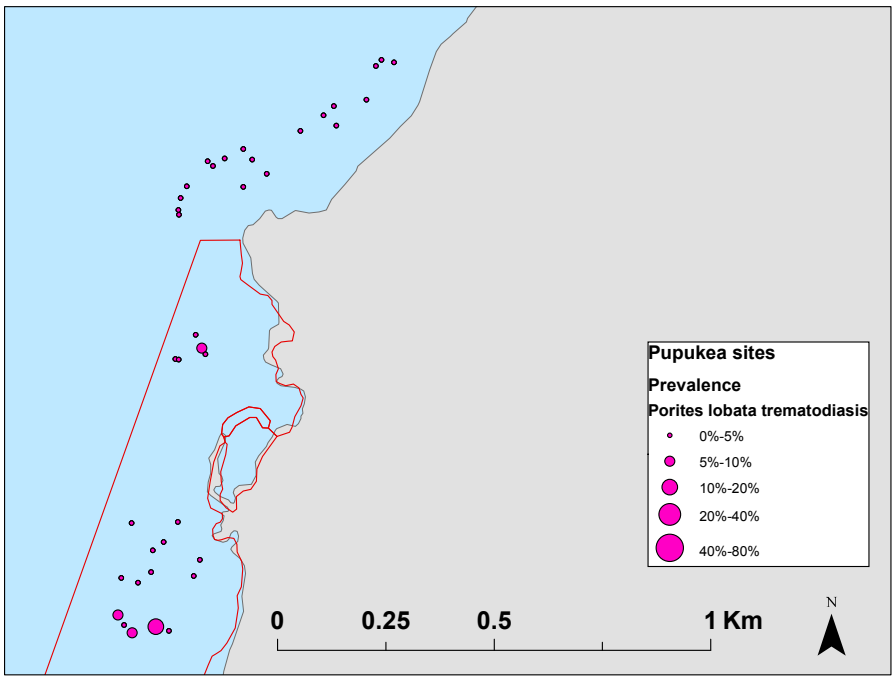

Figure 8. Prevalence of *Porites lobata* trematodiasis at the Pupukea sites. Red lines mark the boundary of the MLCD.

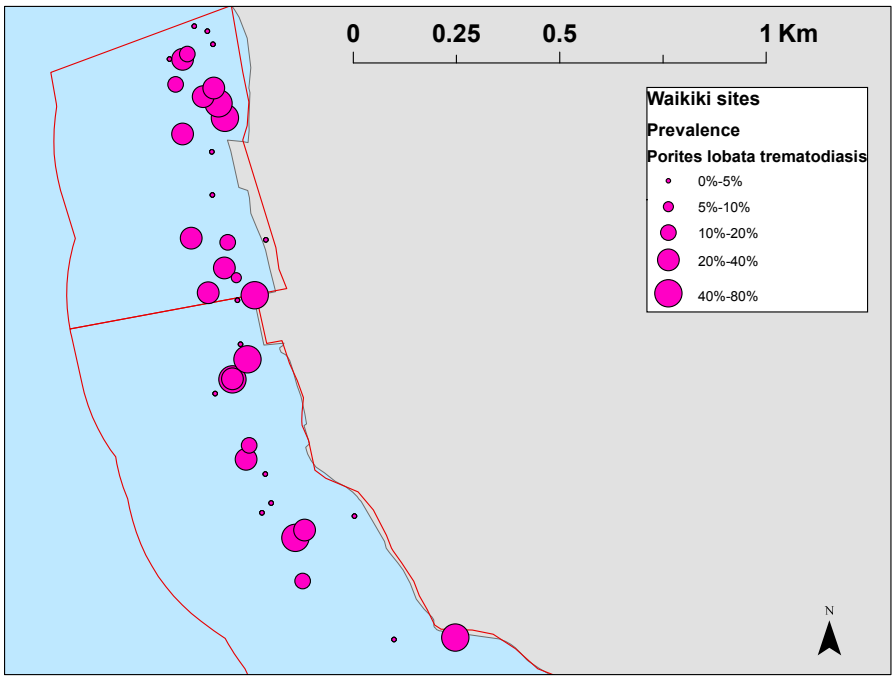

Figure 9. Prevalence of *Porites lobata* trematodiasis at the Waikiki sites. Red lines mark the boundary of the MLCD.

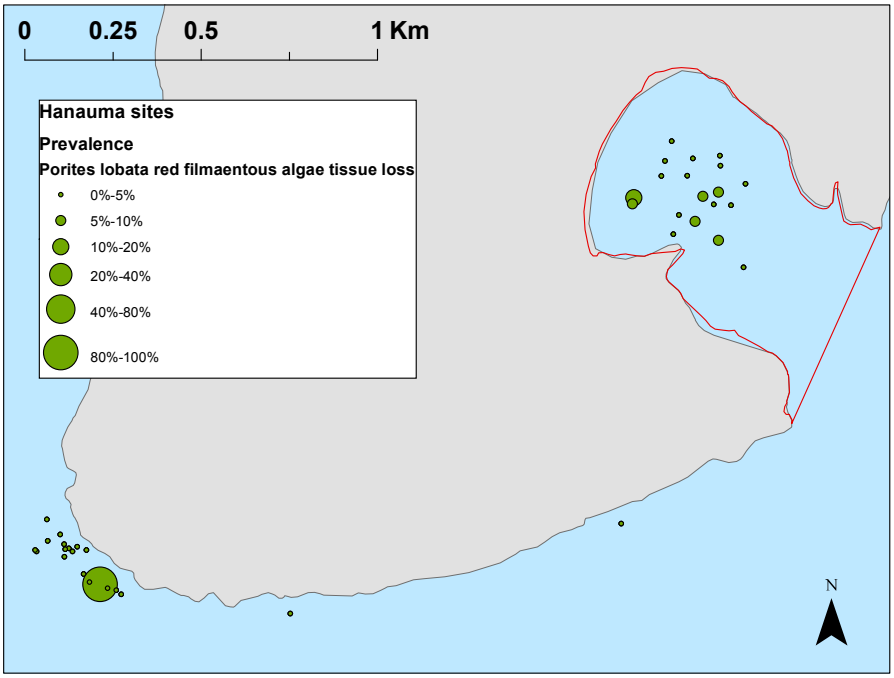

Figure 10. Prevalence of *Porites lobata* red filamentous algae tissue loss at the Hanauma sites. Red lines mark the boundary of the MLCD.

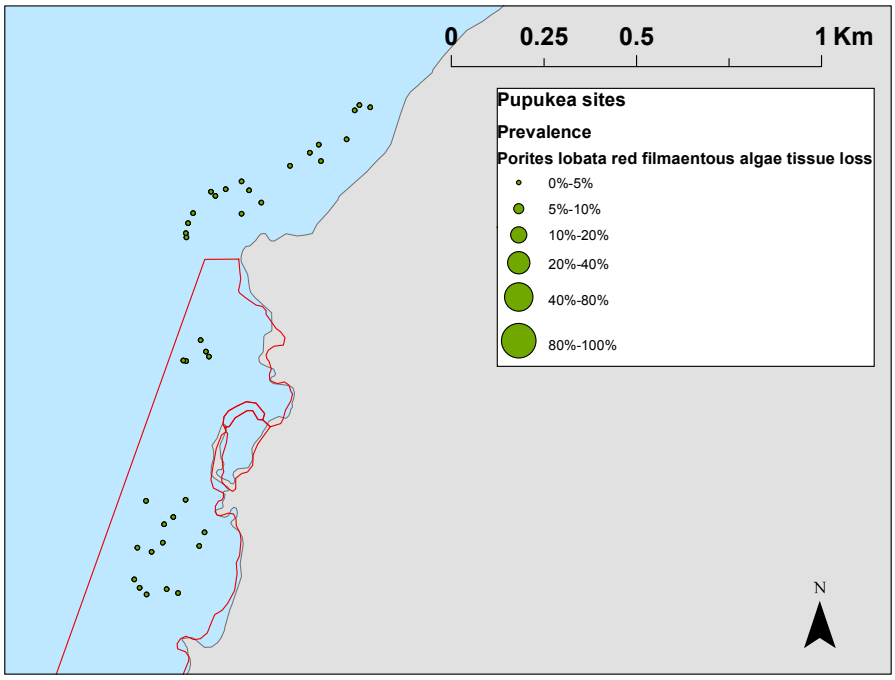

Figure 11. Prevalence of *Porites lobata* red filamentous algae tissue loss at the Pupukea sites. Red lines mark the boundary of the MLCD.

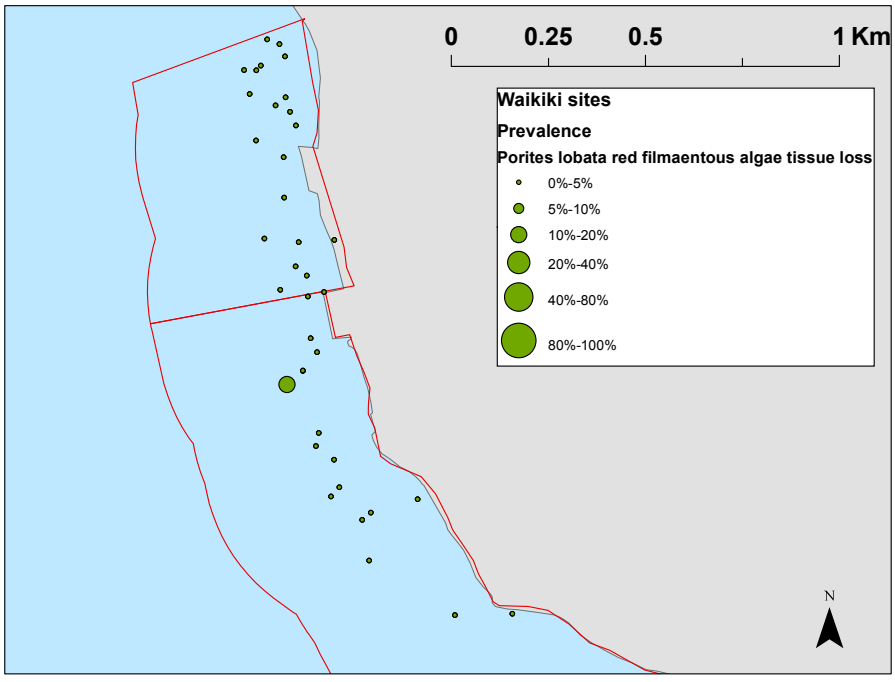

Figure 12. Prevalence of *Porites lobata* red filamentous algae tissue loss at the Waikiki sites. Red lines mark the boundary of the MLCD.

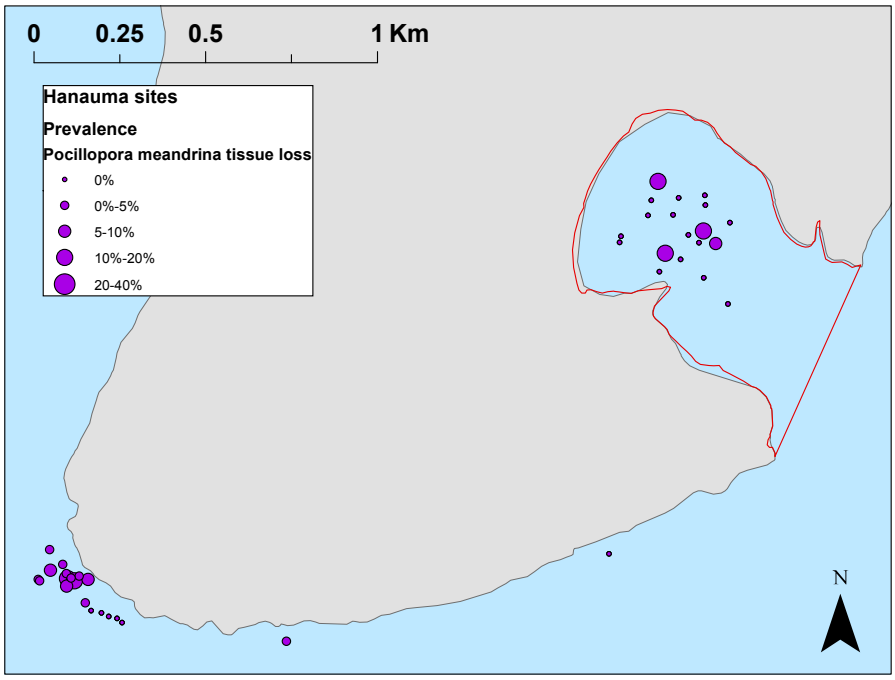

Figure 13. Prevalence of *Pocillopora meandrina* tissue loss at the Hanauma sites. Red lines mark the boundary of the MLCD.

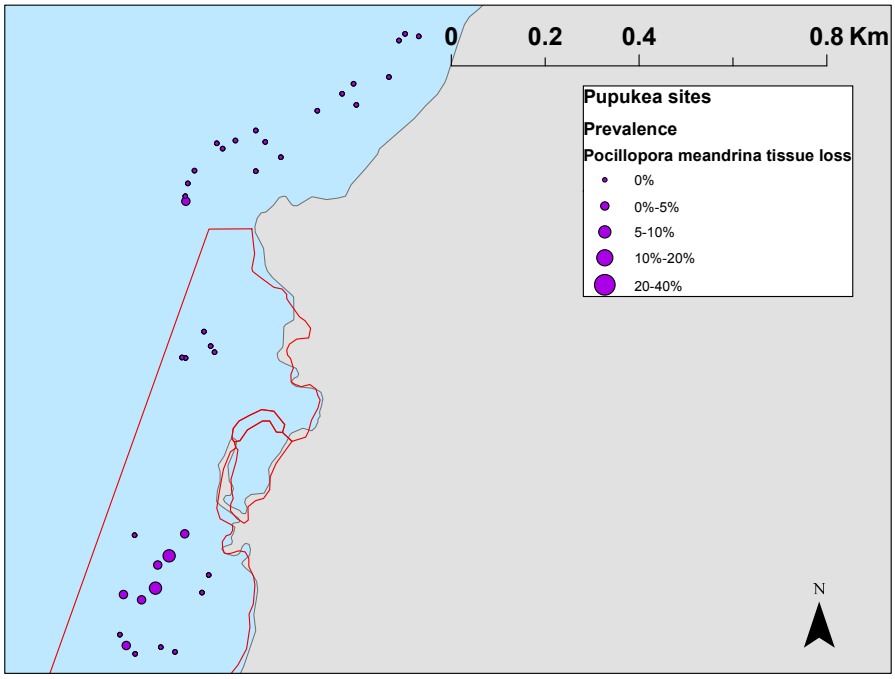

Figure 14. Prevalence of *Pocillopora meandrina* tissue loss at the Pupukea sites. Red lines mark the boundary of the MLCD.

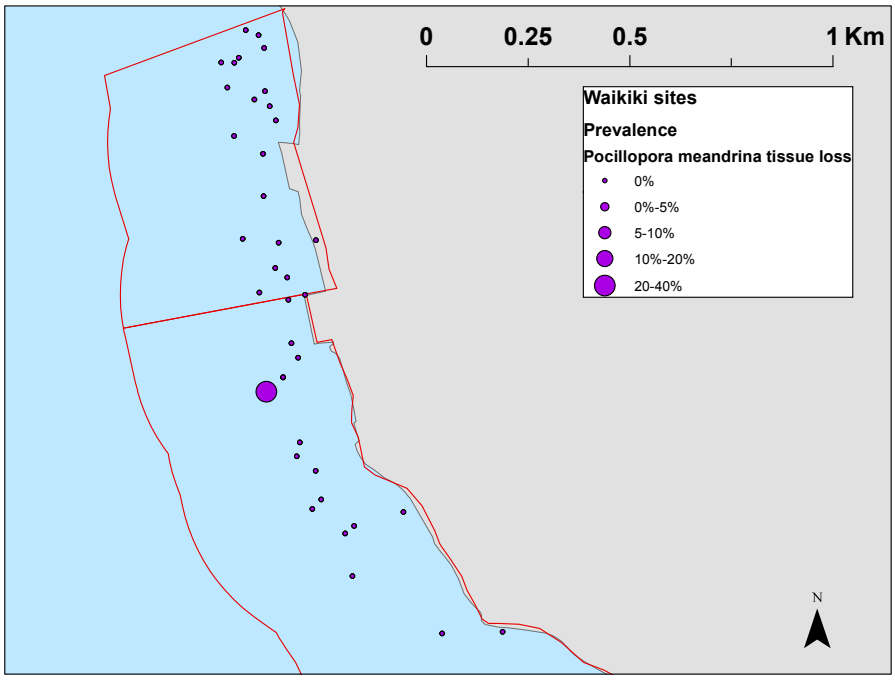

Figure 15. Prevalence of *Pocillopora meandrina* tissue loss at the Waikiki sites. Red lines mark the boundary of the MLCD.