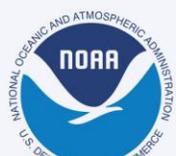




# Relative resilience potential and bleaching severity in the West Hawai'i Habitat Focus Area in 2015

Jeffrey Maynard\*, Eric Conklin\*, Dwayne Minton, Rebecca Most, Courtney Couch, Gareth Williams, Jamison Gove, Brett Schumacher, William Walsh, Jonathan Martinez, Douglas Harper, Danielle Jayewardene, Britt Parker, Lani Watson

\*Project Co-leaders



CITATION:

Maynard, J., Conklin, E., Minton, D., Most, R., Couch, C., Williams, G.J., Gove, J., Schumacher, B., Walsh, W., Martinez, J., Harper, D., Jayewardene D., Parker, B., Watson, L. 2016. Relative resilience potential and bleaching severity in the West Hawai'i Habitat Focus Area in 2015. NOAA Coral Reef Conservation Program. NOAA Technical Memorandum CRCP 26, 53 pp. doi:10.7289/V5T43R4Z

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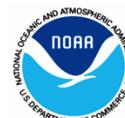
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National Oceanic and Atmospheric Administration  
National Ocean Service  
Office for Coastal Management  
Coral Reef Conservation Program

December 2016



### NOAA Technical Memorandum CRCP 26



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## Relative resilience potential and bleaching severity in the West Hawai'i Habitat Focus Area in 2015

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### **Acknowledgments**

Financial support for this applied research was provided by the NOAA Coral Reef Conservation Program, matched by contributions from The Nature Conservancy and SymbioSeas. The Hawai'i Division of Aquatic Resources helped support the fieldwork. The authors thank the Moana Ohana LLC for field support, and all those that assisted with fieldwork. The contents of this report are solely the opinions of the authors and do not constitute a statement of policy, decision, or position on behalf of NOAA or the U.S. Government.



## Executive Summary

### *Relative resilience potential and bleaching severity in the West Hawai'i Habitat Focus Area in 2015*

Jeffrey Maynard\*, Eric Conklin\*, Dwayne Minton, Rebecca Most, Courtney Couch, Gareth Williams, Jamison Gove, Dieter Tracey, Brett Schumacher, William Walsh, Jonathan Martinez, Douglas Harper, Danielle Jayewardene, Britt Parker, Lani Watson [\*Project Co-leaders]

**Introduction** - The NOAA Coral Reef Conservation Program (CRCP), NOAA Habitat Blueprint, and Sentinel Site Program have an overlapping [Focus Area](#) on the west side of the Island of Hawai'i that includes the South Kohala coastline. The Habitat Blueprint and Sentinel Sites focus areas have merged into a single effort. In addition, the NOAA Hawaiian Islands Humpback Whale National Marine Sanctuary and the West Hawaii Integrated Ecosystem Assessment Program both support and are supported by the focus area initiative. Nearly a quarter of the coral and fish species in Hawaii are endemic (i.e., can only be found in the Hawaiian Islands) and South Kohala contains one of the longest contiguous coral reefs in the state. Coral reefs are of critical importance to the communities and environment of West Hawai'i, and supporting the resilience of reefs is a goal within many management plans in the area.

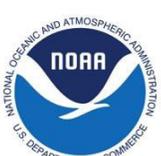
Coral reef resilience is the capacity of a reef to resist or recover from degradation and maintain provision of ecosystem goods and services. Resilience-based management of coral reefs can include assessing spatial variation in resilience potential and then targeting and tailoring appropriate actions to preserve or restore resilience. The assessments involve measuring or assessing resilience indicators (e.g., coral disease, coral recruitment and herbivorous fish biomass) and producing an aggregate score that expresses resilience potential for all sites as relative to the site with the highest (assessed) resilience potential.

Our project team assessed the relative resilience potential of reef sites at two depths along priority areas of South Kohala and North Kona in October of 2015. The surveys were conducted as a collaborative effort with the Hawai'i Division of Aquatic Resources (DAR), The Nature Conservancy, NOAA Coral Reef Ecosystem Program, and community organizations. While conducting the resilience surveys, the project team also assessed coral bleaching prevalence and severity as well as coral disease prevalence. By October 2015, NOAA Coral Reef Watch confirmed that West Hawai'i experienced greater thermal stress than anywhere else in the Hawaiian Archipelago that year. This report presents results from the resilience and bleaching surveys, which forms year 1 of a 2-year project. During Year 2 (Oct. 2016-Sept. 2017) our team will use the resilience analysis outputs to identify, discuss (with stakeholders and community members), and prioritize recommended potential management actions to support the resilience of coral reefs in the Focus Area.

**Objectives** - Study objectives included: 1) Assess the percentage of corals affected by bleaching and severe (>50% of colony) bleaching and by coral diseases; 2) Assess the percentage cover of major benthic groups, including corals, macroalgae, coralline algae, and other (i.e., turf algae and unconsolidated substrate); 3) Assess the relative resilience potential of coral reefs at two depths and compare resilience potential among survey sites, and 4) Determine the primary drivers of differences in resilience potential between sites.

**Methods** - Field surveys were conducted at 20 sites, which included surveys of both shallow (5-7 m) and deep (12-15 m) reef areas. Eighteen of these sites are in the Habitat Focus Area and 2 are south. Surveys were conducted October 13-23, 2015. Survey methods included belt transects, quadrats and photo-quadrats, and are standard methods used by this team and other researchers to survey coral reefs in Hawai'i and the Pacific. The resilience indicators included coral cover, coral recruitment, coral diversity, bleaching resistance, macroalgae cover, rugosity and herbivorous fish biomass. Scores for these indicators were normalized to values of 0-1 by dividing all scores by the greatest score. Indicator scores were then averaged for each depth at each site, and those values normalized to values of 0-1 expressing resilience as a decimal percentage of the site with the greatest

*Assessing relative resilience and bleaching severity in west Hawai'i*





average score for the indicators. Sites were then ranked from highest to lowest score for both depths and put into these relative classes: high (scores that are  $>1$  sd above average (avg) and  $\leq 1$ ), medium-high ( $< \text{avg} + 1\text{sd}$  and  $> \text{avg}$ ), medium-low ( $< \text{avg}$  and  $> \text{avg} - 1\text{sd}$ ), and low ( $< \text{avg} - 1\text{sd}$ ). A canonical analysis of principal coordinates ('CAP analysis') was used to examine which indicators were driving differences in resilience potential.

**Results - Obj. 1 – Bleaching and Disease:** An average ( $\pm 1\text{sd}$ ) of  $68.41 \pm 15.23\%$  of shallow and  $59.96 \pm 17.66\%$  of deep corals were partially or fully bleached. Survey sites in South Kohala had worse bleaching than those in North Kona.

Amongst the most affected sites were shallow regions at Kanekanaka, Kawaihae and Ohai'ula where 80-85% of the corals severely bleached. Preliminary results suggest that some South Kohala reefs experienced 55-99% coral mortality due to bleaching in 2015. Algal overgrowth (primarily by filamentous turf) of recently dead and severely bleached corals ranged from 3-60% and was  $>10\%$  at all sites excepting Keawaiki. Diseases observed include: *Porites* Growth Anomalies, *Montipora* Growth Anomalies, *Porites* Tissue Loss Syndrome, *Pocillopora* Tissue Loss Syndrome and *Porites* Trematodiasis. Disease prevalence (all diseases) was slightly greater among the shallow than deep reef areas and was also more variable among the shallow than deep reef areas. Average disease prevalence was  $6.50 \pm 4.02\%$  among the shallow reef areas and  $5.31 \pm 2.88\%$  among the deep reef areas.

**Obj. 2 – Benthic Cover:** At both depths and across all sites,  $>40\%$  of the substrate was made up by 'other' (i.e., turfing algae and unconsolidated substrate); macroalgae was  $<1\%$  and crustose coralline algae cover was  $<25\%$ . Average coral cover in the shallow reef areas was  $28.24 \pm 9.16\%$  and in the deep reef areas was  $22.67 \pm 10.70\%$ . Coral cover was highest ( $>35\%$ ) in the shallow areas at Kalaemanō (50%), Keanapukalua (42%), and Mākole'ā (39%). Coral cover was highest ( $>30\%$ ) in the deep areas at Honokōhau (54%), Laehou (41%), Makalawena (32%), and Keonenui (32%). Twenty-seven coral species were observed in total. Coral species richness varied among sites from 6 (Honokōhau – Deep) to 15 coral species ('Ōhae'ula Deep).

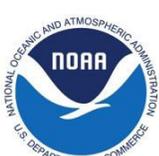
**Obj. 3 – Relative Resilience:**

**Shallow** – Normalized resilience scores ranged from 0.52 to 1.00. Two sites were assessed as having high relative resilience, 8 medium-high, 7 medium-low, and 3 low. The 2 sites with high relative resilience are Laehou and Kumukea; these sites are in central and southern South Kohala (Figure 1). The 3 sites with low relative resilience are 'Ōhae'ula, Kanekanaka Pt, and Puakō; these sites are in northern South Kohala (Figure 1). There is a general pattern that values for all resilience indicators are lower in northern South Kohala and higher in southern South Kohala.

**Deep** – Normalized resilience scores ranged from 0.55 to 1.00. Two sites were assessed as having high relative resilience, 9 medium-high, 6 medium-low, and 3 low. The 2 sites with high relative resilience are Laehou and Kīholo; these are adjacent sites in central South Kohala (Figure 1). The 3 sites with low relative resilience are Kawaihae, Kapalaoa, and Lulahala Pt; these sites are in central and northern South Kohala, respectively (Figure 1). As with the shallow reef areas, there is a general pattern that values for all resilience indicators are lower in northern South Kohala and higher in southern South Kohala.

**Obj. 4 – Resilience Drivers:** It was possible that high resilience sites could have this classification as a result of having high scores for different indicators and low resilience sites could have this classification as a result of having low scores for different indicators. We examined whether high scores for some indicators are consistently associated with high resilience (and low scores for some indicators with low resilience) using a CAP analysis.

*Assessing relative resilience and bleaching severity in west Hawai'i*





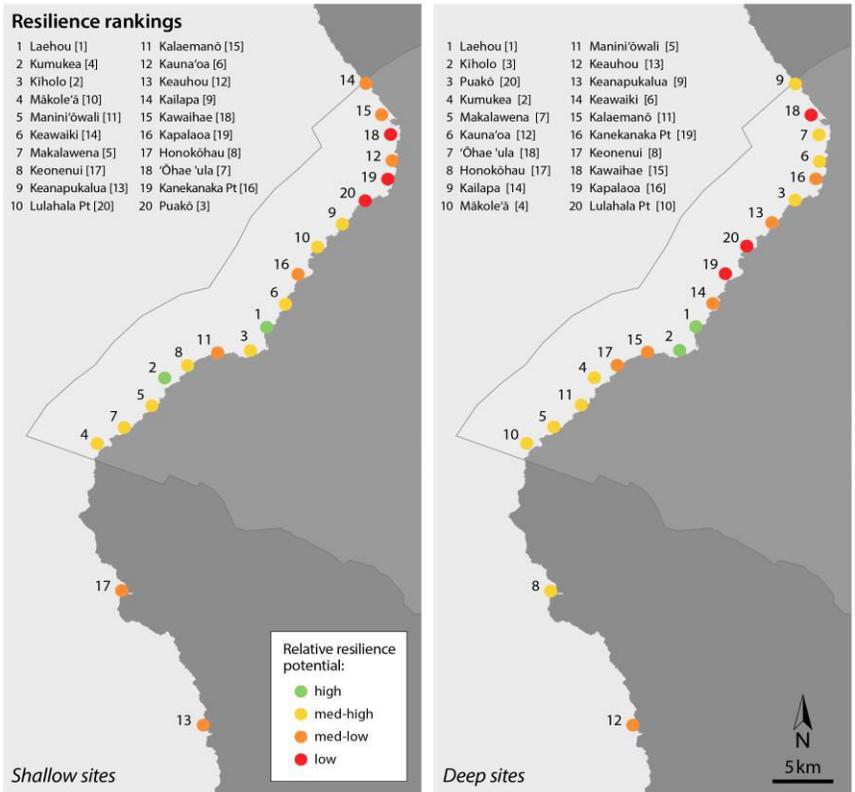
For the shallow sites, high and medium-high resilience potential were principally characterized by high bleaching resistance and to a lesser extent by high herbivorous fish biomass and coral recruitment and low coral disease (Fig. 3 top, see vectors along the CAP1). Low bleaching resistance, herbivorous fish biomass and coral recruitment principally characterized medium-low and low resilience potential.

For the deep sites, high and medium-high resilience potential were principally characterized by high coral recruitment (Fig. 3 bottom, see vector along CAP1) and to a lesser extent by high coral cover and coral diversity and low macroalgae cover. The high resilience potential sites appeared separated out from the medium-high due to having higher bleaching resistance values. (Fig. 3 bottom, see vector along CAP3). Low coral recruitment and herbivorous fish biomass and low coral diversity principally characterized medium-low and low resilience sites.

**Next steps - *Ocean Tipping Points*** project team members have helped us compile information on spatial variation in anthropogenic stress, including: sedimentation, effluent, phosphorous and nitrogen flux, presence of development, and commercial and recreational fishing. We have combined these anthropogenic stress data layers with the resilience assessment results to identify potential management actions to support or improve resilience at low resilience sites and maintain resilience potential at high resilience sites. Following on from these recent efforts, during project year 2 (Oct. 2016 – Sept. 2017) we will chair workshops to discuss the project methods and potential management actions recommended by this work, host community meetings in West Hawai'i to share and discuss the project results, assess coral community recovery from the 2015 bleaching event, develop a 'Summary for Policymakers' describing the final management recommendations and pathways for implementation, present a webinar and prepare a follow-up to this report.

**Site Summaries** - This report concludes with *Site Summaries*. These are 1-page summaries for each survey site that present the site name origin, coordinates and resilience ranks, photographs, resilience indicator scores, a benthic community pie chart, bleaching/disease prevalence values, and coral and fish species lists.

**Acknowledgments** - Financial support for this applied research was provided by the NOAA Coral Reef Conservation Program, with in-kind contributions from The Nature Conservancy and SymbioSeas. The Hawai'i Division of Aquatic Resources and Moana Ohana LLC helped support the fieldwork. The authors thank all those that assisted with fieldwork. The contents of this report are solely the opinions of the authors and do not constitute a statement of policy, decision, or position on behalf of NOAA or the U.S. Government.



**Figure 1.** Resilience assessment results for shallow and deep reef areas along the South Kohala (north) and North Kona (south) coastlines of Hawai'i Island. The polygon shape defines the boundaries of the NOAA Habitat Blueprint West Hawai'i Focus Area. Bracketed values represent the resilience rank for the other depth.

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## **Introduction**

The NOAA Coral Reef Conservation Program (CRCP), NOAA Habitat Blueprint, and Sentinel Site Program have an overlapping [Focus Area](#) on the west side of the Island of Hawai'i that includes the South Kohala and North Kona coastline (see area boundary in Figure 1). The Habitat Blueprint and Sentinel Sites focus areas have merged into a single effort. In addition, the NOAA Hawaiian Islands Humpback Whale National Marine Sanctuary supports and is supported by the focus area initiative. Further, West Hawai'i (Kona Area) is a focus of the NOAA National Marine Fisheries West Hawaii Integrated Ecosystems Assessment Project. Nearly a quarter of the coral and fish species in Hawaii are endemic (i.e., can only be found in the Hawaiian Islands) and South Kohala contains one of the longest contiguous coral reefs in the state. Coral reefs are of critical importance to the communities and environment of West Hawai'i. Reefs in this area are home to culturally significant species, are utilized for subsistence fishing, mitigate wave and storm impacts, and provide recreational and economic benefits. Island communities will acutely feel any degradation of these reefs in multiple ways. Supporting the resilience of reefs in the area is a goal within many management plans for West Hawai'i and is regularly mentioned in meetings with local partners led by the NOAA team.

Coral reef resilience is the capacity of a reef to resist or recover from degradation and maintain provision of ecosystem goods and services (Mumby et al. 2007). Resilience-based management (RBM) has been developed to overcome the challenges of supporting ecosystem resilience in this era of rapid change (Bestelmeyer and Briske 2012). RBM involves the application of resilience theory and tools to deliver ecosystem-based management outcomes into the future (Chapin et al. 2009). RBM of coral reefs can include assessing spatial variation in resilience potential and then targeting and tailoring appropriate actions to preserve or restore the resilience of reefs. Such assessments have been strongly recommended by coral reef ecology experts and leading conservation organizations (Maynard et al. 2015; Anthony et al. 2015; McClanahan et al. 2012; Graham et al. 2013). The assessments involve measuring or assessing resilience indicators (e.g. coral disease, coral recruitment and herbivorous fish biomass) and producing an aggregate score that expresses resilience potential for all sites as relative to the site with the highest (assessed) resilience potential (see Maynard et al. 2015 for guidance). Examples are just emerging of assessments of resilience potential that explicitly guide managers in making targeted decisions (Maynard et al., 2015; Weeks & Jupiter, 2013).

While discussing the need to support resilience, managers and scientists both express frustration about the lack of data on reef condition and relative resilience potential. The Hawai'i Division of Aquatic Resources (DAR, part of the Department of Land and Natural Resources - DLNR) and other local conservation agencies or organizations have conducted surveys of many coral reefs in the West Hawai'i area. However, many reefs have not been surveyed, and surveys at permanent survey sites were not designed to assess relative differences in resilience potential among sites. Partners have also expressed frustration with the challenges of making management decisions to meet conservation goals with inadequate information on how best to prioritize locations and actions. The Blueprint management team conceptualized this project to fill these vital knowledge gaps and inform near- and long-term

management of the Focus Area. NOAA has identified the need to understand the vulnerability of communities both human and natural to the localized effects of climate change.

Our project team assessed the relative resilience potential of reef sites at two depths along priority areas of South Kohala and North Kona in October of 2015. The surveys were conducted as a collaborative effort with DAR, The Nature Conservancy, NOAA CRED, and community organizations. While conducting the resilience surveys, the project team also assessed coral bleaching prevalence and severity as well as coral disease prevalence. NOAA Coral Reef Watch (CRW) issued a bleaching warning for the Main Hawaiian Islands (MHI) in June of 2015. By October 2015, CRW confirmed that the western side of Hawai'i Island experienced greater thermal stress than anywhere else in the Hawaiian Archipelago. When these surveys were conducted in mid-October, sea temperatures had been above the bleaching threshold for over 18 weeks, a level of thermal stress unprecedented in Hawai'i. Our team added bleaching/disease surveys to the Year 1 aims to take advantage of the opportunity to document and report on the bleaching event while conducting the resilience assessment. Bleaching was severe and caused coral mortality. For that reason, we also made reporting on benthic cover a specific objective so that this report can provide a public record of the coral cover when the bleaching occurred. Rounding out the Year 1 aims is an analysis that determines the primary drivers of differences in resilience potential between sites. Year 2 aims (Oct. 2016-Sept. 2017) are to use the resilience analysis outputs to identify and prioritize potential management actions to support the resilience of coral reefs in the Focus Area (see *Next Steps* section of this report).

### **Study Objectives (Year 1 of 2)**

Obj. 1. *Coral Bleaching and Disease* – Assess the percentage of corals affected by mild (<50% of colony) and severe (>50% of colony) bleaching and the percentage of corals affected by coral diseases.

Obj. 2. *Benthic Cover* – Assess the percentage cover of major benthic groups, including corals, macroalgae, coralline algae, and 'other' (i.e., turf algae and unconsolidated substrate).

Obj. 3. *Relative Resilience* – Assess the relative resilience potential of coral reefs at two depths and compare resilience potential among survey sites.

Obj. 4. *Resilience Drivers* – Determine the primary drivers of differences in resilience potential between sites.

### **Methods**

Field surveys were conducted at shallow (5-7 m) and deep (12-15 m) areas at 20 sites of the fringing reefs of West Hawai'i within and south of the Habitat Blueprint Focus Area (South Kohala and North Kona coastline) in October of 2015. The sites surveyed by our 3-4 diver team represent the full range of ecological settings and physical conditions as well as roughly even

spatial coverage of the Focus Area (i.e., a survey site every 1-2 miles along the island coastlines). Methods used to meet all of the study objectives are described below.

*Obj. 1 – Coral Bleaching and Disease* – We conducted comprehensive coral health surveys to document spatial patterns of coral bleaching and disease prevalence and severity and to compare susceptibility among coral species. The belt transect method employed is widely used across the Indo-Pacific to assess coral bleaching and disease (described within Couch et al. 2014). We surveyed the first 10 x 1 m of the three benthic cover transects (see *Obj. 2* below); all coral colonies were counted and identified to species. Each colony was inspected for: signs of bleaching (rated as mild/moderate and severe for < and >50% colony affected, respectively; i.e., refers to 'bleaching', not 'paling'), signs of known diseases (including: *Porites* Growth Anomalies, *Montipora* Growth Anomalies, *Porites* Tissue Loss Syndrome, *Pocillopora* Tissue Loss Syndrome, and *Porites* trematodiasis), and algal overgrowth, which refers to algae overgrowing recently dead corals. Bleaching and disease prevalence for each depth at each site were calculated as: Bleaching - # of colonies affected by bleaching (any severity level) / # of total colonies. Severe Bleaching - # of colonies with >50% of the colony bleached / # of total colonies. Disease (all five types) - # of colonies with each disease / # of total colonies *of the affected genera*; overall disease prevalence is the # of colonies with any disease / # of total colonies (i.e., not prevalences combined as some corals have more than one disease type; i.e. we avoid double-counting). We also calculate the prevalence of bleaching and severe bleaching by species and identify the 5 species most and least affected by bleaching (i.e., susceptibility during this event).

*Obj. 2. Benthic Cover* - Photographs of the bottom were taken every meter along three 25 m transect lines at each survey site using a Canon G12 or S110 camera mounted on a 0.8 m long PVC monopod. This generated 75 images for each depth at each survey site, with each photo covering approximately 0.8 x 0.6 m of the benthos. A 5 cm scale bar marked in 1 cm increments was included in all photographs. Twenty randomly selected photographs from each transect were analyzed to estimate the percent cover of coral, algae, and other benthic organisms present. Each selected photograph was imported into Adobe Photoshop CS5 where its color, contrast, and tone were auto-balanced to improve photo quality prior to analysis. Photos were analyzed using the Coral Point Count program with Excel extension (CPCe) developed by the National Coral Reef Institute (Kohler and Gill 2006). Using CPCe, 30 random points<sup>1</sup> were overlaid on each digital photograph, and the benthic component under each point was identified to the lowest possible taxonomic level. Once completed, the raw point data from each photograph was combined to calculate the percent cover of each major benthic category for the survey site, including: corals, macroalgae, coralline algae and other invertebrates.

*Obj. 3. Relative Resilience* – The resilience indicators included were coral cover, coral diversity, coral recruitment, bleaching resistance, macroalgae cover, herbivorous fish biomass, and rugosity. These indicators were selected from among those reviewed for perceived importance and scientific evidence within McClanahan et al. (2012) and six of these seven (exception: coral cover) were used within the CNMI resilience assessment (Maynard et al. 2015). Temperature

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<sup>1</sup> The number of points analyzed on each photograph (30 points) and the number of photographs along each transect (20 photographs) were selected after determining that these values represented the optimal effort to achieve the greatest power to detect statistical differences.

variability, though examined, was not included as there is almost no variation in warm season temperature variability (Heron et al. in press) among the surveyed sites. The resilience indicators were all assessed in the field. Methods for assessment or measurement of each of the resilience indicators are described in Table 1.

The resilience assessment compared within rather than among depths; i.e., data for the two depths were not aggregated and shallow was not compared to deep or vice versa. Once data were collected and compiled for each indicator, values for each variable were normalized to a uni-directional scale of 0-1 by dividing by the maximum value for the variable among all 20 sites (i.e. this was done for each depth). To ensure that high scores always infer higher relative resilience potential, normalized scores were inverted for macroalgae cover and coral disease. All indicators were equally weighted. Resilience scores were calculated by averaging the normalized indicator scores for each site and then those site averages were normalized. This expresses resilience of all sites as relative to the site with the highest score. The final resilience scores range from 0-1 and represent decimal percentages of the site with the highest score (1.00). Relative classifications for resilience scores are as follows: high (final scores that are greater than 1 sd above average), medium-high (<avg+1sd and >avg), medium-low (<avg and >avg-1sd), and low (<avg-1sd). Resilience rankings and relative classifications, as well as scores for each resilience indicator and relative classifications for these, are all shown within tables and maps in the Results.

**Table 1.** Field survey methods for resilience indicators.

Variable name (unit)	Methods
<b>Coral cover (%)</b>	Average percent of points classified as corals among the three 25-m benthic cover transects (20 photos analyzed for each transect using CPCe).
<b>Coral diversity (unitless)</b>	The inverse of Simpson's index of diversity, which is based on the frequency each species was observed and the species richness. The resultant value ranges from 0-1 and assesses the probability two species selected at random from the sampled community will be different, so higher percentages equate to higher diversity. The formula for Simpson's index is $D = (\sum n(n-1))/(N(N-1))$ , where $n$ = the total number of organisms of a particular species, and $N$ = the total number of organisms of all species observed.
<b>Coral recruitment (#/m<sup>2</sup>)</b>	Average density of corals with a geometric mean <5 cm within 12 assessed quadrats (0.25 m <sup>2</sup> ); we assess new recruits so exclude massive and encrusting colonies that commonly have parts of larger colonies that are <5 cm (e.g., <i>Porites rus</i> ).
<b>Bleaching resistance (%)</b>	Percent of the coral community with less than 50% of the colony affected by bleaching. Actual values could be used rather than estimated or predicted (as in Maynard et al. 2015) since surveys were conducted during a bleaching event.
<b>Macroalgae cover (%)</b>	Average percent of points classified as fleshy macroalgae (>5 cm in height) among the three 25-m benthic cover transects (20 photos analyzed for each transect using CPCe).
<b>Herbivorous fish biomass (g/m<sup>2</sup>)</b>	Divers estimated herbivorous fish biomass along three replicate transects. For each transect, divers slowly deployed a 25 m transect line while identifying to species and sizing into 5 cm bins (i.e., 0-5 cm, >5-10 cm, >10-15 cm, etc.) all fish within or passing through a 5 m wide belt along each of two transects. Divers took between 10 and 15 minutes to complete each fish transect. The weight of each fish in grams was then calculated using standard weight-length relationships (WLRs). The coefficients used were sourced from NOAA's Coral Reef Ecosystem Program (Weijerman et al. 2013). Species were classified as herbivores using NOAA CREP classifications (all functional group designations for herbivores were combined).
<b>Rugosity</b>	Calculated along the first 10 meters of each 25 m transect by dividing the length of brass chain required to contour the bottom by the 10 m transect length (McCormick 1994). For this index, a

Variable name (unit)	Methods
<b>Coral cover (%)</b>	Average percent of points classified as corals among the three 25-m benthic cover transects (20 photos analyzed for each transect using CPCe).
<b>Coral diversity (unitless)</b>	The inverse of Simpson's index of diversity, which is based on the frequency each species was observed and the species richness. The resultant value ranges from 0-1 and assesses the probability two species selected at random from the sampled community will be different, so higher percentages equate to higher diversity. The formula for Simpson's index is $D = (\sum n(n-1))/(N(N-1))$ , where $n$ = the total number of organisms of a particular species, and $N$ = the total number of organisms of all species observed.
<b>Coral recruitment (#/m<sup>2</sup>)</b>	Average density of corals with a geometric mean <5 cm within 12 assessed quadrats (0.25 m <sup>2</sup> ); we assess new recruits so exclude massive and encrusting colonies that commonly have parts of larger colonies that are <5 cm (e.g., <i>Porites rus</i> ).
<b>Bleaching resistance (%)</b>	Percent of the coral community with less than 50% of the colony affected by bleaching. Actual values could be used rather than estimated or predicted (as in Maynard et al. 2015) since surveys were conducted during a bleaching event.
<b>Macroalgae cover (%)</b>	Average percent of points classified as fleshy macroalgae (>5 cm in height) among the three 25-m benthic cover transects (20 photos analyzed for each transect using CPCe).
<b>Herbivorous fish biomass (g/m<sup>2</sup>)</b>	Divers estimated herbivorous fish biomass along three replicate transects. For each transect, divers slowly deployed a 25 m transect line while identifying to species and sizing into 5 cm bins (i.e., 0-5 cm, >5-10 cm, >10-15 cm, etc.) all fish within or passing through a 5 m wide belt along each of two transects. Divers took between 10 and 15 minutes to complete each fish transect. The weight of each fish in grams was then calculated using standard weight-length relationships (WLRs). The coefficients used were sourced from NOAA's Coral Reef Ecosystem Program (Weijerman et al. 2013). Species were classified as herbivores using NOAA CREP classifications (all functional group designations for herbivores were combined).
	value of one represents a flat surface with no relief, and increasing values represent more topographically complex substrate.

*Obj. 4. Resilience Drivers* – Understanding which variables most influence differences in resilience potential is another valuable product of resilience assessments. This is because the indicators most influencing rankings are: 1) the most important to include in monitoring programs, and 2) may reveal the types of management actions that would benefit the greatest number of sites. Indicators with the greatest variability most drive differences in the resilience rankings. We plotted the average  $\pm$  1 standard deviation and maximum and minimum values for the final resilience scores and for the normalized values for the resilience indicators for both depths. We compare the range of values among the indicators for each depth and identify which indicators have highest and lowest range and variability.

We also used a canonical analysis of principal coordinates (CAP) (Anderson and Willis 2003) to examine which indicators were driving differences in resilience potential across the four relative classifications (low, med-low, med-high, and high) at each depth. The CAP was based on a Euclidean distance matrix. Variables that might be responsible for group differences are investigated by calculating the multiple correlations of canonical ordination axes with the original indicator variables (Anderson 2008).

## **Results**

### *Obj. 1 – Coral Bleaching and Disease*

Our team, led by Courtney Couch and Rebecca Most, developed a 2-page summary of the bleaching impacts we observed during these resilience surveys entitled: *Summary of Findings – 2015 Coral Bleaching Surveys: South Kohala, North Kona* (published and made available by TNC's Marine Program, led by Project Co-leader Eric Conklin). The *Summary* is presented in the following two pages; the second page of the summary presents highlight results. We supplement those highlights with these additional results:

- Puakō, Keanapukalua, and Kanekanaka Pt were the worst affected sites with  $\geq 67\%$  of coral colonies severely bleached ( $>50\%$  of colony).
- Keonenui and Kalaemanō were the least affected sites with  $\leq 40\%$  of coral colonies affected by bleaching.
- Algal overgrowth of recently dead corals and severely bleached corals ranged from 3-60% and was greater than 10% at all sites excepting Keawaiki, with bleached colonies especially susceptible to algal overgrowth (Table 2).
- Table 1 (following the *Summary*) presents the percent of colonies affected by bleaching and severe bleaching ( $>50\%$  of colony) for all survey sites, as well as the percent of corals recently overgrown by algae.



## What is Coral Bleaching?

Coral bleaching is a stress response caused by the breakdown of the symbiotic relationship between the coral and the algae (zooxanthellae) that live inside its tissues. When the coral expels these algae the coral skeleton becomes visible, giving it a pale or “bleached” appearance. Mass bleaching events have been linked with mounting thermal stress associated with a warming planet and seas and are expected to continue increasing in severity, geographic extent, and frequency. Although some species and individual coral colonies can withstand more stress than others, corals will eventually die if the stressor does not abate and the symbiosis is not reestablished.



*Bleached Pocillopora eydouxi, Oct, 2015.*

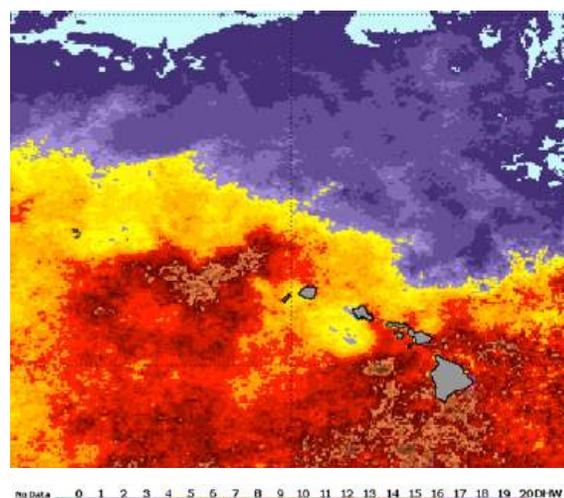
## Coral Bleaching in Hawai'i

Prompted by rising sea surface temperatures south of the Main Hawaiian Islands (MHI) in June 2015, NOAA's Coral Reef Watch Program issued a bleaching warning for the MHI. By October 2015, the agency confirmed that West Hawai'i Island experienced the most severe thermal stress in the MHI for 18.35 consecutive weeks (Fig. 1).

Following the first report of bleached coral from a Puakō Makai Watch volunteer snorkeling at Paniau, scientists from The Nature Conservancy, NOAA's Coral Reef Ecosystem Program (CREP), and Hawai'i's Division of Aquatic Resources (DAR) conducted four weeks of field surveys to assess the damage.

The team surveyed more than 14,000 coral colonies across the South Kohala and North Kona regions of West Hawai'i, assessing the incidence (proportion of coral colonies that bleached) and severity of bleaching of each colony.

We also assessed each reef's resilience, which is its ability to resist or recover from bleaching events. Intensive data sharing and analysis is underway to map thirteen reef resilience indicators, including herbivore biomass, coral health, resistant coral species, and topographic complexity.



*Fig. 1. Map of maximum degree heating weeks across Hawai'i in 2015. Degree heating weeks are the number of consecutive weeks that temperature exceeds 1°C bleaching threshold based on nightly 5-km satellite data. 4 weeks=bleaching likely, 8 weeks=mortality likely. Data from NOAA's Coral Reef Watch Program.*

## Key Findings: Extent and Severity of Bleaching

- 38-92% of all coral colonies on North Kona and South Kohala reefs were partially or fully bleached.
- While there is considerable variation in mortality levels, preliminary results suggest that some South Kohala reefs have experienced 55-99% coral loss since 2014.
- An average of  $68.41 \pm 15.23\%$  of shallow water (18-21') and  $59.96 \pm 17.66\%$  of deeper water (38-42') corals were partially or fully bleached.
- Average bleaching severity across all colonies was ~75%, and similar in shallow ( $74.50 \pm 7.13\%$ ) and deeper ( $75.42 \pm 8.52\%$ ) reef zones.
- Survey sites in South Kohala (north end of the survey area) had worse bleaching than those in North Kona (south end of the survey area).
- Among the most affected sites were shallow regions at Kanekanaka, Kawaihae and 'Ōhai'ula (Spencer Beach) where 80-85% of the corals severely bleached.
- Of the dominant reef-building corals that partially or fully bleached, *Pavona duerdeni* (100% of colonies), *Pocillopora meandrina* (98%), *Porites evermanni/lutea* (81%), *Montipora capitata* (77%) and *Pavona varians* (74%) were the most susceptible to bleaching.
- While bleaching incidence was high to moderate across most taxa, the least affected were *Porites lobata* (50%), *Montipora incrassata* (47%), *Montipora patula* (45%), *Leptastrea purpurea* (40%), *Fungia scutaria* (14%).
- 50 to 60% of the two most abundant species (*Porites lobata* and *Porites compressa*) partially or fully bleached.
- Bleaching caused considerable mortality across many of the dominant reef-building taxa such as *P. lobata*, *P. compressa*, *P. evermanni* and *P. meandrina*.

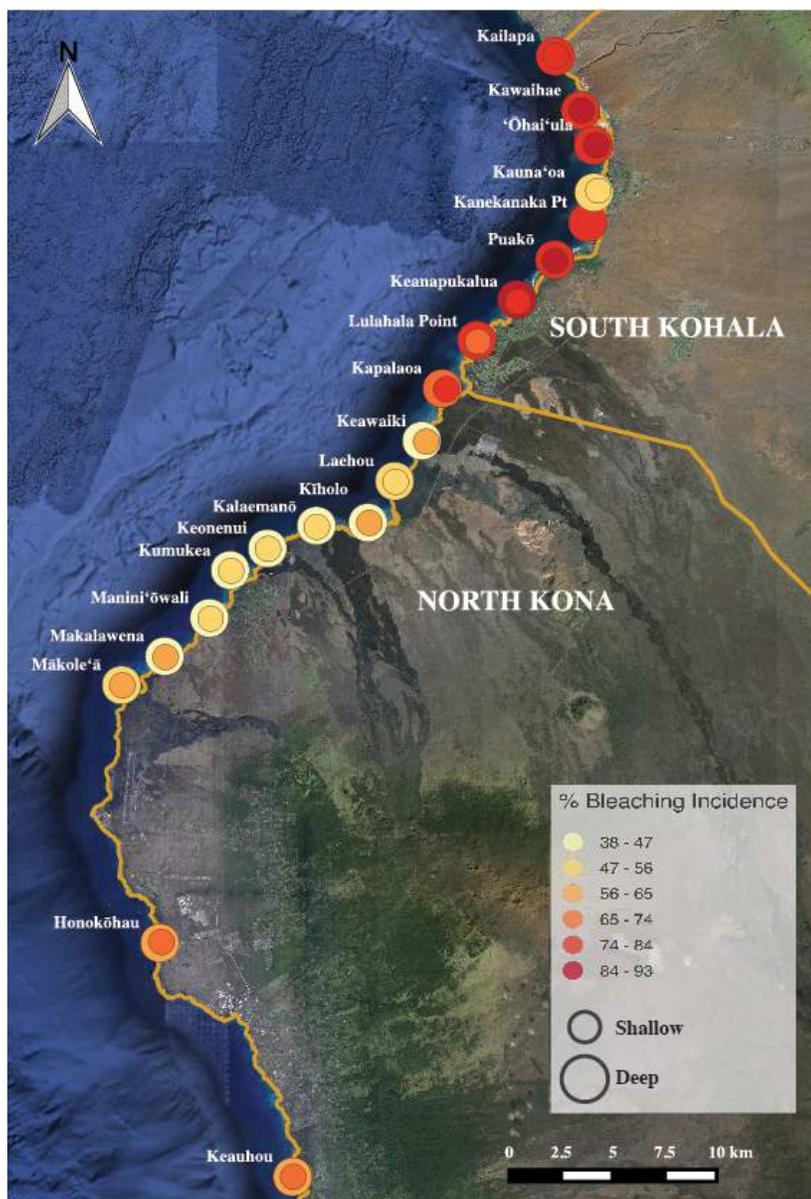


Figure 2. Incidence of partial or complete bleaching at shallow and deep sites in West Hawaii, October 13-24, 2015.

## How We Can Help Improve Reef Resilience

For the first time in history, the MHI experienced back-to-back bleaching events in 2014 and 2015. These events—and the likelihood that they will continue into the future—require us to improve our understanding of bleaching impacts and the application of reef resilience principles to ensure we're doing everything we can to reduce mortality on Hawai'i's reefs. As we continue to monitor reef recovery—or the lack thereof—in West Hawai'i (and in other places throughout the state, including Kāne'ohe Bay), we can identify the areas most resistant and resilient to bleaching and prioritize those for conservation action. In addition, we can redouble efforts to minimize local stressors (e.g., land-based pollution, runoff, and overfishing of herbivores) that are within our control and compromise coral health and the reef's ability to resist or recover from bleaching.

## For Additional Information

Contact Dr. Courtney Couch at [courtneycouch@gmail.com](mailto:courtneycouch@gmail.com), Rebecca Most at [rmost@tnc.org](mailto:rmost@tnc.org), or Dr. Eric Conklin at [econklin@tnc.org](mailto:econklin@tnc.org) for additional information on these findings. Visit [reefresilience.org](http://reefresilience.org) for additional information on coral bleaching and reef resilience principles.

## Mahalo Nui Loa

To Moana Ohana LLC and Marine Applied Research Center for helping to make this work possible.

Diseases observed include: *Porites* Growth Anomalies, *Montipora* Growth Anomalies, *Porites* Tissue Loss Syndrome, *Pocillopora* Tissue Loss Syndrome and *Porites* Trematodiasis. Overall disease prevalence (all diseases) was slightly greater among the shallow than deep reef areas and was also more variable among the shallow than deep reef areas. Average disease prevalence was  $6.50 \pm 4.02\%$  among the shallow reef areas and  $5.31 \pm 2.88\%$  among the deep reef areas. The highest disease prevalence in the shallow reef areas (ranging from 10-15%) was observed at Kalaemano (15%), Honokōhau (14%), Keauhou (12%), Kauna'oa (11%), and Kanekanaka Pt (11%). Disease prevalence in the deep reef areas was  $\geq 10\%$  only at Kalaemano (12%) and Honokōhau (10%). Disease prevalence observed at time of surveys may not be representative of minimum, maximum, or average prevalence of diseases at this survey site. Further surveys are required to assess whether these prevalence values are representative of temporal variation in prevalence at the survey sites. Further, bleached corals that survive are more susceptible to disease meaning disease prevalence levels observed during these surveys likely underestimate prevalence in the 3-6 months that followed the bleaching event (October, 2015). Table 2 presents the percent of colonies affected by any type of disease (all diseases) and the prevalence of the various diseases among the genera affected (i.e. *Porites* Growth Anomalies prevalence among *Porites* colonies).

**Table 2.** Coral health data summary; values are average percentage of the three transects surveyed at each depth (all values are %). Disease is total prevalence; the other five listed diseases are prevalence for the described genera. Bleaching refers to percent of colonies fully or partially bleached. Severe bleaching means >50% of the colony was affected by bleaching. Values are for time of survey only in October of 2015. Sites are sorted alphabetically. Bracketed values after site names refer to shallow and deep rankings, respectively, in the resilience assessment; lower rankings refer to sites with greater relative resilience (see also A1.2 and A1.3).

	Shallow									Deep								
	Disease	Porites GA	Montipora GA	Porites TLS	Pocillopora TLS	Porites Trematodiasis	Algal Overgrowth	Bleaching	Severe Bleaching	Disease	Porites GA	Montipora GA	Porites TLS	Pocillopora TLS	Porites Trematodiasis	Algal Overgrowth	Bleaching	Severe Bleaching
Honokōhau [17,8]	14	15	0	0	0	0	60	70	42	10	13	0	0	0	0	40	61	45
Kailapa [14,9]	6	7	3	0	0	0	14	82	66	2	3	0	0	0	0	10	75	61
Kalaemanō [11,15]	15	11	0	3	10	0	36	55	32	12	15	0	2	0	0	21	40	32
Kanekanaka Pt [19,16]	11	13	13	0	0	0	16	93	86	5	6	0	0	0	0	32	78	67
Kapalaoa [16,19]	5	7	4	1	2	0	24	82	68	7	9	0	0	0	4	20	70	57
Kauna 'oa [12,6]	11	12	0	2	8	0	55	56	42	2	3	1	0	0	0	22	49	44
Kawaihae [15,18]	2	2	0	0	0	0	16	91	80	6	7	0	0	0	0	35	83	66
Keanapukalua [9,13]	6	8	0	0	0	0	33	83	63	6	8	0	0	0	0	36	91	67
Keauhou [13,12]	12	11	0	0	0	0	43	67	56	8	8	0	0	0	0	48	62	42
Keawaiki [6,14]	1	0	2	0	4	0	6	63	49	0	0	0	0	0	0	3	42	33
Keonenui [8,17]	6	7	0	1	0	0	15	55	45	6	10	0	0	0	0	16	38	30
Kīhōlo [3,2]	6	5	0	1	33	0	30	59	42	5	8	0	0	0	0	25	42	30
Kumukea [2,4]	4	5	0	0	7	0	30	48	38	4	10	0	0	4	0	20	44	39
Laehou [1,1]	3	6	0	0	12	0	18	48	40	4	2	0	1	3	0	18	48	42
Lulahala Pt [10,20]	4	5	0	0	0	0	27	71	57	4	5	2	0	0	0	19	79	64
Makalawena [7,5]	6	11	0	1	0	0	30	61	46	6	7	0	0	0	0	24	43	31
Mākole'ā [4,10]	7	10	0	0	0	0	32	60	45	7	8	0	0	13	0	26	52	45
Manini'ōwali [5,11]	6	6	0	0	8	0	25	49	40	3	4	0	0	0	0	15	44	35
Ōhae 'ula [18,7]	4	6	0	0	0	0	13	91	78	6	9	0	0	0	0	16	76	59
Puakō [20,3]	1	1	0	0	0	0	16	84	71	2	2	0	0	0	0	20	82	74

*Obj. 2. Benthic Cover*

At both depths and across all sites, >40% of the substrate was made up 'other' (i.e., turfing algae and unconsolidated substrate). Macroalgae and crustose coralline algae cover was <25% at both depths at all sites (macroalgae cover was <1%). Average coral cover in the shallow reef areas was  $28.24 \pm 9.16\%$  and in the deep reef areas was  $22.67 \pm 10.70\%$ . Coral cover was highest (>35%) in the shallow areas at Kalaemano (50%), Keanapukalua (42%), and Mākole'ā (39%). Coral cover was highest (>30%) in the deep areas at Honokōhau (54%), Laehou (41%), Makalawena (32%) and Keonenui (32%). Coral cover varied between the shallow and deep reef areas >10% at half the sites (10 of 20) and <10% at the other half; differences among depths at some sites were large (e.g. Kalaemano – 50% shallow, 12% deep). The percent cover of the major benthic groups is shown for all sites and both depths within Table 3.

In total, 27 coral species were observed, considering recruits (i.e. <4 cm) and larger corals combined) A coral species list is presented within Table 4. Richness varied among sites from 6 (Honokōhau – Deep) to 15 coral species ('Ōhae'ula – Deep).

**Table 3.** Percent cover of major benthic groups. Values presented are averages among the three transects surveyed. Bracketed values after site names refer to shallow and deep rankings, respectively, in the resilience assessment; lower rankings refer to sites with greater relative resilience (see also A1.2 and A1.3). These data are presented in the form of pie charts within the *Site Summaries* in Appendix 2.

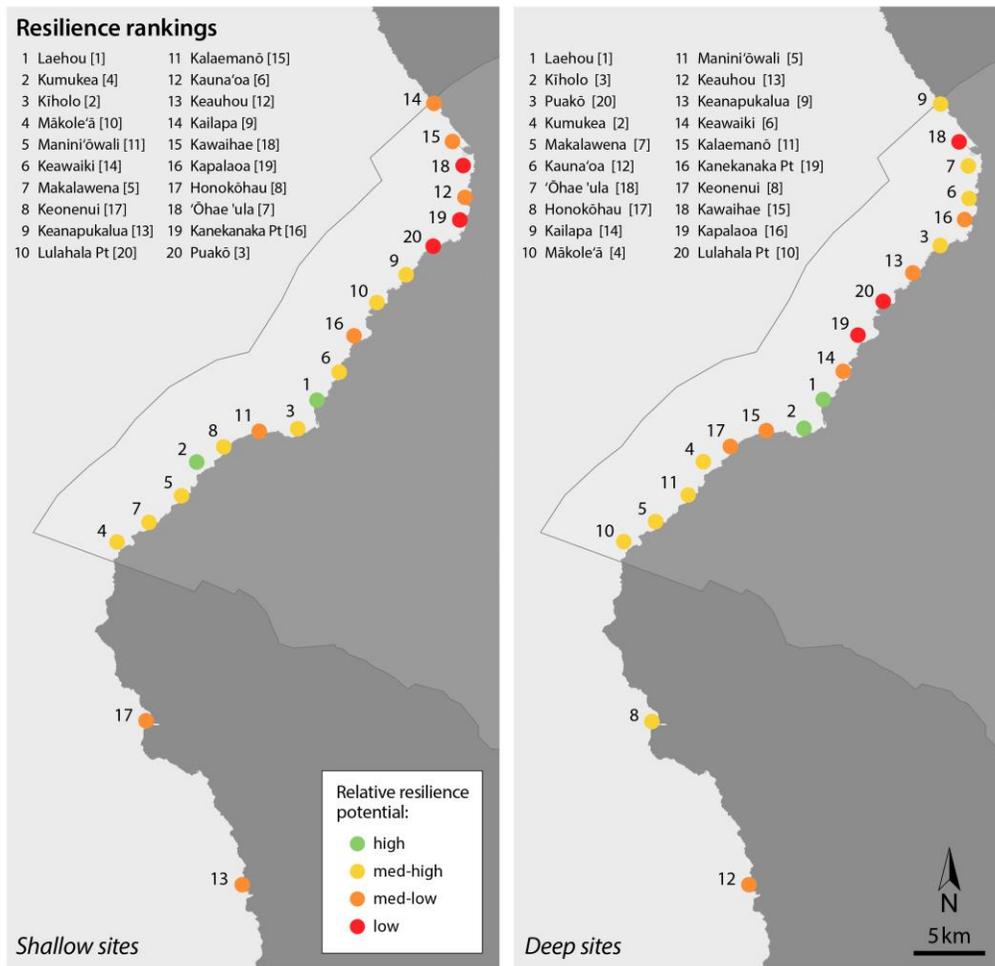
Site	Shallow				Deep			
	Coral (%)	Macroalgae (%)	Coralline Algae (%)	Other (%)	Coral (%)	Macroalgae (%)	Coralline Algae (%)	Other (%)
Honokōhau [17,8]	27	0	1	72	54	0	3	43
Kailapa [14,9]	32	0	9	58	26	0	11	63
Kalaemanō [11,15]	50	0	6	44	12	0	9	80
Kanekanaka Pt [19,16]	23	0	8	69	16	0	16	68
Kapalaoa [16,19]	34	0	0	66	20	0	2	78
Kauna 'oa [12,6]	20	0	1	79	17	0	26	58
Kawaihae [15,18]	20	0	12	68	17	0	17	67
Keanapukalua [9,13]	42	0	5	53	12	0	18	70
Keauhou [13,12]	18.83	0	5	76	24	0	19	57
Keawaiki [6,14]	30	0	1	69	19	0	8	72
Keonenui [8,17]	27	0	7	65	32	0	7	61
Kīhōlo [3,2]	18	0	4	79	21	0	2	77
Kumukea [2,4]	30	0	1	68	15	0	2	83
Laehou [1,1]	33	0	12	56	41	0	4	55
Lulahala Pt [10,20]	26	0	4	70	8	0	1	90
Makalawena [7,5]	31	0	7	61	32	0	4	64
Mākole'ā [4,10]	39	0	1	60	25	0	0	74
Manini'ōwali [5,11]	30	0	11	58	21	0	3	76
'Ōhae 'ula [18,7]	11	0	21	67	22	0	20	59
Puakō [20,3]	21	1	2	77	21	0	12	67

**Table 4.** Coral species observed across all surveyed sites (includes recruits (<5 cm) and larger corals). Lists of the coral species observed at each depth at each site are presented within the *Site Summaries* in Appendix 2.

<b>Coral Species</b>		
<i>Cyphastrea ocellina</i>	<i>Montipora patula</i>	<i>Porites compressa</i>
<i>Fungia scutaria</i>	<i>Pavona duerdeni</i>	<i>Porites evermanni</i>
<i>Leptastrea bewickensis</i>	<i>Pavona maldivensis</i>	<i>Porites lobata</i>
<i>Leptastrea incrusta</i>	<i>Pavona varians</i>	<i>Porites monticulosa</i>
<i>Leptastrea purpurea</i>	<i>Pocillopora damicornis</i>	<i>Porites rus</i>
<i>Leptastrea transversa</i>	<i>Pocillopora eydouxi</i>	<i>Porites solida</i>
<i>Montipora capitata</i>	<i>Pocillopora meandrina</i>	<i>Psammocora haimeana</i>
<i>Montipora flabellata</i>	<i>Porites bernardi</i>	<i>Psammocora nierstraszi</i>
<i>Montipora incrassata</i>	<i>Porites brighami</i>	<i>Psammocora stellata</i>
<i>Tubastrea</i> sp.		

Obj. 3. Relative Resilience

*Shallow* – Normalized resilience scores ranged from 0.52 to 1.00. Two sites were assessed as having high relative resilience, 8 medium-high, 7 medium-low, and 3 low. The 2 sites with high relative resilience are Laehou and Kumukea; these sites are in central and southern South Kohala (Figure 1). The 3 sites with low relative resilience are ‘Ōhae‘ula, Kanekanaka Pt, and Puakō; these sites are in northern South Kohala (Figure 1). There is a general pattern that values for all resilience indicators are lower in northern South Kohala and higher in southern South Kohala. Normalized values and relative classes (low-high) for each resilience indicator are shown within Table A1.2 and Figure A1.1.

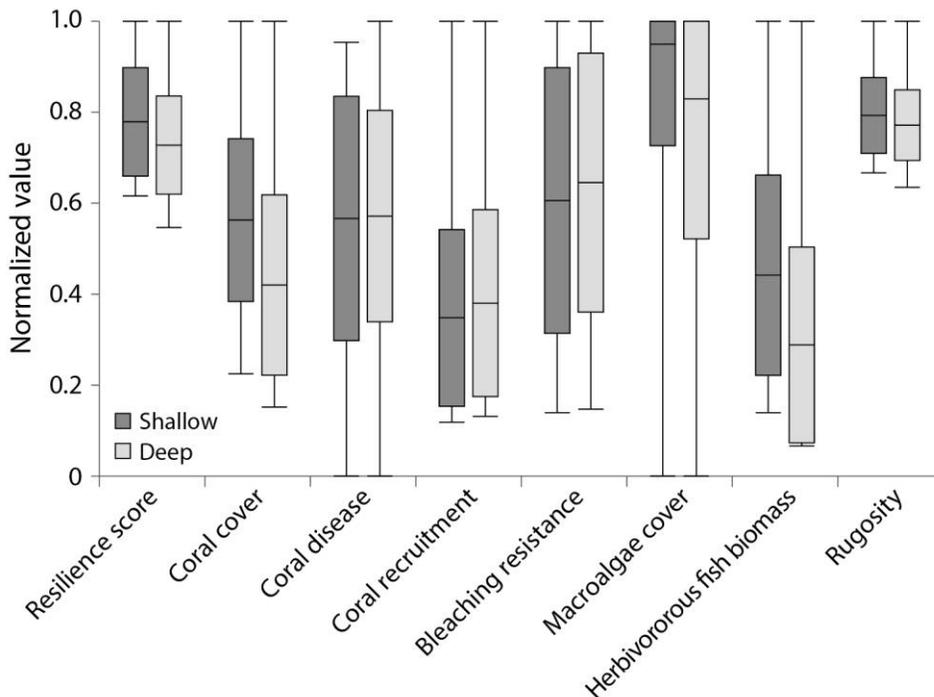


**Figure 1.** Resilience assessment results for shallow (5-7 m) and deep (10-12 m) reef areas along the South Kohala (north) and North Kona (south) coastlines of Hawai'i Island. The polygon shape defines the boundaries of the NOAA Habitat Blueprint West Hawai'i Focus Area. For both shallow and deep, the bracketed values represent the resilience rank for the other depth. Relative classifications for resilience scores (see Figures A1.2 and A1.3) and resilience indicator scores are as follows: high (final scores that are >1 sd above average (avg) and  $\leq 1$ ), medium-high (<avg+1sd and >avg), medium-low (<avg and >avg-1sd), and low (<avg-1sd).

Deep – Normalized resilience scores ranged from 0.55 to 1.00. Two sites were assessed as having high relative resilience, 9 medium-high, 6 medium-low, and 3 low. The 2 sites with high relative resilience are Laehou and Kīholo; these are adjacent sites in central South Kohala (Figure 1). The 3 sites with low relative resilience are Kawaihae, Kapalaoa, and Lulahala Pt; these sites are in central and northern South Kohala (Figure 1). As with the shallow reef areas, there is a general pattern that values for all resilience indicators are lower in northern South Kohala and higher in southern South Kohala. Normalized values and relative classes (low-high) for each resilience indicator are shown within Table A1.3 and Figure A1.2.

*Obj. 4. Resilience Drivers*

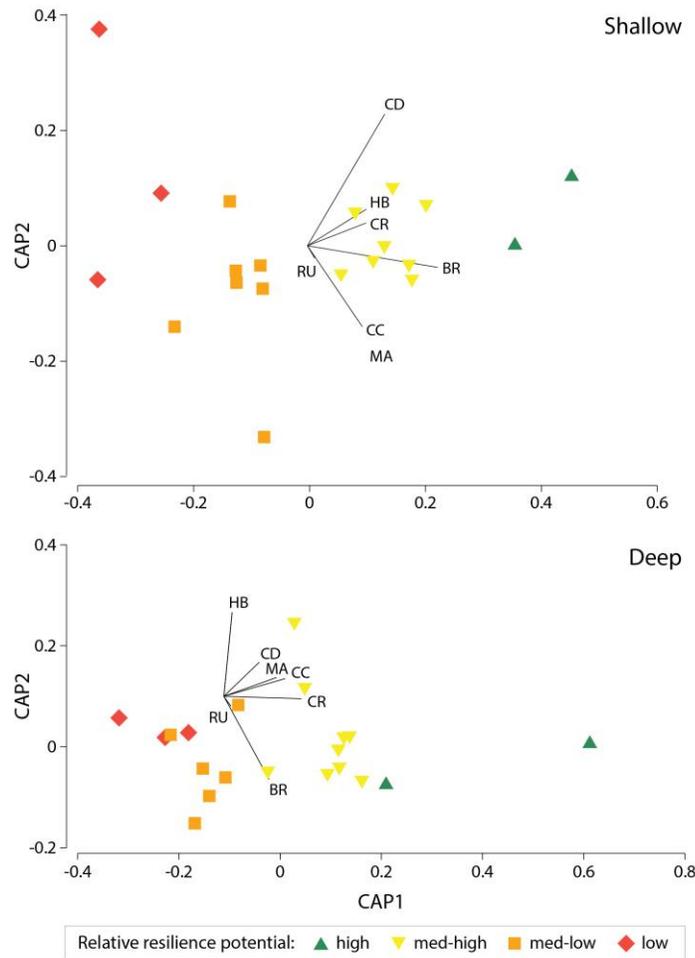
Coral disease and macroalgae cover were the indicators with the greatest range of values and coral disease and bleaching resistance had the greatest variability. These indicators are greater drivers of differences among the sites in resilience scores than rugosity, which has far lower relative variability (Figure 1).



**Figure 2.** Distribution of normalized values for the resilience scores and for the resilience indicators. Mid-lines represent average values, the tops and bottoms of the boxes represent 1 sd and the whiskers denote the min and max values of the data range.

It was possible that high resilience sites could have this classification as a result of having high scores for different indicators and low resilience sites could have low scores for different indicators. We examined whether high scores for some indicators are consistently associated with high resilience (and low scores for some indicators with low resilience) using a CAP analysis.

For the shallow sites, high and medium-high resilience potential were principally characterized by high bleaching resistance and to a lesser extent by high herbivorous fish biomass and coral recruitment and low coral disease (Fig. 3 top, see vectors along the CAP1). Low bleaching resistance, herbivorous fish biomass and coral recruitment principally characterized medium-low and low resilience potential.



**Figure 3.** Canonical analysis of principal coordinates showing the relative contribution of seven resilience indicators (overlaid as vectors) to the overall resilience of reef sites for the shallow and deep reef areas of the 20 surveyed sites. For the shallow reef areas, Squared canonical correlation values ( $\delta^2$ ) of the first and second ordination axes are 0.949 and 0.342, respectively. These correlation values represent the amount of variation, as a proportion, in the dataset that each CAP examples; the axes are not fully independent, which is why the value exceeds 1 when the two are added. For the deep reef areas, Squared canonical correlation values ( $\delta^2$ ) of the first and second ordination axes are 0.845 and 0.144, respectively. Indicator codes are as follows: CC – coral cover, CR – coral recruitment, CD – coral diversity, BR – bleaching resistance, MA – macroalgae cover, RU – rugosity, HB – herbivorous fish biomass.

For the deep sites, high and medium-high resilience potential were principally characterized by high coral recruitment (Fig. 3 bottom, see vector along CAP1) and to a lesser extent by high coral cover and coral diversity and low macroalgae cover. The high resilience potential sites appeared separated out from the medium-high due to having higher bleaching resistance values. (Fig. 3 bottom, see vector along CAP3). Low coral recruitment and herbivorous fish biomass and to a lesser extent low coral diversity principally characterized medium-low and low resilience sites.

## **Next Steps**

Year 2 objectives (Oct. 2016-Sept. 2017) include: 1) using the analysis outputs to identify and prioritize potential management actions to support the resilience of coral reefs in the Focus Area, and 2) discussing actions and deciding on management recommendations with stakeholders and community members. [\*Ocean Tipping Points\*](#) project team members have helped us compile information on spatial variation in anthropogenic stress, including: sedimentation, effluent, phosphorous and nitrogen flux, presence of development, and commercial and recreational fishing. We have combined these anthropogenic stress data layers with the resilience assessment results to identify potential management actions to: 1) support or improve resilience at low resilience sites and, 2) maintain resilience potential at high resilience sites. Following on from these recent efforts, we plan to undertake the following 6 project activities during project year 2 (Oct. 2016 – Sept. 2017): 1) conduct workshops for managers on Oahu and in Kona to: a) review and improve the approach used to identify potential management actions, and b) identify and prioritize specific action options that will support reef resilience in West Hawaii (with outputs of this project combined with priority management strategies for promoting post-bleaching coral recovery identified during a survey and workshop DAR coordinated in 2016); 2) hold a community meeting in Kona to share and discuss the project results; 3) assess recovery of coral communities from the 2015 bleaching event, 4) develop an abbreviated ‘Summary for Policymakers’ describing the final management recommendations and pathways for implementation; 5) schedule and present a NOAA Science Seminar Series seminar on Oahu followed by a brief workshop with NOAA staff to identify the key next steps for this and similar projects; and 6) produce a follow-up (to this report) CRCP technical memorandum to report on Year 2 project activities and identified next steps.

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**Appendix 1 – Site coordinates, resilience summary tables and indicator maps**

Contents

Table A1.1 – Survey site coordinates

Table A1.2 – Resilience and indicator scores for shallow reef areas

Figure A1.1 – Relative classes for resilience indicators in shallow reef areas

Table A1.3 – Resilience and indicator scores for deep reef areas

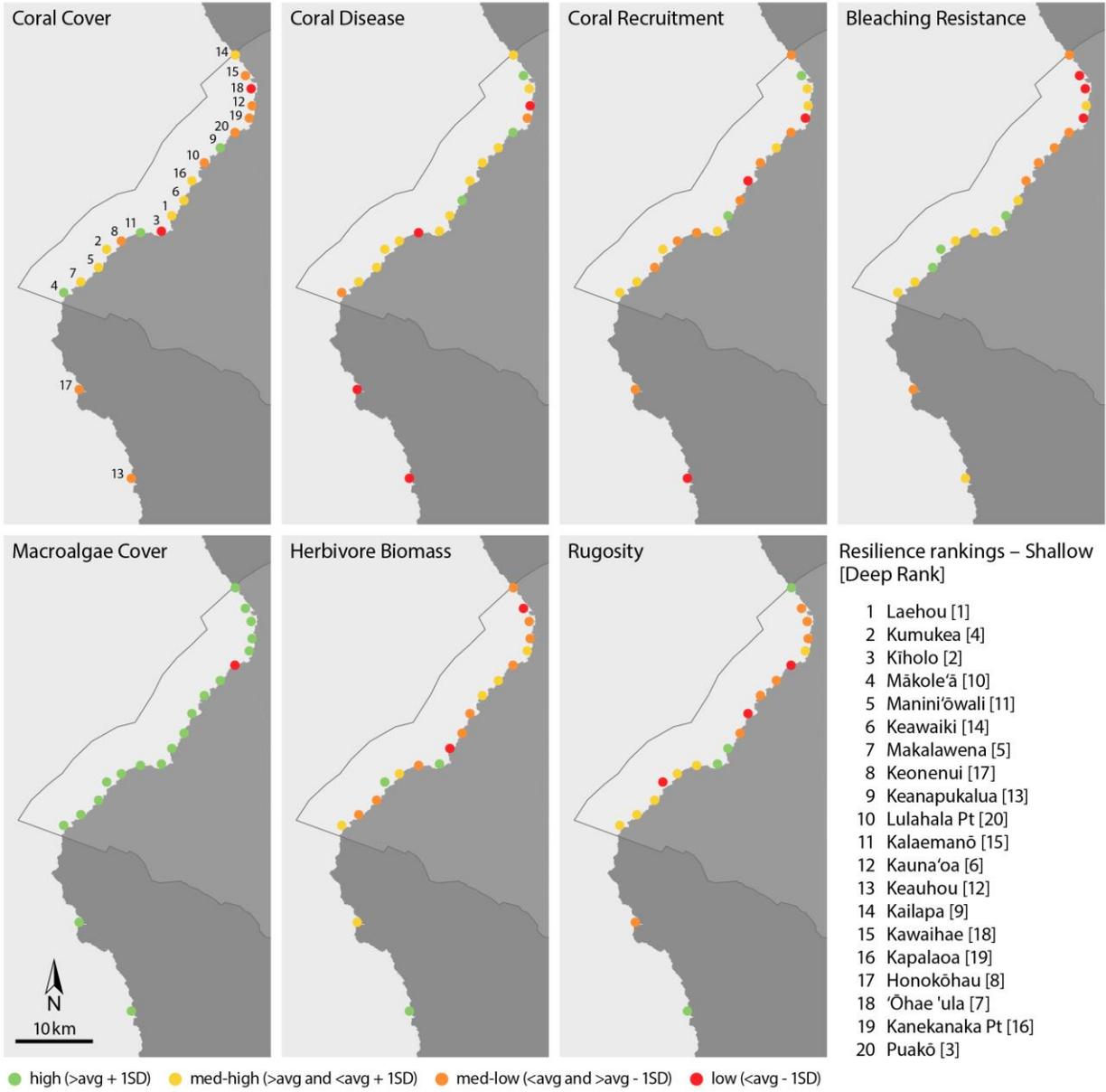
Figure A1.2 – Relative classes for resilience indicators in deep reef areas

**Table A1.1.** Survey site coordinates. All sites were surveyed between October 13 and October 23, 2016.

Site Name	<i>SHALLOW</i>		<i>DEEP</i>	
	Latitude	Longitude	Latitude	Longitude
Kailapa	20.06	-155.85	20.06	-155.85
Kawaihae	20.04	-155.84	20.04	-155.84
‘Ōhae ‘ula	20.02	-155.83	20.02	-155.83
Kauna‘oa	20.00	-155.83	20.00	-155.83
Kanekānaka Pt	19.99	-155.83	19.99	-155.83
Puakō	19.97	-155.85	19.97	-155.85
Keanapukalua	19.95	-155.87	19.95	-155.87
Lulahala Pt	19.93	-155.88	19.94	-155.88
Kapalaoa	19.91	-155.90	19.91	-155.90
Keawaiki	19.89	-155.91	19.89	-155.91
Laehou	19.87	-155.92	19.87	-155.92
Kīholo	19.86	-155.93	19.86	-155.93
Kalaemanō	19.85	-155.96	19.85	-155.96
Keonenui	19.84	-155.98	19.84	-155.98
Kumukea	19.83	-156.00	19.83	-156.00
Manini‘ōwali	19.81	-156.01	19.81	-156.01
Makalawena	19.80	-156.03	19.80	-156.03
Mākole‘ā	19.78	-156.05	19.78	-156.05
Honokōhau	19.67	-156.03	19.67	-156.03
Keauhou	19.57	-155.97	19.57	-155.97

**Table A1.1.** Normalized scores for all resilience indicators, raw and final resilience scores, and site rankings for the shallow reef areas of the survey sites. Relative classifications for resilience scores and resilience indicator scores are as follows: high (final scores that are >1 sd above average (avg) and  $\leq 1$ ), medium-high (<avg+1sd and >avg), medium-low (<avg and >avg-1sd), and low (<avg-1sd). Resilience indicator codes are: CC – coral cover, CD – coral diversity, CR – coral recruitment, BR – bleaching resistance, MA – macroalgae cover, HB – herbivorous fish biomass, RU – rugosity.

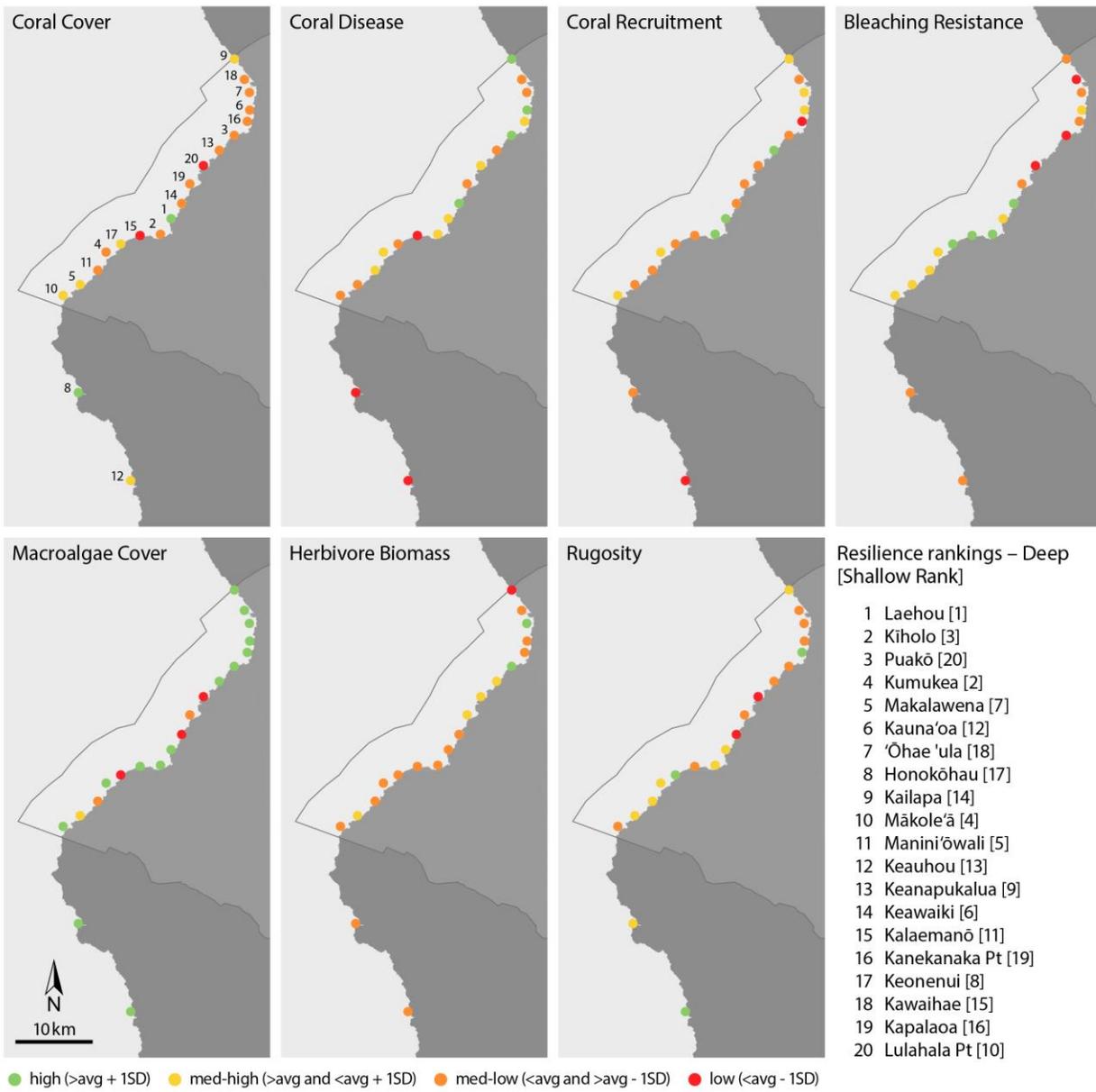
Site Name	Shallow Rank [Deep]	Resilience Score	Raw Resilience Score	CC	CD	CR	BR	MA	HB	RU
Laehou	1 [1]	1.00	0.78	0.65	0.79	1.00	1.00	1.00	0.14	0.90
Kumukeya	2 [4]	0.99	0.77	0.60	0.70	0.43	1.00	1.00	1.00	0.68
Kīholo	3 [2]	0.89	0.70	0.36	0.62	0.41	0.78	1.00	0.72	1.00
Mākole‘ā	4 [10]	0.88	0.69	0.77	0.53	0.36	0.77	1.00	0.55	0.82
Manini‘ōwali	5 [11]	0.86	0.67	0.60	0.59	0.32	0.97	1.00	0.37	0.85
Keawaiki	6 [14]	0.84	0.66	0.59	0.95	0.27	0.71	1.00	0.34	0.75
Makalawena	7 [5]	0.83	0.65	0.62	0.59	0.41	0.75	1.00	0.41	0.80
Keonenui	8 [17]	0.83	0.65	0.54	0.59	0.28	0.85	1.00	0.48	0.81
Keanapukalua	9 [13]	0.82	0.64	0.84	0.57	0.36	0.33	1.00	0.63	0.76
Lulahala Pt	10 [20]	0.80	0.63	0.52	0.71	0.32	0.56	1.00	0.56	0.73
Kalaemanō	11 [15]	0.74	0.58	1.00	0.00	0.16	0.86	1.00	0.26	0.80
Kauna‘oa	12 [6]	0.74	0.58	0.40	0.26	0.42	0.85	1.00	0.36	0.78
Keauhou	13 [12]	0.74	0.58	0.43	0.20	0.12	0.64	1.00	0.76	0.88
Kailapa	14 [9]	0.73	0.57	0.64	0.61	0.29	0.35	1.00	0.24	0.89
Kawaihae	15 [18]	0.72	0.56	0.39	0.88	0.59	0.16	1.00	0.14	0.76
Kapalaoa	16 [19]	0.70	0.55	0.67	0.65	0.14	0.34	1.00	0.38	0.68
Honokōhau	17 [8]	0.67	0.52	0.53	0.10	0.23	0.58	1.00	0.48	0.73
‘Ōhae 'ula	18 [7]	0.65	0.51	0.22	0.74	0.42	0.17	1.00	0.25	0.76
Kanekanaka Pt	19 [16]	0.62	0.48	0.45	0.30	0.14	0.14	1.00	0.53	0.82
Puakō	20 [3]	0.52	0.41	0.42	0.95	0.28	0.31	0.00	0.25	0.67



**Figure A1.1.** Resilience indicator scores for the shallow reef areas of the survey sites.

**Table A1.2.** Normalized scores for all resilience indicators, raw and final resilience scores, and site rankings for the deep reef areas of the survey sites. Relative classifications for resilience scores and resilience indicator scores are as in Table A1.1. Resilience indicator codes are: CC – coral cover, CD – coral diversity, CR – coral recruitment, BR – bleaching resistance, MA – macroalgae cover, HB – herbivorous fish biomass, RU – rugosity.

Site Name	Deep Rank [Shallow]	Resilience Score	Raw Resilience Score	CC	CD	CR	BR	MA	HB	RU
Laehou	1 [1]	1.00	0.77	0.77	0.69	1.00	0.84	1.00	0.25	0.82
Kīholo	2 [3]	0.84	0.64	0.39	0.59	0.59	0.94	1.00	0.18	0.82
Puakō	3 [20]	0.83	0.64	0.39	0.86	0.19	0.28	1.00	1.00	0.72
Kumukea	4 [2]	0.82	0.63	0.28	0.65	0.57	0.90	1.00	0.21	0.79
Makalawena	5 [7]	0.81	0.62	0.60	0.50	0.31	0.92	0.80	0.43	0.77
Kauna'oa	6 [12]	0.80	0.61	0.31	0.85	0.40	0.81	1.00	0.17	0.75
'Ōhae'ula	7 [18]	0.77	0.59	0.40	0.50	0.48	0.38	1.00	0.65	0.75
Honokōhau	8 [17]	0.77	0.59	1.00	0.21	0.22	0.63	1.00	0.24	0.81
Kailapa	9 [14]	0.76	0.58	0.47	0.84	0.54	0.41	1.00	0.07	0.77
Mākole'ā	10 [4]	0.76	0.58	0.47	0.46	0.45	0.78	1.00	0.17	0.75
Manini'ōwali	11 [5]	0.73	0.56	0.38	0.72	0.28	0.89	0.60	0.23	0.80
Keauhou	12 [13]	0.69	0.53	0.45	0.33	0.13	0.62	1.00	0.18	1.00
Keanapukalua	13 [9]	0.67	0.51	0.22	0.51	0.59	0.15	1.00	0.39	0.73
Keawaiki	14 [6]	0.65	0.50	0.36	1.00	0.23	0.94	0.19	0.13	0.66
Kalaemanō	15 [11]	0.64	0.49	0.21	0.00	0.33	0.96	1.00	0.17	0.76
Kanekanaka Pt	16 [19]	0.64	0.49	0.29	0.57	0.14	0.36	1.00	0.23	0.84
Keonenui	17 [8]	0.63	0.48	0.58	0.53	0.29	1.00	0.00	0.13	0.84
Kawaihae	18 [15]	0.61	0.47	0.31	0.53	0.29	0.27	1.00	0.19	0.72
Kapalaoa	19 [16]	0.59	0.45	0.38	0.44	0.25	0.48	0.60	0.33	0.69
Lulahala Pt	20 [10]	0.55	0.42	0.15	0.64	0.33	0.34	0.40	0.43	0.64



**Figure A1.2.** Resilience indicator scores for the deep reef areas of the survey sites.

## Relative resilience potential and bleaching severity in the West Hawai'i Habitat Focus Area in 2015

### Appendix 2 – Site Summaries

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Makalawena	A2.7
Keonenui	A2.8
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Kalaemanō	A2.11
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Keauhou	A2.13
Kailapa	A2.14
Kawaihae	A2.15
Kapalaoa	A2.16
Honokōhau	A2.17
‘Ōhae‘ula	A2.18
Kanekanaka Pt	A2.19
Puakō	A2.20

## Site Summary Guide

The first one-page summary is shown in the graphic below. Each part of the summary is enclosed within a box that has a letter label. Descriptions are provided below for each of these parts of the summary, next to the relevant letter label.

**A** – Site name and resilience rankings for the shallow and deep reef areas.

**B** – Site name origin and map showing the location of Hawai'i Island in the Hawaiian Island chain and the survey area in West Hawai'i.

**C** – Representative site photos, site coordinates, and inset map showing survey site location within the survey area; light grey area on inset map represents the West Hawai'i Habitat Focus Area (NOAA Blueprint).

**D** – Resilience and resilience indicator scores with colors signifying relative classes.

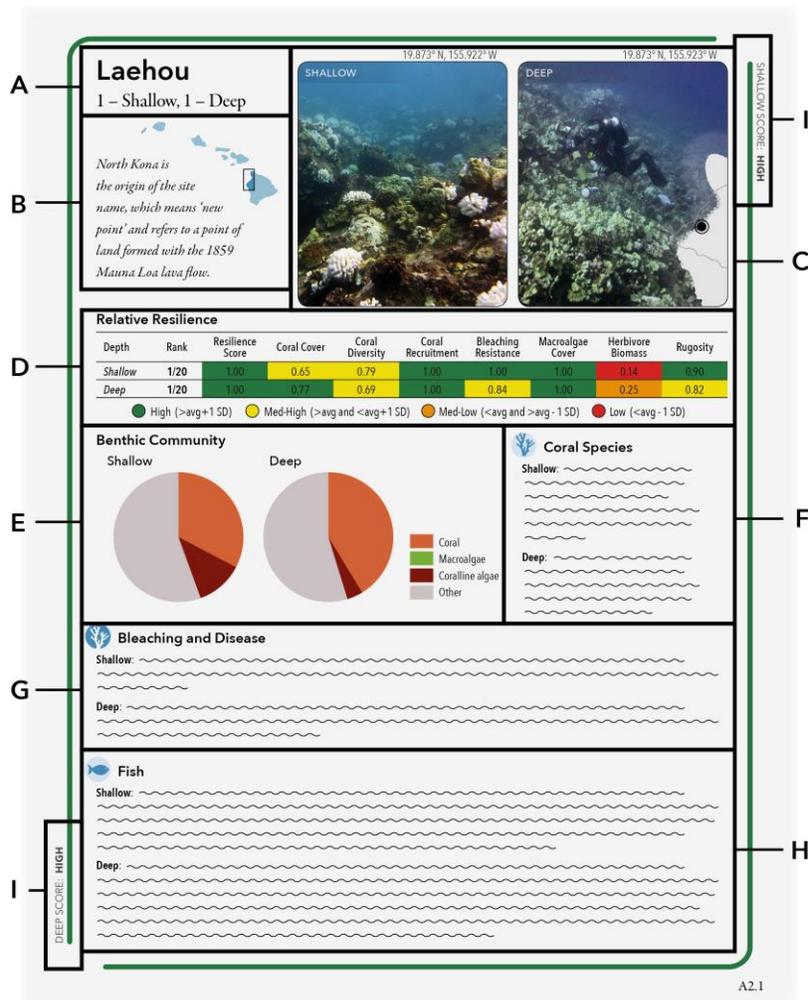
**E** – Benthic community pie chart showing percent cover of the four major benthic groups for the shallow and deep reef areas. 'Other' refers mostly to turfing algae and, to a lesser degree, unconsolidated substrate.

**F** – Lists of coral species observed.

**G** – Coral health summary; the percent of colonies affected by bleaching, severe bleaching and disease, and overgrown by algae, and the types of diseases observed.

**H** –Percent of total fish biomass made up by each functional group and fish families observed.

**I** – Relative class for the resilience scores for the shallow (left and top) and deep (right and bottom) reef areas.



# Laehou

1 – Shallow, 1 – Deep

North Kona is the origin of the site name, which means 'new point' and refers to a point of land formed with the 1859 Mauna Loa lava flow.



19.873° N, 155.922° W



19.873° N, 155.923° W



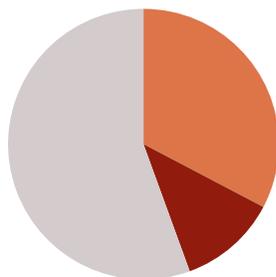
## Relative Resilience

Depth	Rank	Resilience Score	Coral Cover	Coral Diversity	Coral Recruitment	Bleaching Resistance	Macroalgae Cover	Herbivorous Fish Biomass	Rugosity
Shallow	1/20	1.00	0.65	0.79	1.00	1.00	1.00	0.14	0.90
Deep	1/20	1.00	0.77	0.69	1.00	0.84	1.00	0.25	0.82

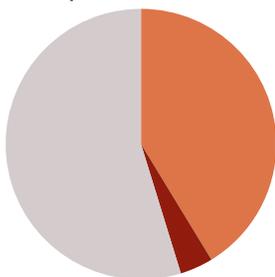
● High (>avg+1 SD) ● Med-High (>avg and <avg+1 SD) ● Med-Low (<avg and >avg - 1 SD) ● Low (<avg - 1 SD)

## Benthic Community

Shallow



Deep



● Coral  
● Macroalgae  
● Coralline algae  
● Other



## Coral Species

**Shallow:** *Leptastrea purpurea*, *Montipora capitata*, *Montipora flabellata*, *Montipora patula*, *Porites compressa*, *Pocillopora damicornis*, *Porites evermani*, *Porites lobata*, *Pavona maldivensis*, *Pocillopora meandrina*, *Pavona varians*.

**Deep:** *Fungia scutaria*, *Leptastrea bewickensis*, *Leptastrea incrusta*, *Leptastrea purpurea*, *Montipora capitata*, *Montipora patula*, *Porites compressa*, *Pocillopora damicornis*, *Pavona duerdeni*, *Porites evermani*, *Porites lobata*, *Pocillopora meandrina*, *Pavona varians*.



## Bleaching and Disease

**Shallow:** 48% of the coral colonies were affected by bleaching (mild and severe). 40% of the coral colonies were severely affected by bleaching. 18% of the coral colonies were overgrown by algae. Total disease prevalence was 3%; diseases present included *Porites* Growth Anomalies and *Pocillopora* Tissue Loss Syndrome.

**Deep:** 48% of the coral colonies were affected by bleaching (mild and severe). 42% of the coral colonies were severely affected by bleaching. 18% of the coral colonies were overgrown by algae. Total disease prevalence was 4%; diseases present included *Porites* Growth Anomalies, *Porites* Tissue Loss Syndrome, and *Pocillopora* Tissue Loss Syndrome.



## Fish

**Shallow:** Percent of total biomass for each functional group: Apex predators (0%), Herbivores (32%), Piscivores (11%), Invertivores (51%), Planktivores (6%). Families observed: Acanthuridae, Balistidae, Chaetodontidae, Cirrhitidae, Holocentridae, Labridae, Lethrinidae, Lutjanidae, Mullidae, Pomacentridae, Scaridae, Tetraodontidae.

**Deep:** Percent of total biomass for each functional group: Apex predators (5%), Herbivores (42%), Piscivores (9%), Invertivores (39%), Planktivores (4%). Families observed: Acanthuridae, Balistidae, Chaetodontidae, Cirrhitidae, Labridae, Lethrinidae, Lutjanidae, Mullidae, Pomacanthidae, Pomacentridae, Scaridae, Tetraodontidae.

SHALLOW SCORE: HIGH

DEEP SCORE: HIGH

# Kumukeya

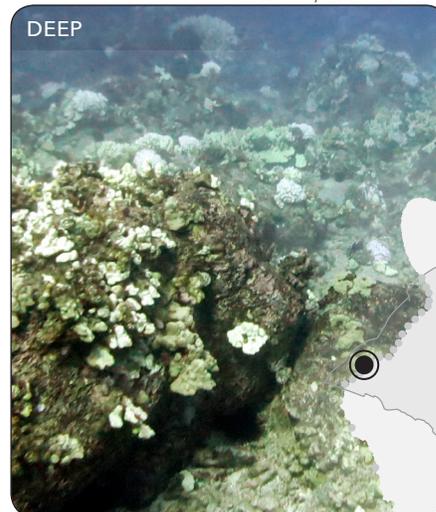
2 – Shallow, 4 – Deep

North Kona is the origin of the site name, which is a reference to the lead aku fish of the deep sea.



19.834° N, 155.998° W

19.834° N, 155.998° W



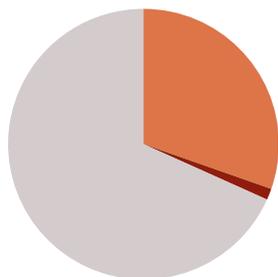
## Relative Resilience

Depth	Rank	Resilience Score	Coral Cover	Coral Diversity	Coral Recruitment	Bleaching Resistance	Macroalgae Cover	Herbivorous Fish Biomass	Rugosity
Shallow	2/20	0.99	0.60	0.70	0.43	1.00	1.00	1.00	0.68
Deep	4/20	0.82	0.28	0.65	0.57	0.90	1.00	0.21	0.79

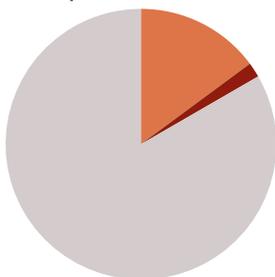
● High (>avg+1 SD) ● Med-High (>avg and <avg+1 SD) ● Med-Low (<avg and >avg - 1 SD) ● Low (<avg - 1 SD)

## Benthic Community

Shallow



Deep



● Coral  
● Macroalgae  
● Coralline algae  
● Other



## Coral Species

**Shallow:** *Leptastrea bewickensis*, *Montipora capitata*, *Montipora patula*, *Porites evermani*, *Pocillopora eydouxi*, *Porites lobata*, *Pocillopora meandrina*, *Pavona varians*.

**Deep:** *Cyphastrea ocellina*, *Montipora capitata*, *Montipora patula*, *Porites compressa*, *Porites evermani*, *Porites lobata*, *Pocillopora meandrina*, *Pavona varians*.



## Bleaching and Disease

**Shallow:** 48% of the coral colonies were affected by bleaching (mild and severe). 38% of the coral colonies were severely affected by bleaching. 30% of the coral colonies were overgrown by algae. Total disease prevalence was 4%; diseases present included *Porites* Growth Anomalies and *Pocillopora* Tissue Loss Syndrome.

**Deep:** 44% of the coral colonies were affected by bleaching (mild and severe). 39% of the coral colonies were severely affected by bleaching. 20% of the coral colonies were overgrown by algae. Total disease prevalence was 4%; diseases present included *Porites* Growth Anomalies and *Pocillopora* Tissue Loss Syndrome.



## Fish

**Shallow:** Percent of total biomass for each functional group: Apex predators (0%), Herbivores (74%), Piscivores (3%), Invertivores (20%), Planktivores (3%). Families observed: Acanthuridae, Aulostomidae, Balistidae, Chaetodontidae, Cirrhitidae, Labridae, Lutjanidae, Monacanthidae, Mullidae, Pomacentridae, Scaridae, Tetraodontidae.

**Deep:** Percent of total biomass for each functional group: Apex predators (0%), Herbivores (39%), Piscivores (10%), Invertivores (51%), Planktivores (0%). Families observed: Acanthuridae, Balistidae, Chaetodontidae, Cirrhitidae, Labridae, Lethrinidae, Monacanthidae, Mullidae, Pomacanthidae, Pomacentridae, Scaridae, Tetraodontidae, Zanclidae.

SHALLOW SCORE: MED-HIGH

DEEP SCORE: HIGH

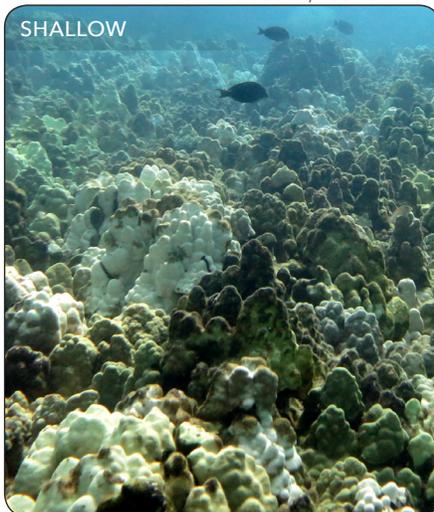
# Kīholo

3 – Shallow, 2 – Deep

North Kona is the origin of the site name, which means 'large wood fish hook', 'large fishing net trailed from a canoe', and 'ti-leaf food package'.



19.855° N, 155.934° W



19.855° N, 155.935° W



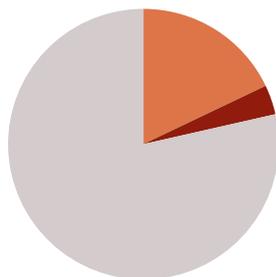
## Relative Resilience

Depth	Rank	Resilience Score	Coral Cover	Coral Diversity	Coral Recruitment	Bleaching Resistance	Macroalgae Cover	Herbivorous Fish Biomass	Rugosity
Shallow	3/20	0.89	0.36	0.62	0.41	0.78	1.00	0.72	1.00
Deep	2/20	0.84	0.39	0.59	0.59	0.94	1.00	0.18	0.82

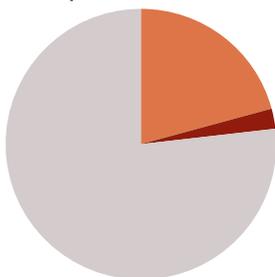
● High (>avg+1 SD) ● Med-High (>avg and <avg+1 SD) ● Med-Low (<avg and >avg - 1 SD) ● Low (<avg - 1 SD)

## Benthic Community

Shallow



Deep



● Coral  
● Macroalgae  
● Coralline algae  
● Other



## Coral Species

**Shallow:** *Cyphastrea ocellina*, *Montipora capitata*, *Montipora patula*, *Porites compressa*, *Pocillopora damicornis*, *Porites evermani*, *Porites lobata*, *Pocillopora meandrina*, *Psammocora stellata*, *Pavona varians*.

**Deep:** *Montipora capitata*, *Montipora patula*, *Porites bernardi*, *Porites compressa*, *Pocillopora damicornis*, *Porites evermani*, *Porites lobata*, *Pocillopora meandrina*, *Pavona varians*.



## Bleaching and Disease

**Shallow:** 59% of the coral colonies were affected by bleaching (mild and severe). 42% of the coral colonies were severely affected by bleaching. 30% of the coral colonies were overgrown by algae. Total disease prevalence was 6%; diseases present included *Porites* Growth Anomalies, *Porites* Tissue Loss Syndrome, and *Pocillopora* Tissue Loss Syndrome.

**Deep:** 42% of the coral colonies were affected by bleaching (mild and severe). 30% of the coral colonies were severely affected by bleaching. 25% of the coral colonies were overgrown by algae. Total disease prevalence was 5%; diseases present included *Porites* Growth Anomalies.



## Fish

**Shallow:** Percent of total biomass for each functional group: Apex predators (0%), Herbivores (66%), Piscivores (5%), Invertivores (25%), Planktivores (4%). Families observed: Acanthuridae, Balistidae, Chaetodontidae, Cirrhitidae, Holocentridae, Labridae, Lutjanidae, Mullidae, Pomacanthidae, Pomacentridae, Scaridae, Tetraodontidae, Zanclidae.

**Deep:** Percent of total biomass for each functional group: Apex predators (0%), Herbivores (43%), Piscivores (12%), Invertivores (45%), Planktivores (0%). Families observed: Acanthuridae, Balistidae, Chaetodontidae, Cirrhitidae, Labridae, Mullidae, Pomacentridae, Scaridae, Tetraodontidae, Zanclidae.

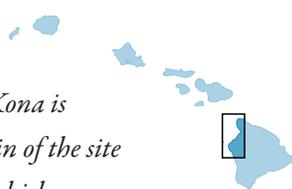
SHALLOW SCORE: HIGH

DEEP SCORE: MED-HIGH

# Mākole'ā

4 – Shallow, 10 – Deep

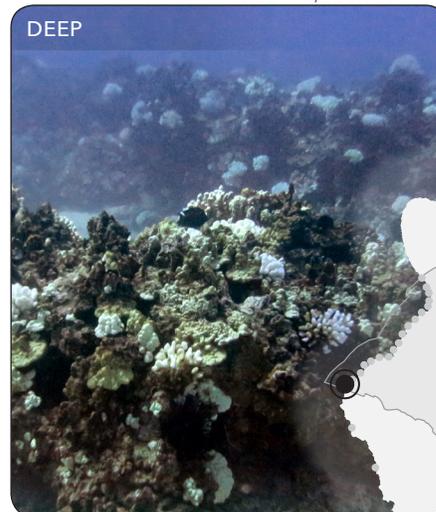
North Kona is the origin of the site name, which means 'glowing red eye' and refers to a point near Keahole created by 1801 lava flow.



19.784° N, 156.048° W



19.784° N, 156.048° W



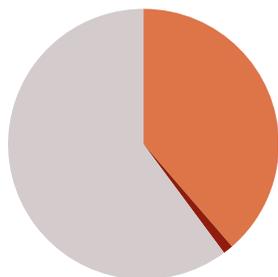
## Relative Resilience

Depth	Rank	Resilience Score	Coral Cover	Coral Diversity	Coral Recruitment	Bleaching Resistance	Macroalgae Cover	Herbivorous Fish Biomass	Rugosity
Shallow	4/20	0.88	0.77	0.53	0.36	0.77	1.00	0.55	0.82
Deep	10/20	0.76	0.47	0.46	0.45	0.78	1.00	0.17	0.75

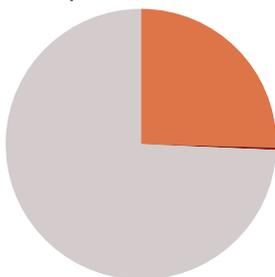
● High (>avg+1 SD) ● Med-High (>avg and <avg+1 SD) ● Med-Low (<avg and >avg - 1 SD) ● Low (<avg - 1 SD)

## Benthic Community

Shallow



Deep



● Coral  
● Macroalgae  
● Coralline algae  
● Other



## Coral Species

**Shallow:** *Leptastrea purpurea*, *Montipora capitata*, *Montipora patula*, *Porites compressa*, *Pavona duerdeni*, *Porites evermani*, *Porites lobata*, *Pavona maldivensis*, *Pocillopora meandrina*.

**Deep:** *Leptastrea bewickensis*, *Montipora capitata*, *Montipora patula*, *Porites compressa*, *Pavona duerdeni*, *Porites evermani*, *Porites lobata*, *Pavona maldivensis*, *Pocillopora meandrina*, *Pavona varians*.



## Bleaching and Disease

**Shallow:** 60% of the coral colonies were affected by bleaching (mild and severe). 45% of the coral colonies were severely affected by bleaching. 32% of the coral colonies were overgrown by algae. Total disease prevalence was 7%; diseases present included *Porites* Growth Anomalies.

**Deep:** 52% of the coral colonies were affected by bleaching (mild and severe). 45% of the coral colonies were severely affected by bleaching. 26% of the coral colonies were overgrown by algae. Total disease prevalence was 7%; diseases present included *Porites* Growth Anomalies and *Pocillopora* Tissue Loss Syndrome.



## Fish

**Shallow:** Percent of total biomass for each functional group: Apex predators (0%), Herbivores (60%), Piscivores (4%), Invertivores (29%), Planktivores (6%). Families observed: Acanthuridae, Aulostomidae, Balistidae, Chaetodontidae, Cirrhitidae, Kyphosidae, Labridae, Lethrinidae, Pomacentridae, Scaridae, Tetraodontidae.

**Deep:** Percent of total biomass for each functional group: Apex predators (0%), Herbivores (45%), Piscivores (11%), Invertivores (34%), Planktivores (10%). Families observed: Acanthuridae, Balistidae, Chaetodontidae, Cirrhitidae, Holocentridae, Labridae, Lethrinidae, Lutjanidae, Monacanthidae, Mullidae, Pomacentridae, Scaridae, Tetraodontidae.

SHALLOW SCORE: MED-HIGH

DEEP SCORE: MED-HIGH

# Manini'ōwali

5 – Shallow, 11 – Deep

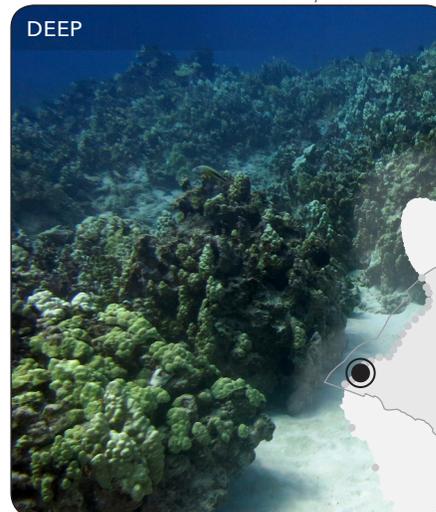
North Kona is the origin of the site name, which means 'weak manini fish' and refers to stone and to the name of a woman who was turned to stone (she remained behind in the story of Pūpūhuelena).



19.813° N, 156.007° W



19.813° N, 156.008° W



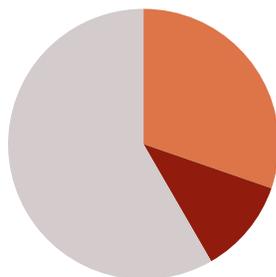
## Relative Resilience

Depth	Rank	Resilience Score	Coral Cover	Coral Diversity	Coral Recruitment	Bleaching Resistance	Macroalgae Cover	Herbivorous Fish Biomass	Rugosity
Shallow	5/20	0.86	0.60	0.59	0.32	0.97	1.00	0.37	0.85
Deep	11/20	0.73	0.38	0.72	0.28	0.89	0.60	0.23	0.80

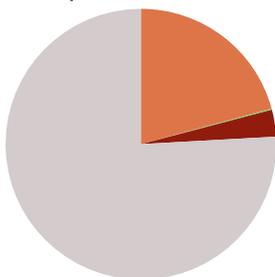
● High (>avg+1 SD) ● Med-High (>avg and <avg+1 SD) ● Med-Low (<avg and >avg - 1 SD) ● Low (<avg - 1 SD)

## Benthic Community

Shallow



Deep



● Coral  
● Macroalgae  
● Coralline algae  
● Other



## Coral Species

**Shallow:** *Cyphastrea ocellina*, *Montipora capitata*, *Montipora patula*, *Porites compressa*, *Porites evermani*, *Porites lobata*, *Pocillopora meandrina*.

**Deep:** *Leptastrea bewickensis*, *Montipora capitata*, *Montipora patula*, *Porites compressa*, *Porites evermani*, *Porites lobata*, *Pocillopora meandrina*, *Pavona varians*.



## Bleaching and Disease

**Shallow:** 49% of the coral colonies were affected by bleaching (mild and severe). 40% of the coral colonies were severely affected by bleaching. 25% of the coral colonies were overgrown by algae. Total disease prevalence was 6%; diseases present included *Porites* Growth Anomalies and *Pocillopora* Tissue Loss Syndrome.

**Deep:** 44% of the coral colonies were affected by bleaching (mild and severe). 35% of the coral colonies were severely affected by bleaching. 15% of the coral colonies were overgrown by algae. Total disease prevalence was 4%; diseases present included *Porites* Growth Anomalies.



## Fish

**Shallow:** Percent of total biomass for each functional group: Apex predators (7%), Herbivores (52%), Piscivores (6%), Invertivores (34%), Planktivores (1%). Families observed: Acanthuridae, Balistidae, Chaetodontidae, Cirrhitidae, Labridae, Lutjanidae, Mullidae, Pomacentridae, Scaridae, Tetraodontidae.

**Deep:** Percent of total biomass for each functional group: Apex predators (8%), Herbivores (50%), Piscivores (0%), Invertivores (41%), Planktivores (1%). Families observed: Acanthuridae, Balistidae, Chaetodontidae, Cirrhitidae, Holocentridae, Labridae, Lutjanidae, Mullidae, Pomacanthidae, Pomacentridae, Scaridae, Tetraodontidae.

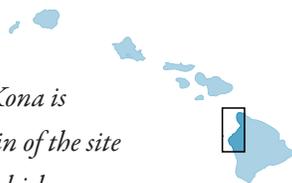
SHALLOW SCORE: MED-HIGH

DEEP SCORE: MED-HIGH

# Keawaiki

6 – Shallow, 14 – Deep

North Kona is the origin of the site name, which means 'small passage/harbor'.



19.891° N, 155.908° W



19.891° N, 155.910° W



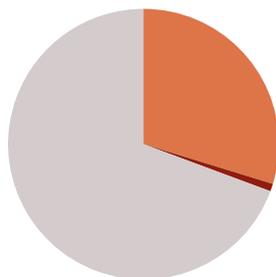
## Relative Resilience

Depth	Rank	Resilience Score	Coral Cover	Coral Diversity	Coral Recruitment	Bleaching Resistance	Macroalgae Cover	Herbivorous Fish Biomass	Rugosity
Shallow	6/20	0.84	0.59	0.95	0.27	0.71	1.00	0.34	0.75
Deep	14/20	0.65	0.36	1.00	0.23	0.94	0.19	0.13	0.66

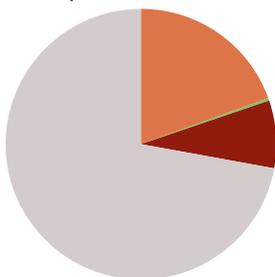
● High (>avg+1 SD) ● Med-High (>avg and <avg+1 SD) ● Med-Low (<avg and >avg - 1 SD) ● Low (<avg - 1 SD)

## Benthic Community

Shallow



Deep



● Coral  
● Macroalgae  
● Coralline algae  
● Other



## Coral Species

**Shallow:** *Montipora capitata*, *Montipora flabellata*, *Montipora patula*, *Porites compressa*, *Pavona duerdeni*, *Psammocora haimeana*, *Porites lobata*, *Pocillopora meandrina*, *Pavona varians*.

**Deep:** *Cyphastrea ocellina*, *Leptastrea transversa*, *Montipora capitata*, *Montipora flabellata*, *Montipora patula*, *Porites compressa*, *Pocillopora damicornis*, *Psammocora haimeana*, *Porites lobata*, *Pavona maldivensis*, *Pocillopora meandrina*, *Porites solida*, *Pavona varians*.



## Bleaching and Disease

**Shallow:** 63% of the coral colonies were affected by bleaching (mild and severe). 49% of the coral colonies were severely affected by bleaching. 6% of the coral colonies were overgrown by algae. Total disease prevalence was 1%; diseases present included *Montipora* Growth Anomalies and *Pocillopora* Tissue Loss Syndrome.

**Deep:** 42% of the coral colonies were affected by bleaching (mild and severe). 33% of the coral colonies were severely affected by bleaching. 3% of the coral colonies were overgrown by algae. No diseases were observed.



## Fish

**Shallow:** Percent of total biomass for each functional group: Apex predators (0%), Herbivores (70%), Piscivores (8%), Invertivores (22%), Planktivores (0%). Families observed: Acanthuridae, Balistidae, Blenniidae, Chaetodontidae, Cirrhitidae, Labridae, Monacanthidae, Mullidae, Ostraciidae, Pomacentridae, Scaridae, Tetraodontidae.

**Deep:** Percent of total biomass for each functional group: Apex predators (0%), Herbivores (53%), Piscivores (5%), Invertivores (42%), Planktivores (0%). Families observed: Acanthuridae, Aulostomidae, Balistidae, Blenniidae, Carangidae, Chaetodontidae, Cirrhitidae, Labridae, Monacanthidae, Mullidae, Pomacentridae, Pomacentridae, Scaridae, Zanclidae.

SHALLOW SCORE: MED-LOW

DEEP SCORE: MED-HIGH

# Makalawena

7 – Shallow, 5 – Deep

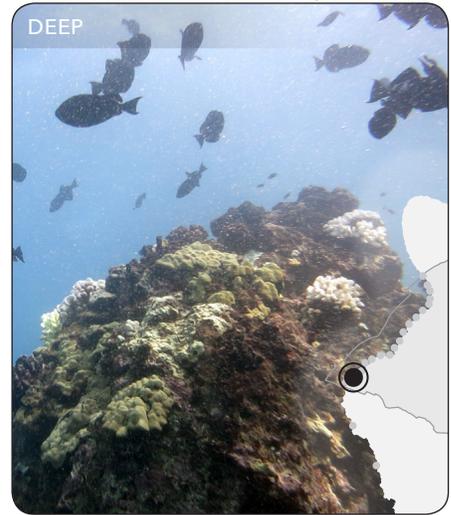
North Kona is the origin of the site name, which means 'release of glow' and is the former site of a fishing village destroyed by a tsunami in 1946.



19.796° N, 156.028° W



19.797° N, 156.028° W



SHALLOW SCORE: MED-HIGH

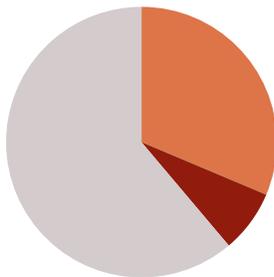
## Relative Resilience

Depth	Rank	Resilience Score	Coral Cover	Coral Diversity	Coral Recruitment	Bleaching Resistance	Macroalgae Cover	Herbivorous Fish Biomass	Rugosity
Shallow	7/20	0.83	0.62	0.59	0.41	0.75	1.00	0.41	0.80
Deep	5/20	0.81	0.60	0.50	0.31	0.92	0.80	0.43	0.77

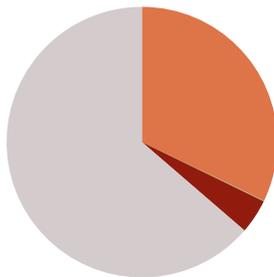
● High (>avg+1 SD) ● Med-High (>avg and <avg+1 SD) ● Med-Low (<avg and >avg - 1 SD) ● Low (<avg - 1 SD)

## Benthic Community

Shallow



Deep



● Coral  
● Macroalgae  
● Coralline algae  
● Other



## Coral Species

**Shallow:** *Leptastrea purpurea*, *Montipora capitata*, *Montipora patula*, *Porites compressa*, *Pavona duerdeni*, *Porites evermani*, *Porites lobata*, *Pocillopora meandrina*.

**Deep:** *Leptastrea bewickensis*, *Montipora capitata*, *Montipora patula*, *Porites compressa*, *Porites evermani*, *Porites lobata*, *Pocillopora meandrina*, *Pavona varians*.



## Bleaching and Disease

**Shallow:** 61% of the coral colonies were affected by bleaching (mild and severe). 46% of the coral colonies were severely affected by bleaching. 30% of the coral colonies were overgrown by algae. Total disease prevalence was 6%; diseases present included *Porites* Growth Anomalies and *Pocillopora* Tissue Loss Syndrome.

**Deep:** 43% of the coral colonies were affected by bleaching (mild and severe). 31% of the coral colonies were severely affected by bleaching. 24% of the coral colonies were overgrown by algae. Total disease prevalence was 6%; diseases present included *Porites* Growth Anomalies.



## Fish

**Shallow:** Percent of total biomass for each functional group: Apex predators (0%), Herbivores (73%), Piscivores (2%), Invertivores (13%), Planktivores (12%). Families observed: Acanthuridae, Balistidae, Chaetodontidae, Cirrhitidae, Labridae, Mullidae, Pomacentridae, Scaridae, Tetraodontidae.

**Deep:** Percent of total biomass for each functional group: Apex predators (0%), Herbivores (55%), Piscivores (3%), Invertivores (42%), Planktivores (0%). Families observed: Acanthuridae, Balistidae, Blenniidae, Chaetodontidae, Cirrhitidae, Labridae, Lethrinidae, Lutjanidae, Mullidae, Pomacentridae, Scaridae, Tetraodontidae, Zanclidae.

DEEP SCORE: MED-HIGH

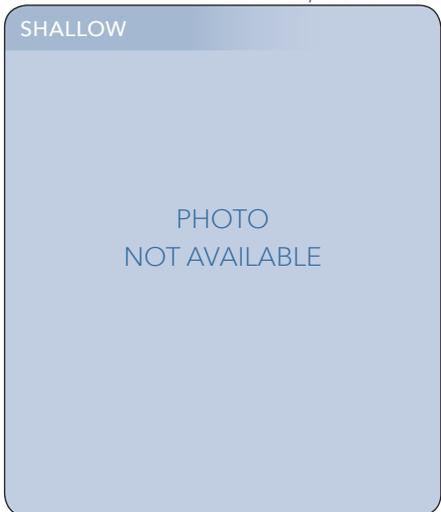
# Keonenui

8 – Shallow, 17 – Deep

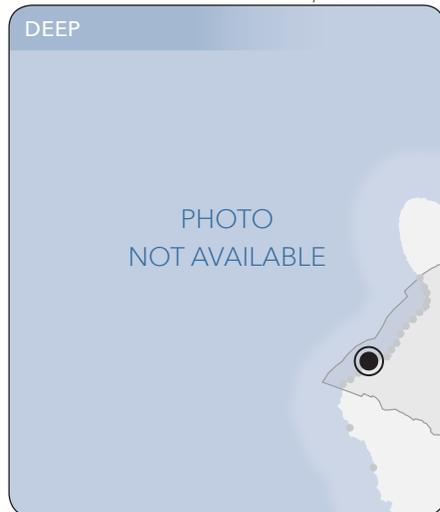
North Kona is the origin of the site name, which means 'big sand' and refers to a black sand beach created by 19th century lava flow.



19.844° N, 155.981° W



19.844° N, 155.981° W



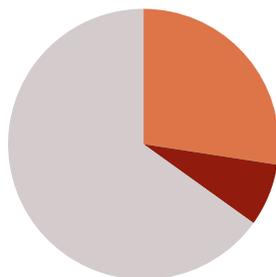
## Relative Resilience

Depth	Rank	Resilience Score	Coral Cover	Coral Diversity	Coral Recruitment	Bleaching Resistance	Macroalgae Cover	Herbivorous Fish Biomass	Rugosity
Shallow	8/20	0.83	0.54	0.59	0.28	0.85	1.00	0.48	0.81
Deep	17/20	0.63	0.58	0.53	0.29	1.00	0.00	0.13	0.84

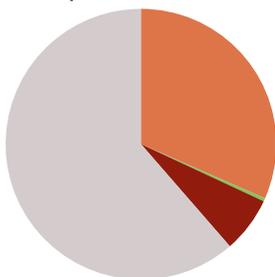
● High (>avg+1 SD) ● Med-High (>avg and <avg+1 SD) ● Med-Low (<avg and >avg - 1 SD) ● Low (<avg - 1 SD)

## Benthic Community

Shallow



Deep



● Coral  
● Macroalgae  
● Coralline algae  
● Other



## Coral Species

**Shallow:** *Cyphastrea ocellina*, *Fungia scutaria*, *Montipora capitata*, *Montipora patula*, *Porites compressa*, *Porites evermani*, *Pocillopora eydouxi*, *Porites lobata*, *Pocillopora meandrina*, *Psammocora stellata*, *Pavona varians*.

**Deep:** *Leptastrea bewickensis*, *Montipora capitata*, *Montipora patula*, *Porites compressa*, *Porites evermani*, *Porites lobata*, *Pocillopora meandrina*, *Pavona varians*.



## Bleaching and Disease

**Shallow:** 55% of the coral colonies were affected by bleaching (mild and severe). 45% of the coral colonies were severely affected by bleaching. 15% of the coral colonies were overgrown by algae. Total disease prevalence was 6%; diseases present included *Porites* Growth Anomalies and *Porites* Tissue Loss Syndrome.

**Deep:** 38% of the coral colonies were affected by bleaching (mild and severe). 30% of the coral colonies were severely affected by bleaching. 16% of the coral colonies were overgrown by algae. Total disease prevalence was 6%; diseases present included *Porites* Growth Anomalies.



## Fish

**Shallow:** Percent of total biomass for each functional group: Apex predators (0%), Herbivores (77%), Piscivores (6%), Invertivores (16%), Planktivores (0%). Families observed: Acanthuridae, Balistidae, Chaetodontidae, Chanidae, Cirrhitidae, Labridae, Lutjanidae, Mullidae, Pomacentridae, Scaridae, Zanclidae.

**Deep:** Percent of total biomass for each functional group: Apex predators (0%), Herbivores (20%), Piscivores (18%), Invertivores (14%), Planktivores (48%). Families observed: Acanthuridae, Balistidae, Chaetodontidae, Cirrhitidae, Holocentridae, Labridae, Mullidae, Muraenidae, Pomacanthidae, Pomacentridae, Scaridae, Zanclidae.

SHALLOW SCORE: MED-LOW

DEEP SCORE: MED-HIGH

# Keanapukalua

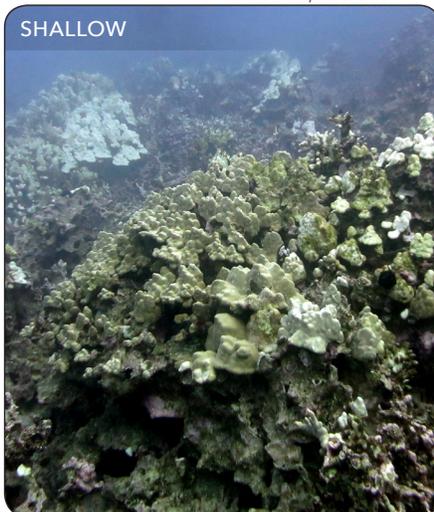
9 – Shallow, 13 – Deep

South Kohala is the origin of the site name, which means 'the cave of the roasted shell'.



19.952° N, 155.866° W

19.953° N, 155.866° W



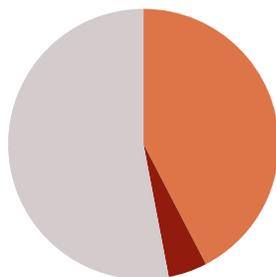
## Relative Resilience

Depth	Rank	Resilience Score	Coral Cover	Coral Diversity	Coral Recruitment	Bleaching Resistance	Macroalgae Cover	Herbivorous Fish Biomass	Rugosity
Shallow	9/20	0.82	0.84	0.57	0.36	0.33	1.00	0.63	0.76
Deep	13/20	0.67	0.22	0.51	0.59	0.15	1.00	0.39	0.73

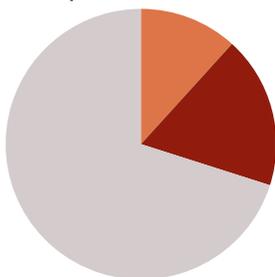
● High (>avg+1 SD) ● Med-High (>avg and <avg+1 SD) ● Med-Low (<avg and >avg - 1 SD) ● Low (<avg - 1 SD)

## Benthic Community

Shallow



Deep



● Coral  
● Macroalgae  
● Coralline algae  
● Other



## Coral Species

**Shallow:** *Leptastrea purpurea*, *Montipora capitata*, *Montipora patula*, *Porites compressa*, *Porites lobata*, *Pocillopora meandrina*, *Pavona varians*.

**Deep:** *Montipora capitata*, *Montipora incrassata*, *Montipora patula*, *Porites compressa*, *Pocillopora damicornis*, *Porites lobata*, *Pocillopora meandrina*, *Psammocora stellata*, *Pavona varians*.



## Bleaching and Disease

**Shallow:** 83% of the coral colonies were affected by bleaching (mild and severe). 63% of the coral colonies were severely affected by bleaching. 33% of the coral colonies were overgrown by algae. Total disease prevalence was 6%; diseases present included *Porites* Growth Anomalies.

**Deep:** 91% of the coral colonies were affected by bleaching (mild and severe). 67% of the coral colonies were severely affected by bleaching. 36% of the coral colonies were overgrown by algae. Total disease prevalence was 6%; diseases present included *Porites* Growth Anomalies.



## Fish

**Shallow:** Percent of total biomass for each functional group: Apex predators (0%), Herbivores (60%), Piscivores (6%), Invertivores (33%), Planktivores (0%). Families observed: Acanthuridae, Balistidae, Chaetodontidae, Cirrhitidae, Labridae, Lutjanidae, Mullidae, Muraenidae, Myliobatidae, Pomacentridae, Scaridae.

**Deep:** Percent of total biomass for each functional group: Apex predators (0%), Herbivores (48%), Piscivores (14%), Invertivores (35%), Planktivores (4%). Families observed: Acanthuridae, Balistidae, Chaetodontidae, Cirrhitidae, Labridae, Lethrinidae, Mullidae, Pomacentridae, Scaridae, Zanclidae.

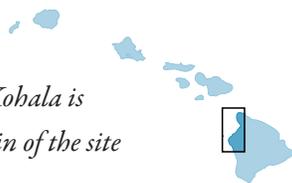
SHALLOW SCORE: MED-LOW

DEEP SCORE: MED-HIGH

# Lulahala Pt

10 – Shallow, 20 – Deep

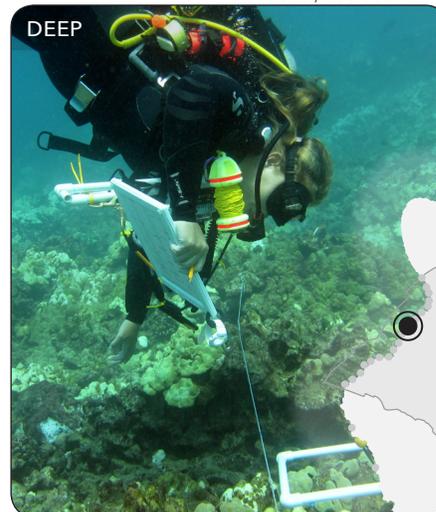
South Kohala is the origin of the site name.



19.935° N, 155.884° W



19.935° N, 155.885° W



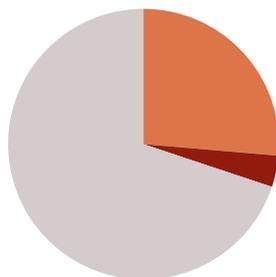
## Relative Resilience

Depth	Rank	Resilience Score	Coral Cover	Coral Diversity	Coral Recruitment	Bleaching Resistance	Macroalgae Cover	Herbivorous Fish Biomass	Rugosity
Shallow	10/20	0.80	0.52	0.71	0.32	0.56	1.00	0.56	0.73
Deep	20/20	0.55	0.15	0.64	0.33	0.34	0.40	0.43	0.64

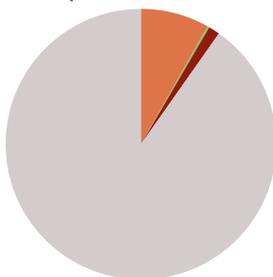
● High (>avg+1 SD) ● Med-High (>avg and <avg+1 SD) ● Med-Low (<avg and >avg - 1 SD) ● Low (<avg - 1 SD)

## Benthic Community

Shallow



Deep



● Coral  
● Macroalgae  
● Coralline algae  
● Other



## Coral Species

**Shallow:** *Montipora capitata*, *Montipora flabellata*, *Montipora patula*, *Porites compressa*, *Porites lobata*, *Pocillopora meandrina*, *Pavona varians*.

**Deep:** *Montipora capitata*, *Montipora patula*, *Porites compressa*, *Porites lobata*, *Pocillopora meandrina*, *Porites monticulosa*, *Pavona varians*.



## Bleaching and Disease

**Shallow:** 79% of the coral colonies were affected by bleaching (mild and severe). 64% of the coral colonies were severely affected by bleaching. 19% of the coral colonies were overgrown by algae. Total disease prevalence was 4%; diseases present included *Porites* Growth Anomalies.

**Deep:** 71% of the coral colonies were affected by bleaching (mild and severe). 57% of the coral colonies were severely affected by bleaching. 27% of the coral colonies were overgrown by algae. Total disease prevalence was 4%; diseases present included *Porites* Growth Anomalies.



## Fish

**Shallow:** Percent of total biomass for each functional group: Apex predators (0%), Herbivores (65%), Piscivores (9%), Invertivores (26%), Planktivores (0%). Families observed: Acanthuridae, Balistidae, Chaetodontidae, Cirrhitidae, Kyphosidae, Labridae, Lutjanidae, Mullidae, Ostraciidae, Pomacentridae, Scaridae.

**Deep:** Percent of total biomass for each functional group: Apex predators (0%), Herbivores (83%), Piscivores (4%), Invertivores (13%), Planktivores (0%). Families observed: Acanthuridae, Balistidae, Chaetodontidae, Cirrhitidae, Labridae, Mullidae, Muraenidae, Ostraciidae, Pomacentridae, Scaridae, Zanclidae.

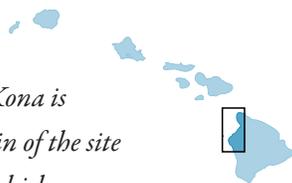
SHALLOW SCORE: LOW

DEEP SCORE: MED-HIGH

# Kalaemanō

11 – Shallow, 15 – Deep

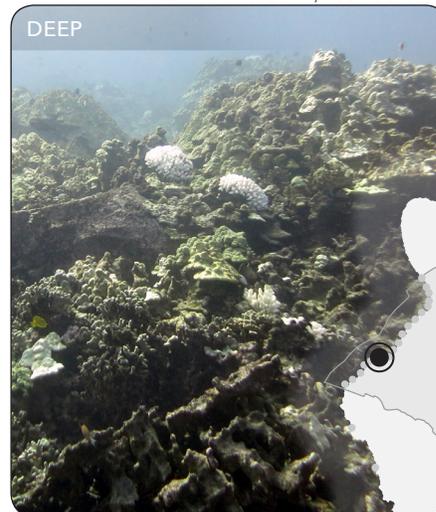
North Kona is the origin of the site name, which means 'point of the shark' and refers to the niuhi or man-eating shark.



19.853° N, 155.958° W



19.854° N, 155.958° W



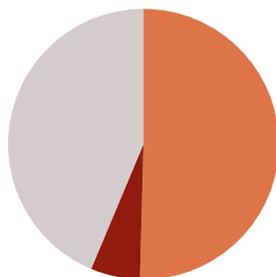
## Relative Resilience

Depth	Rank	Resilience Score	Coral Cover	Coral Diversity	Coral Recruitment	Bleaching Resistance	Macroalgae Cover	Herbivorous Fish Biomass	Rugosity
Shallow	11/20	0.74	1.00	0.00	0.16	0.86	1.00	0.26	0.80
Deep	15/20	0.64	0.21	0.00	0.33	0.96	1.00	0.17	0.76

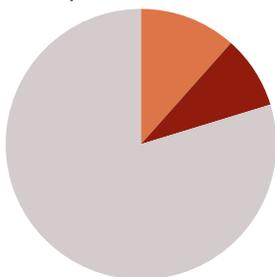
● High (>avg+1 SD) ● Med-High (>avg and <avg+1 SD) ● Med-Low (<avg and >avg - 1 SD) ● Low (<avg - 1 SD)

## Benthic Community

Shallow



Deep



● Coral  
● Macroalgae  
● Coralline algae  
● Other



## Coral Species

**Shallow:** *Cyphastrea ocellina*, *Montipora capitata*, *Montipora patula*, *Porites compressa*, *Pavona duerdeni*, *Porites evermani*, *Porites lobata*, *Pocillopora meandrina*.

**Deep:** *Montipora capitata*, *Montipora patula*, *Porites compressa*, *Porites evermani*, *Porites lobata*, *Pocillopora meandrina*, *Pavona varians*.



## Bleaching and Disease

**Shallow:** 55% of the coral colonies were affected by bleaching (mild and severe). 32% of the coral colonies were severely affected by bleaching. 36% of the coral colonies were overgrown by algae. Total disease prevalence was 15%; diseases present included *Porites* Growth Anomalies, *Porites* Tissue Loss Syndrome and *Pocillopora* Tissue Loss Syndrome.

**Deep:** 40% of the coral colonies were affected by bleaching (mild and severe). 32% of the coral colonies were severely affected by bleaching. 21% of the coral colonies were overgrown by algae. Total disease prevalence was 12%; diseases present included *Porites* Growth Anomalies and *Porites* Tissue Loss Syndrome.



## Fish

**Shallow:** Percent of total biomass for each functional group: Apex predators (0%), Herbivores (65%), Piscivores (6%), Invertivores (25%), Planktivores (3%). Families observed: Acanthuridae, Balistidae, Chaetodontidae, Cirrhitidae, Holocentridae, Labridae, Pomacanthidae, Pomacentridae, Scaridae.

**Deep:** Percent of total biomass for each functional group: Apex predators (0%), Herbivores (41%), Piscivores (19%), Invertivores (25%), Planktivores (14%). Families observed: Acanthuridae, Aulostomidae, Balistidae, Chaetodontidae, Cirrhitidae, Labridae, Lutjanidae, Mullidae, Pomacanthidae, Pomacentridae, Scaridae, Zanclidae.

SHALLOW SCORE: MED-LOW

DEEP SCORE: MED-LOW

# Kauna'oa

12 – Shallow, 6 – Deep

South Kohala is the origin of the site name, which refers to a native species of dodder, a parasitic brilliant orange plant found on pohuehue (beach morning glory).



20.001° N, 155.829° W



20.000° N, 155.831° W



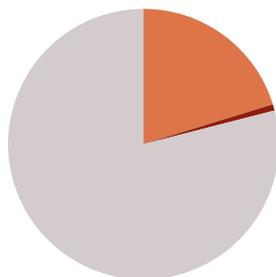
## Relative Resilience

Depth	Rank	Resilience Score	Coral Cover	Coral Diversity	Coral Recruitment	Bleaching Resistance	Macroalgae Cover	Herbivorous Fish Biomass	Rugosity
Shallow	12/20	0.74	0.40	0.26	0.42	0.85	1.00	0.36	0.78
Deep	6/20	0.80	0.31	0.85	0.40	0.81	1.00	0.17	0.75

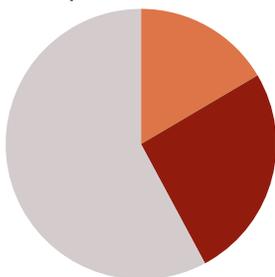
● High (>avg+1 SD) ● Med-High (>avg and <avg+1 SD) ● Med-Low (<avg and >avg - 1 SD) ● Low (<avg - 1 SD)

## Benthic Community

Shallow



Deep



● Coral  
● Macroalgae  
● Coralline algae  
● Other



## Coral Species

**Shallow:** *Cyphastrea ocellina*, *Montipora capitata*, *Montipora patula*, *Porites brighami*, *Porites compressa*, *Porites evermani*, *Porites lobata*, *Pocillopora meandrina*, *Porites rus*, *Pavona varians*.

**Deep:** *Montipora capitata*, *Montipora patula*, *Porites compressa*, *Pocillopora damicornis*, *Porites evermani*, *Porites lobata*, *Pocillopora meandrina*, *Pavona varians*.



## Bleaching and Disease

**Shallow:** 56% of the coral colonies were affected by bleaching (mild and severe). 42% of the coral colonies were severely affected by bleaching. 55% of the coral colonies were overgrown by algae. Total disease prevalence was 11%; diseases present included *Porites* Growth Anomalies, *Porites* Tissue Loss Syndrome and *Pocillopora* Tissue Loss Syndrome.

**Deep:** 49% of the coral colonies were affected by bleaching (mild and severe). 44% of the coral colonies were severely affected by bleaching. 22% of the coral colonies were overgrown by algae. Total disease prevalence was 2%; diseases present included *Porites* Growth Anomalies and *Montipora* Growth Anomalies.



## Fish

**Shallow:** Percent of total biomass for each functional group: Apex predators (0%), Herbivores (60%), Piscivores (4%), Invertivores (35%), Planktivores (1%). Families observed: Acanthuridae, Balistidae, Chaetodontidae, Cirrhitidae, Kyphosidae, Labridae, Lethrinidae, Mullidae, Pomacentridae, Scaridae, Zanclidae.

**Deep:** Percent of total biomass for each functional group: Apex predators (0%), Herbivores (36%), Piscivores (23%), Invertivores (30%), Planktivores (10%). Families observed: Acanthuridae, Aulostomidae, Balistidae, Chaetodontidae, Cirrhitidae, Holocentridae, Labridae, Lethrinidae, Mullidae, Ostraciidae, Pomacentridae, Scaridae, Tetraodontidae, Zanclidae.

SHALLOW SCORE: MED-HIGH

DEEP SCORE: MED-LOW

# Keauhou

13 – Shallow, 12 – Deep

North Kona is the origin of the site name, which means 'new era/current'.



19.568° N, 155.969° W



19.568° N, 155.969° W



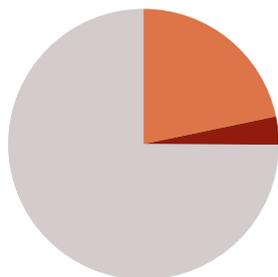
## Relative Resilience

Depth	Rank	Resilience Score	Coral Cover	Coral Diversity	Coral Recruitment	Bleaching Resistance	Macroalgae Cover	Herbivorous Fish Biomass	Rugosity
Shallow	13/20	0.74	0.43	0.20	0.12	0.64	1.00	0.76	0.88
Deep	12/20	0.69	0.45	0.33	0.13	0.62	1.00	0.18	1.00

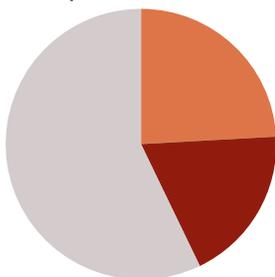
● High (>avg+1 SD) ● Med-High (>avg and <avg+1 SD) ● Med-Low (<avg and >avg - 1 SD) ● Low (<avg - 1 SD)

## Benthic Community

Shallow



Deep



● Coral  
● Macroalgae  
● Coralline algae  
● Other



## Coral Species

**Shallow:** *Cyphastrea ocellina*, *Montipora capitata*, *Porites compressa*, *Porites evermani*, *Porites lobata*, *Pavona varians*.

**Deep:** *Cyphastrea ocellina*, *Leptastrea incrusta*, *Porites bernardi*, *Porites compressa*, *Pocillopoa damicornis*, *Porites evermani*, *Porites lobata*, *Pavona varians*.



## Bleaching and Disease

**Shallow:** 67% of the coral colonies were affected by bleaching (mild and severe). 56% of the coral colonies were severely affected by bleaching. 43% of the coral colonies were overgrown by algae. Total disease prevalence was 12%; diseases present included *Porites* Growth Anomalies and *Porites* Tissue Loss Syndrome.

**Deep:** 62% of the coral colonies were affected by bleaching (mild and severe). 42% of the coral colonies were severely affected by bleaching. 48% of the coral colonies were overgrown by algae. Total disease prevalence was 8%; diseases present included *Porites* Growth Anomalies and *Porites* Tissue Loss Syndrome.



## Fish

**Shallow:** Percent of total biomass for each functional group: Apex predators (0%), Herbivores (74%), Piscivores (1%), Invertivores (24%), Planktivores (1%). Families observed: Acanthuridae, Balistidae, Chaetodontidae, Cirrhitidae, Holocentridae, Labridae, Mullidae, Pomacentridae, Scaridae, Tetraodontidae, Zanclidae.

**Deep:** Percent of total biomass for each functional group: Apex predators (1%), Herbivores (30%), Piscivores (15%), Invertivores (52%), Planktivores (2%). Families observed: Acanthuridae, Aulostomidae, Balistidae, Chaetodontidae, Holocentridae, Labridae, Lethrinidae, Lutjanidae, Mullidae, Pomacanthidae, Pomacentridae, Scaridae, Zanclidae.

SHALLOW SCORE: MED-LOW

DEEP SCORE: MED-LOW

# Kailapa

14 – Shallow, 9 – Deep

South Kohala is the origin of the site name, which means ‘ocean ridge’.



20.060° N, 155.848° W



20.059° N, 155.849° W



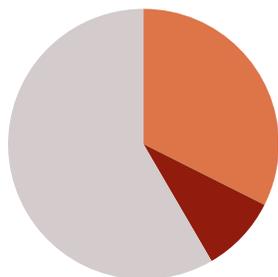
## Relative Resilience

Depth	Rank	Resilience Score	Coral Cover	Coral Diversity	Coral Recruitment	Bleaching Resistance	Macroalgae Cover	Herbivorous Fish Biomass	Rugosity
Shallow	14/20	0.73	0.64	0.61	0.29	0.35	1.00	0.24	0.89
Deep	9/20	0.76	0.47	0.84	0.54	0.41	1.00	0.07	0.77

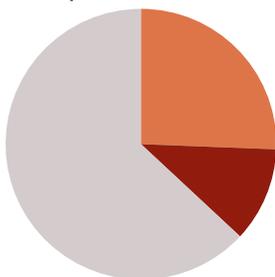
● High (>avg+1 SD) ● Med-High (>avg and <avg+1 SD) ● Med-Low (<avg and >avg - 1 SD) ● Low (<avg - 1 SD)

## Benthic Community

Shallow



Deep



● Coral  
● Macroalgae  
● Coralline algae  
● Other



## Coral Species

**Shallow:** *Montipora capitata*, *Montipora patula*, *Porites compressa*, *Porites evermani*, *Porites lobata*, *Pocillopora meandrina*, *Psammocora nierstraszi*, *Psammocora stellata*, *Pavona varians*.

**Deep:** *Montipora capitata*, *Montipora flabellata*, *Montipora patula*, *Porites compressa*, *Pocillopora damicornis*, *Porites lobata*, *Pavona maldivensis*, *Pocillopora meandrina*, *Porites monticulosa*, *Psammocora stellata*, *Pavona varians*.



## Bleaching and Disease

**Shallow:** 82% of the coral colonies were affected by bleaching (mild and severe). 66% of the coral colonies were severely affected by bleaching. 14% of the coral colonies were overgrown by algae. Total disease prevalence was 6%; diseases present included *Porites* Growth Anomalies and *Montipora* Growth Anomalies.

**Deep:** 75% of the coral colonies were affected by bleaching (mild and severe). 61% of the coral colonies were severely affected by bleaching. 10% of the coral colonies were overgrown by algae. Total disease prevalence was 2%; diseases present included *Porites* Growth Anomalies.



## Fish

**Shallow:** Percent of total biomass for each functional group: Apex predators (0%), Herbivores (50%), Piscivores (10%), Invertivores (40%), Planktivores (0%). Families observed: Acanthuridae, Aulostomidae, Balistidae, Blenniidae, Chaetodontidae, Cirrhitidae, Labridae, Lethrinidae, Lutjanidae, Mullidae, Pomacentridae, Scaridae.

**Deep:** Percent of total biomass for each functional group: Apex predators (0%), Herbivores (10%), Piscivores (22%), Invertivores (26%), Planktivores (43%). Families observed: Acanthuridae, Aulostomidae, Balistidae, Chaetodontidae, Holocentridae, Labridae, Lethrinidae, Lutjanidae, Mullidae, Pomacanthidae, Pomacentridae.

SHALLOW SCORE: MED-HIGH

DEEP SCORE: MED-LOW

# Kawaihae

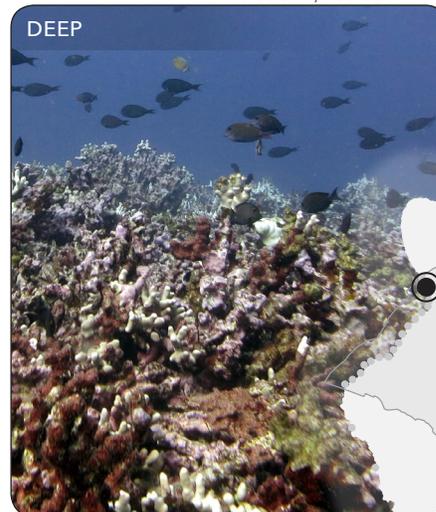
15 – Shallow, 18 – Deep

South Kohala is the origin of the site name, which means ‘remnant of old fringing reef’.



20.036° N, 155.837° W

20.036° N, 155.837° W



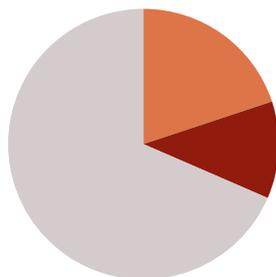
## Relative Resilience

Depth	Rank	Resilience Score	Coral Cover	Coral Diversity	Coral Recruitment	Bleaching Resistance	Macroalgae Cover	Herbivorous Fish Biomass	Rugosity
Shallow	15/20	0.72	0.39	0.88	0.59	0.16	1.00	0.14	0.76
Deep	18/20	0.61	0.31	0.53	0.29	0.27	1.00	0.19	0.72

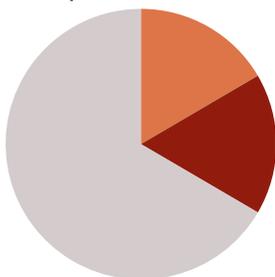
● High (>avg+1 SD) ● Med-High (>avg and <avg+1 SD) ● Med-Low (<avg and >avg - 1 SD) ● Low (<avg - 1 SD)

## Benthic Community

Shallow



Deep



● Coral  
● Macroalgae  
● Coralline algae  
● Other



## Coral Species

**Shallow:** *Montipora capitata*, *Montipora patula*, *Porites compressa*, *Porites lobata*, *Pocillopora meandrina*, *Psammocora stellata*, *Pavona varians*.

**Deep:** *Montipora incrassata*, *Montipora patula*, *Porites compressa*, *Pocillopora damicornis*, *Porites lobata*, *Pocillopora meandrina*, *Psammocora stellata*, *Pavona varians*.



## Bleaching and Disease

**Shallow:** 91% of the coral colonies were affected by bleaching (mild and severe). 80% of the coral colonies were severely affected by bleaching. 16% of the coral colonies were overgrown by algae. Total disease prevalence was 2%; diseases present included *Porites* Growth Anomalies.

**Deep:** 83% of the coral colonies were affected by bleaching (mild and severe). 66% of the coral colonies were severely affected by bleaching. 35% of the coral colonies were overgrown by algae. Total disease prevalence was 6%; diseases present included *Porites* Growth Anomalies.



## Fish

**Shallow:** Percent of total biomass for each functional group: Apex predators (0%), Herbivores (40%), Piscivores (6%), Invertivores (55%), Planktivores (0%). Families observed: Acanthuridae, Balistidae, Blenniidae, Chaetodontidae, Cirrhitidae, Labridae, Mullidae, Pomacentridae, Scaridae, Zanclidae.

**Deep:** Percent of total biomass for each functional group: Apex predators (0%), Herbivores (37%), Piscivores (8%), Invertivores (45%), Planktivores (9%). Families observed: Acanthuridae, Aulostomidae, Balistidae, Chaetodontidae, Cirrhitidae, Labridae, Lethrinidae, Mullidae, Pomacanthidae, Pomacentridae, Scaridae, Zanclidae.

DEEP SCORE: MED-LOW

SHALLOW SCORE: LOW

# Kapalaoa

16 – Shallow, 19 – Deep

South Kohala is the origin of the site name, which means 'the sacred whalebone pendant of the ruling chief'.



19.914° N, 155.899° W

19.914° N, 155.901° W



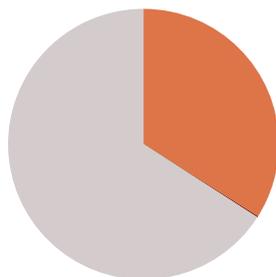
## Relative Resilience

Depth	Rank	Resilience Score	Coral Cover	Coral Diversity	Coral Recruitment	Bleaching Resistance	Macroalgae Cover	Herbivorous Fish Biomass	Rugosity
Shallow	16/20	0.70	0.67	0.65	0.14	0.34	1.00	0.38	0.68
Deep	19/20	0.59	0.38	0.44	0.25	0.48	0.60	0.33	0.69

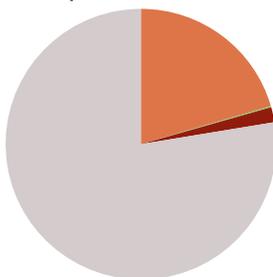
● High (>avg+1 SD) ● Med-High (>avg and <avg+1 SD) ● Med-Low (<avg and >avg - 1 SD) ● Low (<avg - 1 SD)

## Benthic Community

Shallow



Deep



● Coral  
● Macroalgae  
● Coralline algae  
● Other



## Coral Species

**Shallow:** *Montipora capitata*, *Montipora flabellata*, *Montipora incrassata*, *Montipora patula*, *Porites compressa*, *Pavona duerdeni*, *Psammocora haimeana*, *Porites lobata*, *Pocillopora meandrina*, *Pavona varians*.

**Deep:** *Montipora capitata*, *Montipora patula*, *Porites compressa*, *Porites evermani*, *Porites lobata*, *Pocillopora meandrina*, *Pavona varians*.



## Bleaching and Disease

**Shallow:** 70% of the coral colonies were affected by bleaching (mild and severe). 57% of the coral colonies were severely affected by bleaching. 20% of the coral colonies were overgrown by algae. Total disease prevalence was 7%; diseases present included *Porites* Growth Anomalies and *Porites* Trematodiasis.

**Deep:** 82% of the coral colonies were affected by bleaching (mild and severe). 68% of the coral colonies were severely affected by bleaching. 24% of the coral colonies were overgrown by algae. Total disease prevalence was 5%; diseases present included *Porites* Growth Anomalies, *Montipora* Growth Anomalies, *Porites* Tissue Loss Syndrome, *Pocillopora* Tissue Loss Syndrome, and *Porites* Trematodiasis.



## Fish

**Shallow:** Percent of total biomass for each functional group: Apex predators (2%), Herbivores (80%), Piscivores (0%), Invertivores (17%), Planktivores (1%). Families observed: Acanthuridae, Balistidae, Blenniidae, Carangidae, Chaetodontidae, Cirrhitidae, Labridae, Monacanthidae, Pomacentridae, Scaridae, Zanclidae.

**Deep:** Percent of total biomass for each functional group: Apex predators (0%), Herbivores (56%), Piscivores (27%), Invertivores (17%), Planktivores (0%). Families observed: Acanthuridae, Balistidae, Chaetodontidae, Cirrhitidae, Labridae, Mullidae, Pomacentridae, Scaridae.

DEEP SCORE: MED-LOW

SHALLOW SCORE: LOW

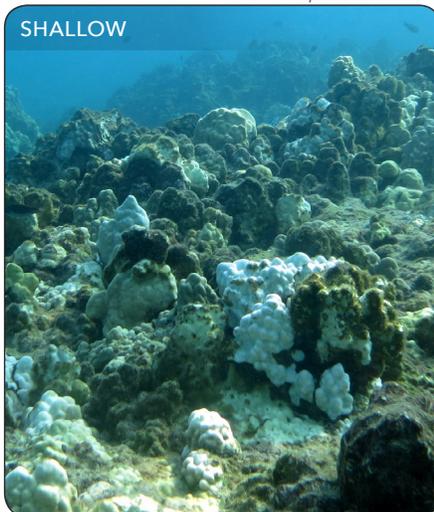
# Honokōhau

17 – Shallow, 8 – Deep

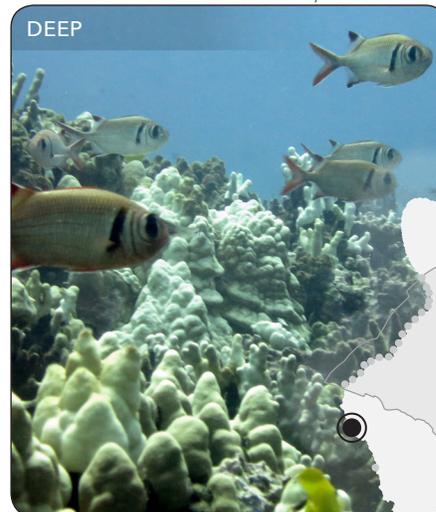
North Kona is the origin of the site name, which means 'bay drawing dew'.



19.671° N, 156.030° W



19.671° N, 156.030° W



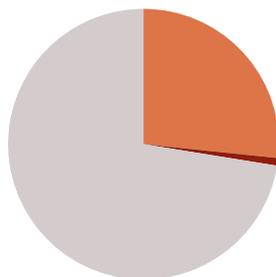
## Relative Resilience

Depth	Rank	Resilience Score	Coral Cover	Coral Diversity	Coral Recruitment	Bleaching Resistance	Macroalgae Cover	Herbivorous Fish Biomass	Rugosity
Shallow	17/20	0.67	0.53	0.10	0.23	0.58	1.00	0.48	0.73
Deep	8/20	0.77	1.00	0.21	0.22	0.63	1.00	0.24	0.81

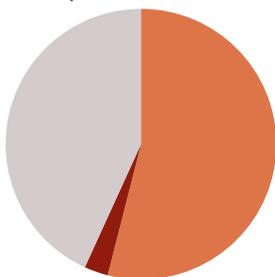
● High (>avg+1 SD) ● Med-High (>avg and <avg+1 SD) ● Med-Low (<avg and >avg - 1 SD) ● Low (<avg - 1 SD)

## Benthic Community

Shallow



Deep



● Coral  
● Macroalgae  
● Coralline algae  
● Other



## Coral Species

**Shallow:** *Cyphastrea ocellina*, *Leptastrea bewickensis*, *Montipora capitata*, *Porites bernardi*, *Porites compressa*, *Porites evermani*, *Porites lobata*, *Pocillopora meandrina*.

**Deep:** *Montipora capitata*, *Montipora patula*, *Porites compressa*, *Porites evermani*, *Porites lobata*, *Pocillopora meandrina*.



## Bleaching and Disease

**Shallow:** 61% of the coral colonies were affected by bleaching (mild and severe). 45% of the coral colonies were severely affected by bleaching. 40% of the coral colonies were overgrown by algae. Total disease prevalence was 10%; diseases present included *Porites* Growth Anomalies.

**Deep:** 70% of the coral colonies were affected by bleaching (mild and severe). 42% of the coral colonies were severely affected by bleaching. 60% of the coral colonies were overgrown by algae. Total disease prevalence was 14%; diseases present included *Porites* Growth Anomalies.



## Fish

**Shallow:** Percent of total biomass for each functional group: Apex predators (7%), Herbivores (67%), Piscivores (4%), Invertivores (21%), Planktivores (1%). Families observed: Acanthuridae, Balistidae, Carangidae, Chaetodontidae, Cirrhitidae, Labridae, Lutjanidae, Monacanthidae, Mullidae, Pomacentridae, Scaridae, Tetraodontidae.

**Deep:** Percent of total biomass for each functional group: Apex predators (10%), Herbivores (25%), Piscivores (12%), Invertivores (29%), Planktivores (25%). Families observed: Acanthuridae, Aulostomidae, Balistidae, Blenniidae, Carangidae, Chaetodontidae, Cirrhitidae, Holocentridae, Labridae, Lethrinidae, Mullidae, Pomacanthidae, Pomacentridae, Scaridae, Zanclidae.

SHALLOW SCORE: MED-HIGH

DEEP SCORE: MED-LOW

# 'Ōhae 'ula

18 – Shallow, 7 – Deep

South Kohala is the origin of the site name, which refers to the red ōhai shrub, a type of native coastal vegetation.



20.020° N, 155.830° W

20.020° N, 155.831° W



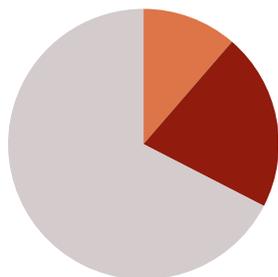
## Relative Resilience

Depth	Rank	Resilience Score	Coral Cover	Coral Diversity	Coral Recruitment	Bleaching Resistance	Macroalgae Cover	Herbivorous Fish Biomass	Rugosity
Shallow	18/20	0.65	0.22	0.74	0.42	0.17	1.00	0.25	0.76
Deep	7/20	0.77	0.40	0.50	0.48	0.38	1.00	0.65	0.75

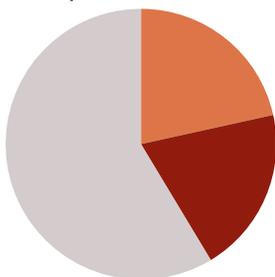
● High (>avg+1 SD) ● Med-High (>avg and <avg+1 SD) ● Med-Low (<avg and >avg - 1 SD) ● Low (<avg - 1 SD)

## Benthic Community

Shallow



Deep



● Coral  
● Macroalgae  
● Coralline algae  
● Other



## Coral Species

**Shallow:** *Montipora capitata*, *Porites bernardi*, *Porites compressa*, *Porites lobata*, *Pocillopora meandrina*, *Porites monticulosa*, *Porites rus*, *Pavona varians*.

**Deep:** *Fungia scutaria*, *Montipora capitata*, *Montipora flabellata*, *Montipora incrassata*, *Montipora patula*, *Porites bernardi*, *Porites compressa*, *Psammocora haimeana*, *Porites lobata*, *Pavona maldivensis*, *Pocillopora meandrina*, *Porites monticulosa*, *Psammocora nierstraszi*, *Pavona varians*.



## Bleaching and Disease

**Shallow:** 76% of the coral colonies were affected by bleaching (mild and severe). 59% of the coral colonies were severely affected by bleaching. 16% of the coral colonies were overgrown by algae. Total disease prevalence was 6%; diseases present included *Porites* Growth Anomalies.

**Deep:** 91% of the coral colonies were affected by bleaching (mild and severe). 78% of the coral colonies were severely affected by bleaching. 13% of the coral colonies were overgrown by algae. Total disease prevalence was 4%; diseases present included *Porites* Growth Anomalies.



## Fish

**Shallow:** Percent of total biomass for each functional group: Apex predators (0%), Herbivores (67%), Piscivores (0%), Invertivores (33%), Planktivores (0%). Families observed: Acanthuridae, Balistidae, Blenniidae, Chaetodontidae, Cirrhitidae, Labridae, Lethrinidae, Mullidae, Pomacentridae, Scaridae, Zanclidae.

**Deep:** Percent of total biomass for each functional group: Apex predators (0%), Herbivores (70%), Piscivores (3%), Invertivores (25%), Planktivores (2%). Families observed: Acanthuridae, Balistidae, Chaetodontidae, Cirrhitidae, Diodontidae, Kyphosidae, Labridae, Lethrinidae, Lutjanidae, Mullidae, Pomacentridae, Scaridae, Zanclidae.

SHALLOW SCORE: MED-HIGH

DEEP SCORE: LOW

# Kanekanaka Pt

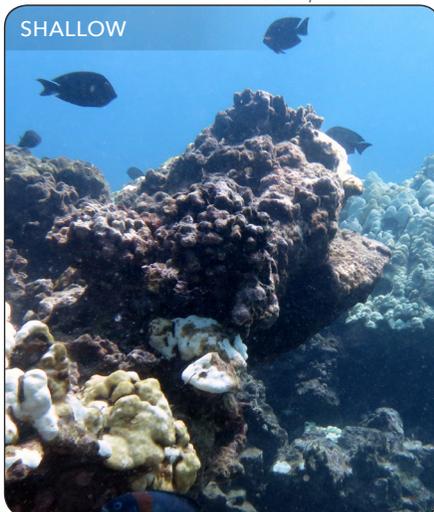
19 – Shallow, 16 – Deep

South Kohala is the origin of the site name, which means ‘man of the human form’, a point at Hāpuna.



19.986° N, 155.832° W

19.987° N, 155.834° W



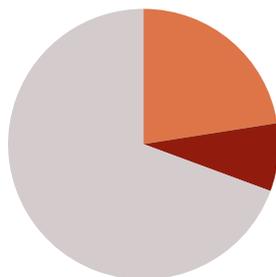
## Relative Resilience

Depth	Rank	Resilience Score	Coral Cover	Coral Diversity	Coral Recruitment	Bleaching Resistance	Macroalgae Cover	Herbivorous Fish Biomass	Rugosity
Shallow	19/20	0.62	0.45	0.30	0.14	0.14	1.00	0.53	0.82
Deep	16/20	0.64	0.29	0.57	0.14	0.36	1.00	0.23	0.84

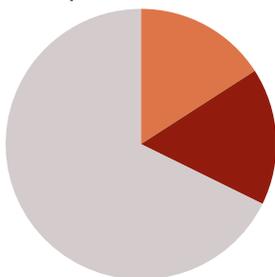
● High (>avg+1 SD) ● Med-High (>avg and <avg+1 SD) ● Med-Low (<avg and >avg - 1 SD) ● Low (<avg - 1 SD)

## Benthic Community

Shallow



Deep



● Coral  
● Macroalgae  
● Coralline algae  
● Other



## Coral Species

**Shallow:** *Leptastrea purpurea*, *Leptastrea transversa*, *Montipora capitata*, *Montipora incrassata*, *Montipora patula*, *Porites bernardi*, *Porites compressa*, *Pocillopora damicornis*, *Porites evermani*, *Pocillopora eydouxi*, *Porites lobata*, *Pocillopora meandrina*, *Pavona varians*.

**Deep:** *Cyphastrea ocellina*, *Montipora capitata*, *Montipora patula*, *Porites compressa*, *Pocillopora damicornis*, *Porites lobata*, *Pocillopora meandrina*, *Pavona varians*.



## Bleaching and Disease

**Shallow:** 78% of the coral colonies were affected by bleaching (mild and severe). 67% of the coral colonies were severely affected by bleaching. 32% of the coral colonies were overgrown by algae. Total disease prevalence was 5%; diseases present included *Porites* Growth Anomalies.

**Deep:** 93% of the coral colonies were affected by bleaching (mild and severe). 86% of the coral colonies were severely affected by bleaching. 16% of the coral colonies were overgrown by algae. Total disease prevalence was 11%; diseases present included *Porites* Growth Anomalies and *Montipora* Growth Anomalies.



## Fish

**Shallow:** Percent of total biomass for each functional group: Apex predators (0%), Herbivores (73%), Piscivores (2%), Invertivores (23%), Planktivores (2%). Families observed: Acanthuridae, Balistidae, Blenniidae, Chaetodontidae, Cirrhitidae, Holocentridae, Labridae, Lethrinidae, Mullidae, Pomacentridae, Scaridae.

**Deep:** Percent of total biomass for each functional group: Apex predators (0%), Herbivores (43%), Piscivores (25%), Invertivores (33%), Planktivores (0%). Families observed: Acanthuridae, Aulostomidae, Balistidae, Chaetodontidae, Cirrhitidae, Labridae, Lutjanidae, Monacanthidae, Mullidae, Pomacentridae, Scaridae, Zanclidae.

SHALLOW SCORE: MED-LOW

DEEP SCORE: LOW

# Puakō

20 – Shallow, 3 – Deep

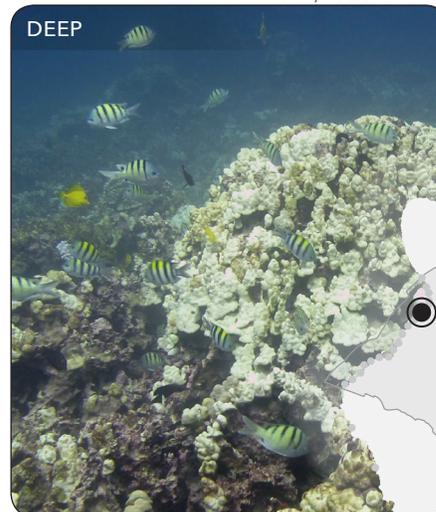
South Kohala is the origin of the site name, which refers to a fishing village named for a chiefess from Puna who settled down here with a skilled fisherman named Lalamilo to enjoy the local abundant and large octopi.



19.970° N, 155.849° W



19.970° N, 155.849° W



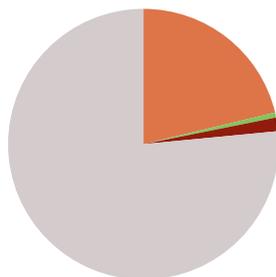
## Relative Resilience

Depth	Rank	Resilience Score	Coral Cover	Coral Diversity	Coral Recruitment	Bleaching Resistance	Macroalgae Cover	Herbivorous Fish Biomass	Rugosity
Shallow	20/20	0.52	0.42	0.95	0.28	0.31	0.00	0.25	0.67
Deep	3/20	0.83	0.39	0.86	0.19	0.28	1.00	1.00	0.72

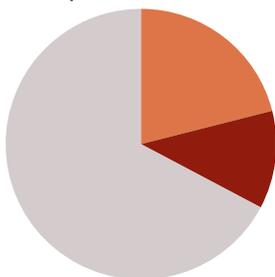
● High (>avg+1 SD) ● Med-High (>avg and <avg+1 SD) ● Med-Low (<avg and >avg - 1 SD) ● Low (<avg - 1 SD)

## Benthic Community

Shallow



Deep



● Coral  
● Macroalgae  
● Coralline algae  
● Other



## Coral Species

**Shallow:** *Montipora capitata*, *Montipora flabellata*, *Montipora patula*, *Porites lobata*, *Pocillopora meandrina*.

**Deep:** *Montipora capitata*, *Montipora patula*, *Porites compressa*, *Porites lobata*, *Pocillopora meandrina*, *Pavona varians*.



## Bleaching and Disease

**Shallow:** 82% of the coral colonies were affected by bleaching (mild and severe). 74% of the coral colonies were severely affected by bleaching. 20% of the coral colonies were overgrown by algae. Total disease prevalence was 2%; diseases present included *Porites* Growth Anomalies.

**Deep:** 84% of the coral colonies were affected by bleaching (mild and severe). 71% of the coral colonies were severely affected by bleaching. 16% of the coral colonies were overgrown by algae. Total disease prevalence was 1%; diseases present included *Porites* Growth Anomalies.



## Fish

**Shallow:** Percent of total biomass for each functional group: Apex predators (0%), Herbivores (60%), Piscivores (2%), Invertivores (35%), Planktivores (2%). Families observed: Acanthuridae, Balistidae, Chaetodontidae, Cirrhitidae, Labridae, Pomacentridae, Scaridae.

**Deep:** Percent of total biomass for each functional group: Apex predators (0%), Herbivores (66%), Piscivores (7%), Invertivores (8%), Planktivores (19%). Families observed: Acanthuridae, Aulostomidae, Balistidae, Chaetodontidae, Cirrhitidae, Holocentridae, Labridae, Lethrinidae, Mullidae, Pomacanthidae, Pomacentridae, Scaridae.

SHALLOW SCORE: MED-HIGH

DEEP SCORE: LOW



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