EXPERT REPORT

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Hawaii Wildlife Fund, et al. v. County of Maui, CIV. No. 12-00198 SOM BMK (D. Haw.)

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Purpose of the Expert Report

A tracer dye study conducted by the University of Hawaiʻi ("Tracer Study") has demonstrated a hydraulic connection between groundwater underlying the County of Maui's Lāhainā Wastewater Reclamation Facility (LWRF) and nearby coastal waters at Kahekili. The tracer dye injected into two of the LWRF's four wells was found in the groundwater as it emerges at two groups of freshwater seeps, both located in shallow depths at the landward edge of the Kahekili reef. It has been argued that water from the seeps has had, and continues to have, a negative impact on the reef at Kahekili, defined as decline in coral and increase in algae, primarily turf. In January 2008, the State of Hawaiʻi Division of Aquatic Resources (DAR) surveyed the reef at Kahekili. The U.S. National Ocean and Atmosphere Administration Coral Reef Ecosystem Division (CRED) has conducted subsequent surveys, annually or biannually, at least through April 2014.

This Report has three objectives: (1) review and evaluate data from these surveys to find and describe any trends that are relevant to the issue at hand; (2) respond to statements in the Jennifer E. Smith Expert Disclosure Report (February 9, 2015) ("Smith Report"), both those regarding the DAR-CRED data and others more generally regarding coral reef ecology; and (3) explain methods and results of a combined in-water/remote sensing study of the Kahekili reef that I conducted with Dr. Steven J. Dollar during August 2014. This Report is organized as follows: I. Summary of Education and Experience, II. Description of Kahekili Reef, III. Summary of Opinions, IV. Coral Reef Terminology, V. Description of DAR-CRED Survey Methods and Data, VI. Quantitative Statistical Analyses of the DAR-CRED Data, VII. Conclusions to be Drawn from the DAR-CRED Data, VIII. Response to Smith Report, and IX. August 2014 In-Water/Remote Sensing Survey.

I. Summary of Education and Experience

My educational history is as follows: 1991, Bachelor of Arts in Biology, Brown University, Providence, RI; 1998, Master of Science in Oceanography, University of Hawaiʻi at Mānoa, Honolulu, HI; 2002, Doctor of Philosophy in Oceanography, University of Hawaiʻi at Mānoa, Honolulu, HI. I have cross-cutting expertise and experience in coral reef ecology, biogeochemistry, bio-optics, and remote sensing. I am also expert in scientific computing, including basic and advanced statistics. I have researched coral reef ecology since 1995, including field studies in Hawaiʻi (statewide), French Polynesia (Rangiroa, Moorea), Guam, Palau, Japan (Okinawa), Australia (Great Barrier Reef), Indonesia (Bali), New Caledonia, Florida (Keys), Puerto Rico (La Parguera), U.S. Virgin Islands (St. Croix), Mexico (Puerto Morelos), Cuba (Guantánamo Bay), Bahamas (Andros), and Bermuda. I lived, studied, and worked in Hawai‘i for 14 years (1994–2008), and I am very familiar with Hawai‘i's reefs and their conservation issues. A copy of my CV is attached at the end of this Report.

II. Description of Kahekili Reef

Kahekili is located on the northwestern shore of Maui (Exhibit 1). There is patchy fringing reef along the sandy shoreline at Kahekili, as well as to the north and south, interspersed with extensive sand areas (Exhibit 2). The Kahekili reef proper is a narrow strip, ~850 m long, 60–110 m wide, oriented north-south, with a total plan-view area of ~65,300 m^2 (Exhibit 3). The depth of the reef ranges from ~0.5 m to ~7.5 m, mean lower low water (Exhibit 4). The Kahekili reef has very simple geomorphology, comprising only a reef front and narrow reef flat, lacking a reef crest (see §IV for definition of fringing reef). Otherwise, the Kahekili reef is a typical, (geologically) early developmental, beach-base fringing reef (Smithers 2011).

There are two predominant habitats on the Kahekili reef, corresponding to the geomorphology. Shallow pavement habitat occurs at very shallow depths (2 m or less) adjacent to the beach, which exposes resident organisms to high light, high wave action, and abrasion by beach sand. Shallow aggregate reef habitat occurs farther offshore at depths greater than 2 m, moderating the impacts of light, waves, and abrasion, which makes this habitat more hospitable to corals. A third habitat labeled "mixed mid-depth" occurs in patches at the northern end of the reef. All three habitat labels were given by DAR-CRED, and I use them for consistency. Shallow pavement and shallow aggregate reef occur across the whole breadth of the Kahekili reef. That is, if one enters the water from any point on the beach and swims toward open sea, the shallow pavement zone will be encountered first, followed by the shallow aggregate reef zone (Exhibits 5 and 6).

Two groups of freshwater seeps, the north seep group (NSG) and south seep group (SSG) are located toward the middle (with respect to north-south) of the reef, within the shallow pavement zone (Exhibits 5 and 6). Geographic coordinates for the NSG and SSG are taken from the Tracer Study. The Smith Report asserts that groundwater discharge from the seeps has a negative impact on the benthic biological community of the Kahekili reef system.

III. Summary of Opinions

1. The Kahekili reef exhibits very strong morphological and concomitant ecological zonation, which is by far the primary driver of spatial patterns in benthic community structure.
2. Because it occupies depths of 1–2 m adjacent to shore, the shallow pavement zone has low coral cover and high turf-bare cover.
3. Because it occupies depths greater than 2 m further from shore, the shallow aggregate reef zone has high coral and low turf-bare cover.
4. The freshwater seeps occur in the shallow pavement zone, and so do not impact any areas of high coral cover.
5. Data sets from DAR-CRED, as well as from the Pacific Whale Foundation and Hawai‘i Coral Reef Assessment and Monitoring Program, show that both habitats are stable over time, exhibiting no change in coral and turf-bare cover, which indicates no ongoing impacts.
6. The data show no correlation between either coral or turf-bare cover and proximity to the seeps, indicating that the seeps do not impact the reef.
7. The data do show correlation between proximity to shore and both coral and turf-bare cover, indicating that presence of a shore—likely the shallowness of the water and/or the presence

of copious sand—is responsible for patterns in the biological community on the Kahekili reef.

8. The Smith Report completely neglects the fundamental principle of ecological zonation, which is well established for coral reefs worldwide, as well as specifically for the Kahekili reef.
9. The Plaintiff's hypothesis is that the freshwater seeps at Kahekili create an inhospitable environment for corals, either directly by impeding their growth or indirectly by enhancing the growth of competing organisms (turf algae). This hypothesis leads to a very specific prediction: There should be a gradient of increasing coral cover with increasing distance from the seeps. The observed pattern of coral cover does not show this trend, so the hypothesis must be rejected, and it must be accepted that the seeps do not impact the Kahekili reef.
10. The Kahekili reef is a small fringing reef fronted by a sandy beach, its zonation and patterns of coral and turf-bare cover are typical of similar reefs worldwide, and the presence of small groups of freshwater seeps has no impact on the "health" of the system.

IV. Coral Reef Terminology

Benthic: Of, relating to, or occurring at the seafloor. The term can refer to organisms or substrates. "Benthos" is the noun form, and it refers to the organisms living on the seafloor. Corals and turf algae are benthic organisms and thus are components of the benthos.

Coral reef: A complete ecosystem, comprising corals, various algae, other organisms, and substrates. Done (2011) gives this definition: "A tract of corals growing on a massive, wave-resistant structure and associated sediments, substantially built by skeletons of successive generations of corals and other calcareous reef-biota" (p. 261). It is important to recognize that coral by itself is not the same as a coral reef. A coral reef *requires* the other components, including algae, for regular ecosystem function.

Coral: An animal. In the context of Kahekili, corals belong to phylum Cnidaria, class Anthozoa, order Scleractinia. These are often termed "hard corals" or "reef-building corals." Veron (2011) gives this description: "Scleractinian corals have a simple structure. Their bodies are sac-like polyps that usually grow together to form colonies. They have a body wall with only two cell layers and a skeleton made of calcium carbonate which is actually outside their body so that the living polyp grows on its skeleton. This simple structure allows most corals to form complex colonies that are readily modified to suit a wide range of environments. Modern coral reefs are principally made of calcium carbonate that has been derived from coral skeletons and cemented into a wave-resistant structure by coralline algae" (p. 275).

Fringing reef: From Smithers (2011): "Reefs that grow very close to the shore on mainland or high island (continental shelf or volcanic mid-ocean island) coasts. They are generally shore-attached, although back-reef areas can be shallowly submerged. Most fringing reefs are simple structures geomorphologically which can be divided into three main zones: forereef, reef crest, and backreef" (p. 430).

Habitat zonation: It is a basic principle of ecology that, if environmental conditions occur in gradients, then habitats become zoned, with their biological communities following the same spatial pattern. It is well established that coral reefs exhibit strong habitat zonation, mirroring that of reef geomorphology (Stoddart 1969).

Habitat: The ecological area where an organism lives, comprising biological factors such as food and predators, as well as physical factors such as light, temperature, and waves. Because different habitats have different growth conditions, they typically host different biological communities.

Point counting: This is a method to estimate benthic cover from underwater photographs of a portion of a reef surface. A diver underwater points the camera vertically downward at the reef surface and captures an image. Later, in an office, an analyst (the same diver or another individual) loads the image into a computer program that overlays a set of points randomly across the image. The analyst identifies the organism or substrate underneath each point. These identifications are tallied (the "point counting") then divided by the total number of points to provide estimates of benthic cover. For example, if a total of 50 points are overlaid on an image, and if 25 of those points are identified as coral, then the proportional cover of coral is 25 ÷ 50 = 0.5. The proportion is often multiplied by 100 to obtain benthic cover as a percentage; in the preceding example, the percent cover would be 50%. Details of the method as implemented in one specific software package are provided in Kohler and Gill (2006).

Reef geomorphology: The physical shape of a coral reef. There is strong similarity in the structural forms of reefs across the Indian, Pacific, and Atlantic Oceans (Stoddart 1969; Blanchon 2011). Typical geomorphic zones include lagoon, reef flat, shallow reef front, and deep reef slope. These zones arise from long-term (thousands to tens of thousands of years) accretion of the reef in relation to fluctuating sea level. In the present day, these zones represent the physical habitat for organisms living on a reef.

Shallow aggregate reef: Defined by DAR (Walsh et al. 2010) as "Some patches and sand, but substrate largely dominated by corals. Consequently, reef has moderate or high complexity." DAR gives the depth range as 5–23 ft, noting that it is "largely corresponding with depth range of fringing reef in front of Kahekili Beach Park" (p. 48).

Shallow pavement: Defined by DAR (Walsh et al. 2010) as "Largely flat, low relief and low coral cover areas dominated by limestone pavement and loose sediment" (p. 48).

Turf-bare: As described by DAR (Williams et al. 2006), "Turf algae encrusts the substratum and has no discernible structural features. This category also includes substrate which is apparently bare, but which is presumably colonized by microalgae. NB turf/bare substratum generally falls in a continuum between completely bare (e.g. very recent grazing scar) and moderately thick turf. Especially with photographs, it is difficult to create a clear distinction" (p. 10). Thus, "turf-bare" is assigned to any substrate that is not obviously another benthic type (e.g., crustose coralline algae). The source for this information is Exhibit 12, described below.

V. Description of DAR-CRED Survey Methods and Data

In preparing this Report, I reviewed and relied on the following materials:

1. *all Kahekili DATA_3.xlsx* (Williams 2014) — This file contains site coordinates and summary data from the CRED surveys at Kahekili. It was provided via email from Dr. Steven Dollar of UH, who obtained it from Dr. Bernardo Vargas-Ángel of CRED. The file properties indicate that the author is Dr. Ivor Williams of CRED. This file is provided digitally as Exhibit 7.
2. *Coral Reef Ecosystem Division Standard Operating Procedures: Data Collection for Rapid Ecological Assessment Fish Surveys* (Ayotte et al. 2011) — This is NOAA/PISFC Administrative Report H-11-08, authored by Paula Ayotte, Kaylyn McCoy, Ivor Williams, and Jill Zamzow. This document describes the methods employed by CRED to collect and analyze benthic data. This file was downloaded on September 25, 2014 from the CRED web site: http://www.pifsc.noaa.gov/library/pubs/admin/PIFSC_Admin_Rep_11-08.pdf. It is provided digitally as Exhibit 8.

3. An email thread between Dr. Dollar, Dr. Bernardo Vargas-Ángel of CRED, and Dr. Ivor Williams of CRED (Dollar et al. 2014) — This email thread contains clarifications about methods described in NOAA/PIFSC Administrative Report H-11-08. This thread also clarifies that the data are collected in partnership with State of Hawaiʻi, Department of Land and Natural Resources, Division of Aquatic Resources and thus should probably not be labeled solely as "CRED." This thread is provided digitally as Exhibit 9.
4. *Long-Term Monitoring of Coral Reefs of the Main Hawaiian Islands: Final Report 2009* (Walsh et al. 2010) — This is a report from DAR to the NOAA Coral Reef Conservation Program describing monitoring results at selected sites across Hawaiʻi, including Kahekili. The file was downloaded from http://www.coralreefnetwork.com/kona/NOAA%20961%20Final%20Report.pdf on November 21, 2014. It is provided digitally as Exhibit 10.
5. *CRED Biological Monitoring of Coral Reefs in the Kahekili Herbivore Fisheries Management Area, Maui* (CRED 2014) — This is a metadata file that describes the ongoing CRED data collections at Kahekili. The file was downloaded from the NOAA Coral Reef Information System (CORIS) http://www.coris.noaa.gov/ on December 9, 2014. It is provided digitally as Exhibit 11.
6. *Long-Term Monitoring of Coral Reefs of the Main Hawaiian Islands: Standard Operating Procedure 1: Surveys of Benthic Reef Communities Using Digital Still Photos* (Williams et al. 2006) — This is a report from DAR describing benthic survey methods. The file was located using basic Google search and downloaded on March 7, 2015 from https://www.nceas.ucsb.edu/~jsmith/Quest/DAR%20Photo%20SOP.doc. It is provided digitally as Exhibit 12.
7. *Monitoring of Coral Reef Ecosystems on Maui, Hawaii during 1989-1998* (Brown 1999) — This is a metadata file accompanying data from the Pacific Whale Foundation, which includes surveys of Kahekili. The file was downloaded from the NOAA Coral Reef Information System (CORIS) http://www.coris.noaa.gov/ on March 2, 2015. It is provided digitally as Exhibit 13.

<u>Description of DAR-CRED Survey Methods</u>

No documentation was provided with the data file (Exhibit 7), but there are many NOAA reports that reference the data and provide descriptions of the methods. Methods described here are extracted from Exhibits 8–13.

Exhibit 11 presents an overview of survey methods. This excerpt focuses on the benthic survey portion:

"Survey teams comprising of divers and working off a small boat were haphazardly dropped over hardbottom areas throughout the [Kahekili Herbivore Fisheries Management Area]. The divers would then swim straight down to the nearest suitable habitat (hardbottom large enough to lay a survey transect in); one of the survey divers would then tie off the starting point of the survey transect and the other recorded the transect start location using a GPS in a waterproof bag attached to a float. As much as possible, surveys were always run parallel to the shoreline running approximately northwards. Survey transects were of 25m length... The other survey diver followed the fish survey diver, and conducted a photo quadrat survey of the benthos under the transect line... Photos were subsequently analyzed using point count image analysis software, with cover recorded to lowest possible taxonomic level (species for coral, genera for macroalgae, functional group for others (crustose coralline algae, turf, sand, other sessile invert).

Surveys covered by this metadata record were gathered for the project ‘Scientific support for Kahekili Herbivore Fisheries Management Area, Maui’ conducted by NOAA CRED, and funded by the CRCP in Fiscal Years 2010, 2011 and 2012 (FY10 Project#: 20482, FY11#:F200; FY12# F374). Surveys were completed in three 'rounds', each round being an intensive 4 day survey effort. Those rounds took place on 09/01/2009-09/04/2009, 09/13/2010-09/16/2010, 02/28/2011-03/03/2011, 9/26/2011-9/29/2011, 4/23/2012-4/26/2012, 9/24/2012-9/28/2012, 4/22/14-4/25/14 and 9/19/14-9/19/14.”

From the Dollar/Vargas-Ángel/Williams email thread in Exhibit 9, in the first survey year (2008, when the program was run by DAR), 50 random points were counted per photo. In all subsequent years, the number was reduced to 15 points per photo.

Description of DAR-CRED Data

The file *all Kahekili DATA_3.xlsx* (Exhibit 7) contains all the data used in this analysis. The file comprises three worksheets. The first worksheet, “Site Coordinates,” has 1,026 data records. Each record corresponds to an individual transect from a specific survey round. The columns list the survey round, site (all but eight specifying Kahekili), a method code (all specifying “KAHE BASELINE”), date and time of the transect, transect label, observer ID, identifier for habitat in which the transect was conducted, latitude and longitude for the transect, and depth of the transect. Transect labels are reused across survey rounds; they do not refer to a specific geographic location. The observer ID is always labeled as “DV” followed by a number from one to ten (e.g., “DV06”), and these are also reused across survey rounds. It is unknown whether an observer ID refers to the same specific individual across survey rounds. It is also not clear whether the observer is the diver acquiring the photos or the analyst conducting the point counts. Only 999 records (transects) include time of day, and only 997 have latitudes and longitudes.

There are seven unique habitat types listed. Descriptions for six of these is found on page 48 of Exhibit 10, with the seventh habitat type being “unknown.” The six known habitat types are (1) deep aggregate reef, (2) shallow aggregate reef, (3) mid-deep spur and groove, (4) shallow spur and groove, (5) mixed mid-depth, and (6) shallow pavement. Importantly, Figure 26 of this document (page 47) classifies almost the entirety of the nearshore zone along the length of the Kahekili reef as shallow pavement, which has the characteristics: “Largely flat, low relief and low coral cover areas dominated by limestone pavement and loose sediment” (page 48).

The second worksheet of Exhibit 7, “Fish Data,” has 19,946 data records. Its seven columns list survey round (year and month), transect ID, fish species code, fish family, fish genus and species, average fish length, and number of individuals observed. The objective of this analysis is to quantitatively characterize the benthic community at Kahekili, not the fish, thus these data are not utilized in this analysis.

The third worksheet of Exhibit 7, “Benthic Data,” has 977 data records. Each record corresponds to a specific transect from a specific survey round. Columns are survey round (year and month), transect ID, and proportional cover (values in range 0–1) for each of eight benthic classes. The benthic classes are (1) cyanobacteria (blue-green algae), (2) crustose coralline algae, (3) encrusting macroalgae, (4) hard coral, (5) macroalgae, (6) sand, (7) sessile invertebrates, and (8) turf-bare. DAR-CRED descriptions for the different algae types are given in Exhibit 12. Of the 977 benthic survey records, 26 do not have corresponding geographic coordinates. Of the 951 remaining survey records, 330 fall within the bounds of the Kahekili reef area. Exhibit 14 lists the number of survey transects in each survey round, and Exhibit 15 shows the spatial distribution of those transects. As noted in the survey methods, sites were chosen haphazardly, and the same sites were not visited during different survey rounds. These 330 transects comprise the data set utilized in this Report's statistical analyses.

Importantly, the benthic data provided in Exhibit 7 represent the final product of photoanalysis and basic processing to generate per-transect statistics. The underlying data are not provided, and there are no error estimates. Error is engendered in the point-counting of each photograph and again when averaging data across multiple photographs. For analysis of any single photograph using 15 randomly placed points, the ±95% confidence limits on the estimated cover parameter range from 20–25% absolute cover (binomial distribution). That is, the 15 points give an estimate of benthic cover that is accurate to within 20–25%. A transect is represented by the mean across multiple photos. The mean also has its own accuracy limits, which depends on the variability between photographs. Thus, the accuracies of the values reported in Exhibit 7 depend on the accuracies within and across photographs. Ideally, those accuracies would be considered when interpreting further analyses, but they are unfortunately not available in the provided data set.

VI. Quantitative Statistical Analyses of the DAR-CRED Data

Reef Habitat Zonation

The Kahekili reef shows very strong habitat zonation (Exhibits 5 and 6). Adjacent to the shoreline and submerged sandy beach is a ~25-m-wide strip of shallow pavement. Most of this habitat occurs at depths of about 2 m and shallower, though sites as deep as 4 m are labeled as shallow pavement (Exhibit 16). Most of the remainder of the reef, 50–80 m wide, is shallow aggregate reef. This habitat is mostly distributed at depths between 2 and 7 m, though there are both shallower and deeper sites (Exhibit 16). Toward the northern, narrower end of the reef, 15 total sites are classified as mixed mid-depth (Exhibit 5). This pattern of habitat zones, especially the predominant shallow pavament and shallow aggregate reef, is common to fringing coral reefs around the world (Smithers 2011).

There is significant correlation between habitat type at each transect site and distance to the freshwater seeps (Mantel test, $r = 0.11$, $p < 0.01$). However, it is important to note that there is also significant correlation between habitat type at each transect site and distance to the shoreline (Mantel test, $r = 0.14$, $p < 0.01$). Correcting for distance to shore, there is no significant correlation between habitat type and distance to the freshwater seeps (partial-Mantel test, $r = 0.02$, $p = 0.25$). Conversely, correcting for distance to the seeps, there remains a statistically significant correlation between habitat type and distance to shore (partial-Mantel test, $r = 0.08$, $p < 0.01$). Thus, the spatial arrangement of habitats at Kahekili cannot be attributed to the distance to the freshwater seeps. The simplest explanation is that habitat zonation at Kahekili is driven by the same factors influencing other fringing coral reefs around the world, primarily light and wave action.

Benthic Cover Within and Between Habitats

Across all survey rounds, shallow pavement habitat exhibits low coral cover and high turf-bare cover, while shallow aggregate reef habitat has much higher coral cover and much lower turf-bare cover (Exhibit 17). Over time, coral and turf-bare cover are stable in both habitats (Exhibit 18). Two-way analysis of variance (ANOVA) with coral cover as the response variable shows a significant main effect of habitat ($F_{1,314} = 619.69$, $p < 0.05$) but not a significant main effect of survey round ($F_{10,314} = 1.39$, $p = 0.18$). The interaction term habitat × survey round is significant ($F_{10,314} = 2.61$, $p < 0.05$), which means that the two habitats have different patterns of coral cover between survey rounds. For two-way ANOVA with turf-bare, both habitat and survey round main effects are significant (habitat $F_{1,314} = 585.16$, $p < 0.05$; survey round $F_{10,314} = 3.08$, $p < 0.05$). The turf-bare interaction term habitat × survey round is also significant ($F_{10,314} = 2.73$, $p < 0.05$).

Taken together, these statistics mean that turf-bare and coral cover each differ between habitats and that those covers change over time differently in each habitat. The statistics do not indicate direction of change, merely that there are differences in time. Exhibit 18 demonstrates that there is no directionality in time. Rather, individual survey rounds have higher or lower cover. This is due to the DAR-CRED haphazard survey design, which causes unequal and non-repetitive sampling between habitats and survey rounds. Note that this is not meant to disparage the DAR-CRED effort, but to point out that the data were not collected with the present analytical purpose in mind.

<u>Full Spatial Analysis of Benthic Cover</u>

The seeps on Kahekili reef discharge freshwater and associated materials. As groundwater enters the ocean, it mixes with surrounding seawater. This creates a gradient of groundwater concentration, with the highest levels occurring at the seeps, then decreasing to background oceanic conditions away from the seeps. In theory, such a gradient may be gradual or sudden, and isotropic or directional, depending on the amount of discharge and local hydrodynamic conditions. The Smith Report's premise is that the groundwater discharge negatively impacts a large portion, if not all, of the Kahekili reef. This is a specific prediction: for two small freshwater seep groups to affect such a large area, the mixing gradient must be gradual and mostly isotropic (uniform in all directions), so that groundwater materials retain sufficient concentration to impact the reef at distance from the seeps.

A basic tenet of ecology is that, for every environmental factor (e.g., temperature, nutrients), there is an optimal range where a given species is best adapted to thrive. Above and below the optimal range are zones of stress, where the species can survive but not thrive. The zones of stress are bounded by the upper and lower tolerance limits, beyond which the species cannot survive. Different environmental factors convolve to collectively influence the successful growth and reproduction of a species, and with more factors in the optimal range, that species may have a competitive advantage over others. Environmental factors vary in space and time, and species distributions reflect the underlying variation of environment.

The Smith Report argues that groundwater from the seeps has increased stress to corals, thereby reducing their viability, while at the same time providing algae a competitive advantage over corals. As explained above, that argument necessitates that physical mixing of groundwater from the seeps is gradual and isotropic. The prediction becomes this: If groundwater does impact the coral and algae as proposed by the Smith Report, then the distributions of coral and algae must reflect the physical gradient. That is, benthic community structure — primarily coral and turf-bare cover — must be correlated with proximity to the seeps. Moreover, that correlation must hold even when accounting for proximity to shore, which drives habitat zonation at Kahekili.

To test the Smith Report's prediction, a series of partial correlations were calculated to measure the degree of association between benthic community structure and proximity to the seeps, while removing the effect of proximity to shore. Because there is some variability in benthic cover over time, and because there is also variability between habitats, partial correlations were calculated for each benthic type in each habitat in each survey round. Further calculations considered the reef as a whole (ignoring habitat differences). Finally, all partial correlations were recalculated to measure the degree of association between benthic community structure and proximity to shore, while removing the effect of proximity to the seeps.

Within the shallow pavement zone, there is effectively no correlation between coral or turf-bare cover and proximity to either seeps or shore (Exhibit 19). The same is true within the shallow aggregate reef zone (Exhibit 20). This means that, within each habitat zone, benthic cover is relatively homogeneous. Considering the entire reef (i.e., ignoring habitat zonation), coral and turf-bare cover are not significantly correlated with proximity to seeps, but they are correlated with proximity to shore (Exhibit 21). Pooling the data across habitats and survey rounds, neither coral nor turf-bare cover are significantly correlated with proximity to seeps, while both are very strongly correlated with proximity to shore (Exhibit 22). These trends indicate that distance to shore, not distance to the seeps, drives benthic cover. This is to be expected, owing to the strong habitat zonation on the reef.

Finally, a multivariate form of correlation called partial redundancy analysis (Legendre and Legendre 2012) was applied to test whether composition of the entire benthic community (cyanobacteria, crustose coralline algae, encrusting macroalgae, coral, macroalgae, sand, sessile invertebrates, turf-bare) is related to distance from the seeps and/or shore. This analysis has the advantage of considering multiple variables at once, which reduces the risk of both false-positive and false-negative results. Again, the analysis was performed once for each survey round. Results are shown in Exhibit 23. Only two of 11 survey rounds show a significant relationship between benthic community structure and distance to the seeps, corrected for distance to shore. Conversely, nine of 11 survey rounds show a significant relationship between benthic community structure and distance to shore, corrected for distance to the seeps. Again, this analysis indicates that distance to shore, not distance to the seeps, drives benthic cover.

VII. Conclusions to be Drawn from the DAR-CRED Data

The habitat analysis simply reaffirms basic reef ecological zonation. Pavement occurs in shallow environments and is characterized by low coral cover. Deeper areas have higher coral cover. This pattern is ubiquitous on fringing reefs around the world (Smithers 2011). It is very important to understand that both freshwater seep groups at Kahekili occur in the shallow pavement zone (Exhibits 5 and 6). Thus, it is expected a priori that the reef community near the seeps has low coral cover and high turf-bare cover, without invoking seep discharge characteristics.

The spatial analysis of benthic cover unequivocally shows that the seeps do not influence benthic community structure across the Kahekili reef. Rather, coral and turf-bare cover (and the entire community) are driven by proximity to shore. This spatial pattern means that we must reject the hypothesis that groundwater discharge from the seeps has widespread impact on the benthic community structure of the Kahekili reef.

VIII. Response to Smith Report

The following is my critique of key portions of the Smith Expert Report dated February 9, 2015.

1A1. Smith's definition of a healthy coral reef is not complete. In fact, Smith's definition is not meaningfully different than the simple definition of a coral reef regardless of health, as given by Done (2011): “A rigid wave-resistant structure in which scleractinian (stony) corals and crustose coralline algae are the dominant frame-builders” (p. 261). However, defining the “health” of a reef is not so simple. Connell (1997) points out that reefs are highly dynamic, and coral cover should be expected to vary over time. A “healthy” reef system would lose coral due to some disturbance, then recover coral over time. The reef is “healthy” because it can support coral growth, and because it has not undergone a permanent shift to algal dominance. Conditions on an “unhealthy” reef might continue to favor algal over coral growth, and disturbed areas may enter a macroalgal phase, where they remain indefinitely. Smith discusses algal vs. coral dominance, but not in terms of reef dynamism. It is not so important that a reef’s coral has died, but that new coral can recolonize.

Other aspects of reef ecosystems are also vital to reef “health.” Fish and urchins consume virtually all excess algal growth (Van Rooij et al. 1998), and removing those grazers can dramatically affect the character of a reef (Mumby et al. 2007). More importantly, photosynthesis is arguably the most basic and most important reef ecosystem function. It represents the energy input that drives all biological transformations in the reef system (Odum and Odum 1955), ultimately limiting the growth and reproduction of reef herbivores and predators (Atkinson and Grigg 1984; Grigg et al. 1984; Polovina 1984). The calcification mentioned by Smith is strongly light-enhanced (Chalker 1981; Barnes and Devereux 1984), indicating that photosynthesis enables those high rates of reef accretion.

It is very important to understand that there is no universally accepted metric of reef “health.” In contrast to humans, for which we have millions of observations of blood pressure and core temperature over the course of centuries, we have no magic number for how much coral a reef should have, nor how fast it should recover from disturbance, in order to be “healthy.”

I have no first-hand knowledge of the condition of the Kahekili reef during the 1990s, but I am given to understand that there were large macroalgae blooms during that time, and those macroalgae killed corals across large areas of the reef. However, those macroalgae are no longer present on the Kahekili reef, and there is ample evidence of coral re-growth. This is very demonstrative of a “healthy” reef ecosystem.

1A2. Coral cover has **not** declined at Kahekili. First, two fixed transect stations simply do not represent a wider coral reef ecosystem, regardless of their rigor. The geographic coordinates provided on the CRAMP website (http://cramp.wcc.hawaii.edu/LT_Montoring_files/lt_study_sites_Maui_Kahekili.htm) indicate that the stations are not particularly near either seep group (Exhibit 24). Moreover, it is unclear exactly what spatial coverage the transects have, since only single point coordinates are given. Is this the start, center, or end of the 100-m transect? Does the transect move northward or southward from the point?

Second, the Pacific Whale Foundation (PWF, 1993–1998) and CRAMP (1999–onward) used different survey techniques during the period covered by the graphic in Smith Exhibit 1. In 1993, PWF surveyed a single site at Kahekili, then increased coverage to three sites during 1994–1998. CRAMP assumed responsibility in 1999 and established two sites. Given available information (from metadata provided by PWF to NOAA CORIS, Exhibit 13), it is not possible to establish whether the PWF and CRAMP sites actually are the same geographically. With respect to actual methods, in 1993, the PWF transect method was to observe benthic cover within a 1×1 m quadrat every 10 m along a 100-m transect. Data were recorded on underwater dive slates. In 1994–1998, the transect length was reduced to 50 m. The CRAMP survey protocol at each site consisted of 10 video transects, each of 10 m length, in series along 100 m of reef parallel to shore. For each transect, 20 video frames were extracted and analyzed using the point count method. In 2003, equipment was switched from video to digital still photographs, with no expected loss of accuracy. During 1999–2005, CRAMP point-counting included 50 points per image; beginning in 2006, the number was reduced to 25 points per image, which decreases precision and accuracy.

Third, both CRAMP stations are within the DAR-CRED zone "Shallow Aggregate Reef," but examination of aerial photography on Google Earth shows that the stations are in different ecological zones (Exhibit 25). The 3 m station is in a zone of the reef characterized by abundance of *Porites lobata*, though it is near the shallow pavement habitat. while the 7 m station is in a reef zone characterized by abundance of *Porites compressa*. Overall, the CRAMP transects describe neither the wider Kahekili reef nor the area specifically near the seeps, which is where any degradation would be expected under Dr. Smith's hypothesis. Regardless of effort or precision, any observed trends at the CRAMP transects cannot be attributed to the seeps, and those trends cannot be extrapolated across the entire reef. No precise geographic information is available for the PWF sites, but three sites cannot provide meaningfully better coverage than two.

I have downloaded all PWF and CRAMP data available for Kahekili at the NOAA Coral Reef Information System (CORIS). My objective was to replicate the plot in Smith's Exhibit 1 using the raw data collected by PWF and CRAMP, with the exceptions of keeping survey sites separate and identifying which data are PWF and which are CRAMP. My results are in Exhibit 26. (Note that Exhibit 26 only presents data available from CORIS, and data for other years may exist elsewhere.) PWF "Kahekili Site 1" has coral cover greater than 50% except for 1995, and "Kahekili Site 2" has greater than 50% coral cover in all surveyed years. It is "Kahekili Site 3" that has low coral cover at 25–30%. Coral cover at the CRAMP 7 m site starts in 1995 at 45%, drops to 30% in 2001, then gradually increases back to 45%. The trend is similar at the CRAMP 3 m site, beginning at 30%, dropping to 20%, then increasing back to 30%. Since it cannot be established that the PWR and CRAMP data sets are from the same geographic locations, they must be considered separately, and neither shows a decline over time. To the contrary, the CRAMP data show an increase in coral cover over the course of a decade, which indicates a "healthy" reef system.

It is important to note the error bars in Exhibit 26. They show the standard deviations of the data underlying each estimate of coral cover, thus describing the variability of the data. These error bars are very wide, which indicates a good amount of spread in the data, which in turn means that there is fairly large uncertainty in these estimates of coral cover.

Smith claims that data are not available for components of the reef benthic community other than coral, but this is incorrect. The PWF and CRAMP data have explicit identifications of tens of benthic types. I have condensed those into six functional groups: crustose coralline algae (CCA), coral, macroalgae, other, sand, and turf-bare (following the DAR-CRED protocol). Exhibit 27 is a stacked bar chart showing percent cover for each of these benthic types at each survey site in each year for which survey data are available. For the PWF data, each year except 1993 has three bars, from left to right, "Kahekili Site 1," "Kahekili Site 2," and "Kahekili Site 3." The CRAMP data have two bars for each year; the left and right bars represent the 7 m and 3 m transects, respectively. The important thing to note in this figure is that, with the exception of 1999–2002, turf-bare cover hovers around 40%. The reason PWF "Kahekili Site 3" and CRAMP

3 m sites have low coral cover is because they have higher sand cover, not because of greater algae cover.

Smith acknowledges that the DAR-CRED surveys were stratified by habitat, but she ignores that stratification in her Exhibit 3. This gives the false impression that turf algae occupies more reef area than coral. I have performed the same analysis with the exception of keeping the habitats stratified (as well as including the 2008 DAR data). Results are shown in Exhibit 28. For each year, the left-hand bar shows benthic cover within the shallow aggregate reef habitat zone, and the right-hand bar shows benthic cover within the shallow pavement habitat zone. The differences are obvious: shallow aggregate reef has markedly higher coral and less turf than shallow pavement. To aid interpretation, the table in Exhibit 29 provides numerical values for the benthic cover in Exhibit 28. It is clear that in the shallow aggregate reef zone, coral is generally equal to turf-bare in cover. As expected, turf-bare dominates the shallow pavement zone.

So, Smith is absolutely correct that "one must consider the other components of the benthos," and in this instance it is clear that there is no increase in turf algae, nor is there a decrease in coral. Smith is incorrect in stating that "coral cover has declined substantially over the past two decades at Kahekili, and ... the reef is now dominated by fleshy algae." Thus, Smith's professional opinion that "the reef at Kahekili is not actively growing, and as such is an unhealthy reef" is also incorrect.

1A4. Corals are **not** suffering mortality due to overgrowth by turf algae, and turf algae is **not** the most dominant member of the reef community at Kahekili. See my discussion above and Exhibits 26–28. Further, Smith's Exhibit 5 is extremely limited in scope and does not demonstrate that turf algae has killed or outcompeted any coral. As noted by (Williams et al. 2006) in Exhibit 12, any bare surface is rapidly colonized by turf algae (Hixon and Brostoff 1996; McClanahan 1997). The explanation for Smith's Exhibit 5 that coral tissue area has retracted, which has exposed the bare carbonate skeleton, which in turn has been colonized by turf algae. Smith Exhibit 6 is also extremely limited in scope, and while these photos do show interactions between coral and different algae types, they do not definitively show algal competitive dominance over corals, which is often overstated (McCook et al. 2001). Moreover, from my personal observations of Kahekili reef in August 2014, these photographs represent a small fraction of reef area; they do not represent the reef as a whole. Smith's opinion that "it is only a matter of time before the entire reef is overtaken by this turf algal community" is not supported by either the preponderance of data at Kahekili or basic reef ecology.

1A5. The data do not show a decline in reef health at Kahekili. A review of all of the available data — PWF, CRAMP, and DAR-CRED — show low macroalgae and stable or even slightly increasing coral cover. The data demonstrate that this is a "healthy" reef and the ecosystem has not undergone a phase shift.

1B2. The "coral reef community" around the seeps where groundwater is emerging is **not** dead. The seeps are located in the shallow pavement zone (see Exhibits 24 and 25). The studies cited by Smith describe a perfectly normal shallow pavement community. It is absolutely expected that pavement would be low in coral cover (see §IV. Coral Reef Terminology).

Smith's Exhibit 8 is a poorly produced graphic of three-dimensional data on a two-dimensional page. It misrepresents the spatial relationships of coral, turf, and seeps, and it completely ignores the presence of habitat zonation on the reef. I have used the same data to redraw the graphic twice. The first, attached as Exhibit 30, is in the style that Smith drew it, with a few differences. Smith left out three data points at the north of the reef, and I included them. I also added stems to the dots so that percent cover values can actually be interpreted as values above zero. Moreover, I color-coded the stems using the color scheme for habitats in Figure 26 of the DAR report by Walsh et al. (2010) (Exhibit 10). Purple stems are sites in shallow pavement habitat and light-blue stems are sites in shallow aggregate reef habitat. It can clearly be seen that the high turf and low coral sites are all in the shallow pavement habitat.

The second, attached as Exhibit 31, is a much more informative representation. It is the same stem plot, but overlaid on the satellite image of Kahekili, providing reef context for site locations. Also, the axes are properly scaled, allowing ready visualization of distances between sites. Importantly, the seep locations are marked by yellow asterisks. The sites denoted by Smith as being near the south seep group (red dots) are actually ~100 m away. There are at least two, possibly three sites which are closer to the south seep group, and those sites all have high coral cover. There is also at least one high coral cover site near the north seep group.

Smith's July 2014 survey may be flawed as well. Based on the transect locations depicted in her Exhibit 9, the north and south transects at each seep are in the shallow pavement zone, while the west transect begins in that zone and traverses into the shallow aggregate reef zone. These west transects are expected to show increasing coral cover, which they do, as shown in Smith Exhibit 12. However, the boundaries between zones are not straight lines, and they can also be blurred as one zone grades into another. So, the north and south transects may also move from the low-coral pavement zone, where the seeps are located, into higher coral areas. That could easily explain the trends in coral cover for those transects, as shown in Smith Exhibit 12.

The data show that Smith's interpretation is incorrect. Turf algae and coral cover are not related to proximity to the seeps. To the contrary, the reef near the seeps is merely shallow pavement. Habitat zonation is basic reef ecology. Dr. Smith either is unfamiliar with this fundamental concept or chooses to ignore it.

1B3a. <u>Inorganic nutrients actually tend to not impact coral reefs, except under special circumstances</u>. Corals host endosymbiotic algae that perform photosynthesis. These algae require nutrients for growth, just as agricultural crops require fertilizer. Nutrient additions to corals can actually be beneficial. This has been unequivocally demonstrated at the Waikiki Aquarium, where corals are cultured in high-nutrient, low pH well water. The Waikiki Aquarium corals exhibit excellent growth (Atkinson et al. 1995). I have personally observed corals there actually growing out of the water. On a larger scale, nutrient additions are not typically harmful to whole reef ecosystems (Szmant 2002). Just because most oceanic reefs occur in low-nutrient water does not mean that reefs cannot tolerate or even thrive in high-nutrient water. For example, Kanton Atoll lies within the south equatorial upwelling zone and thus experiences nutrient-rich water, yet this ecosystem has exhibited abundant coral cover (Smith and Henderson 1976). The truth is that only sustained loading by very high levels of nutrients has direct impact on corals or reef communities (Koop et al. 2001). The seeps at Kahekili do not fit that description.

1B3b. <u>Low pH water from the seeps does not impact the Kahekili reef</u>. Setting aside Smith's neglect of a substantial literature base demonstrating limited or no impact of ocean acidification on coral reefs (e.g.,(Langdon and Atkinson 2005; Takahashi and Kurihara 2013), the fact is that seep water rapidly mixes with ambient seawater and does not contact any part of the reef other than the very immediate seep area. The Kahekili reef has pH well within nominal range for natural reefs. See comments to 1B4 below.

1B3c. Low salinity water from the seeps does not impact the Kahekili reef. Again, seep water rapidly mixes with ambient seawater and does not contact any part of the reef other than the very immediate seep area. The Kahekili reef has salinity well within nominal range for natural reefs. See comments to 1B4 below.

1B3d. Low oxygen water from the seeps does not impact the Kahekili reef. Again, seep water rapidly mixes with ambient seawater and does not contact any part of the reef other than the very immediate seep area. The Kahekili reef is absolutely not hypoxic. See comments to 1B4 below.

1B3e. High temperature water from the seeps does not impact the Kahekili reef. Again, seep water rapidly mixes with ambient seawater and does not contact any part of the reef other than the very immediate seep area. See comments to 1B4 below.

1B4. The effluent emerging from the seeps encounters a very small area of the reef benthos before being mixed with surrounding seawater. This is basic physics. Density differences cause fresh water leaving the seeps to travel vertically to the sea surface. (The same density differences cause an observer to see "shimmering water" when swimming over the seeps.) There is mixing into the surrounding volume as it rises, as evidenced by the stark difference in water quality parameters between seep and surface. However, that mixing should not be misconstrued as bulk movement of homogeneous masses of seep water horizontally across the reef. In fact, the flux of fresh water discharged from the seeps is tiny compared to the flux of oceanic seawater advected across the reef. Any impact must be extremely local to the seeps themselves before the seep water either rises to the surface or is mixed with ambient seawater.

1C. There is absolutely no basis in fact for Smith's estimate of 15 years for recovery of Kahekili reef (if it has in fact declined). Connell et al. (1997) actually performed a 30-year study of disturbance and recovery of coral communities within different reef zones. Their data show that coral cover can increase 10–20% in as few as 3–5 years (see their Fig. 2). Sheppard et al. (2008) documented strong recovery of coral communities within eight years of a mass mortality event. However, this discussion presupposes that a decline has actually occurred. It should be noted that 40–50% coral cover in the shallow aggregate reef zone is among the higher values reported by the Connell and Sheppard studies for unimpacted reefs. Thus, it is actually inappropriate to discuss "recovery."

IX. August 2014 In-Water/Remote Sensing Survey

In-Water Survey Methods

The in-water survey had the objective to quantify the spatial distribution of benthic community structure across the Kahekili reef and nearby areas. At each site, 50–100 vertical photographs of the reef were taken to completely cover an area approximately 5×5 m. These photos were stitched together to form a seamless mosaic using the software Kolor Autopano Giga v3.6 (example in Exhibit 32). A total of 82 survey sites were visited (selected haphazardly), 71 of which were within the Kahekili reef extent (defined by visual interpretation of WorldView-2 imagery, Exhibits 33 and 34). The 71 Kahekili sites together comprised an approximate area of 1,400 m^2.

It is important to understand that the mosaics are not intended to be absolute representations of the reef at the cm-scale. The point of building and using mosaics in this analysis is to gain a better perspective of a reef community than is afforded by a few small (<1 m) quadrats in the same reef area. Even if the software is unable to perfectly align small features, the mosaic as a whole remains the better representation of the local community (Gleason et al. 2007; Lirman et al. 2007). This improved perspective is important for spatial analysis of benthic cover derived from the mosaics, as well as for calibrating and validating remote sensing classification products.

Photomosaic Analysis

To analyze a photomosaic, 100 circles were overlain on the image in a 10×10 grid. Each circle had a radius of 75 pixels, which corresponded to areal coverage of 8–178 cm^2 per circle, depending on the pixel dimensions of the mosaic. The dominant benthic type within each circle was identified (example Exhibit 35). The identifications were counted, then divided by the total number of counts (=100, except for three instances of holes in mosaics) to provide proportional cover for each benthic type.

Spatial Analysis of Field Data

Partial Redundancy Analysis (RDA) was performed to test whether distance from the Kahekili seeps can explain the distribution of benthic community structure, while accounting for distance from the shoreline. The basis and method for conducting partial RDA in this setting are explained in the book *Numerical Ecology, Third English Edition* by Legendre and Legendre (2012): "In partial RDA, the linear effects of the explanatory variables **X** on the response variables **Y** are adjusted for the effects of the covariables **W**" (p. 649). Partial RDA is a form of multivariate multiple regression. In this case, the explanatory variables **X** were distances from each of the 71 survey sites to each of the two Kahekili seep groups, i.e., two distances for each survey site. The response variables were the percent benthic cover for the three categories algae, coral, and sand. The covariable **W** was the shortest distance from each survey site to shore.

Partial RDA computes a statistic called "pseudo-F," which is a version of the very well known (among scientists) F-statistic. Next, a permutation test repeatedly randomizes the response variables and recomputes pseudo-F to determine the frequency that random data might produce a value of the statistic higher than that observed. With a suitable number of iterations (1,000–10,000), this frequency is the probability, or *p*-value, for the test.

The statistical software R, with additional community ecology package VEGAN (co-written by Pierre Legendre), was used for this analysis. The function *rda* computed pseudo-F, and the function *permutest* performed the permutation test with 10,000 iterations to find the *p*-value. The analysis was performed once as described, with benthic cover of coral, algae, and sand as the response variables **Y**; distances from survey sites to the two seeps as the explanatory variables **X**; and shortest distance from each survey sites to shore as the covariable **W**. The analysis was then repeated, switching the explanatory and covariables, to evaluate whether distance from shore can explain the distribution of benthic community structure, while accounting for distance from the seeps.

The results are striking. Given distance from shore as a covariable, distance to the seeps does not explain the distribution of benthic community structure Kahekili (pseudo-F = 1.17, p = 0.32). However, given distance to the seeps as a covariable, distance to shore very strongly explains the distribution of benthic community structure Kahekili (pseudo-F = 121.6, p = 0.000099). This unequivocally indicates that the seeps do not influence the benthic community. Rather, it is the proximity to shore (possibly the shallowness of the water or the presence of copious sand) that is responsible for patterns in the benthic community.

Remote Sensing Analysis

A cloud-free, sea surface clutter-free WorldView-2 remote sensing scene of the wider Kahekili area — Honokowai Beach Park at the north to the Westin Maui Resort and Spa at the south — was identified using the DigitalGlobe web-based ImageFinder tool. The scene (Product Catalog ID 2030010111D11C00) was acquired October 19, 2013 at 11:29 HST. A standard imagery bundle of panchromatic and eight-band multispectral data was purchased through an certified reseller (Spatial Solutions, Inc.). The panchromatic image had 0.5 m resolution, while the multispectral image had 2 m resolution. Imagery was delivered as georeferenced and gridded on the Universal Transverse Mercator zone 4Q projection, based on the WGS84 ellipsoid. A subset of the imagery surrounding the Kahekili reef was "pan-sharpened" using the Gram-Schmidt algorithm in the commercial software ENVI, producing a 0.5-m-resolution, eight-band multispectral image of the study area. A mask of the reef was created by manually digitizing a polygon around the reef edge, and sea surface clutter (whitecaps, boats, swimmers) was also masked.

In ENVI, each of the 71 field mosaic sites was located on the image and used to define a region of interest (ROI) of 20–30 image pixels (71 sites = 71 regions of interest). Additional ROIs were defined through visual interpretation to identify areas of purely sandy seafloor, which were not visited in the field survey. The ROIs were used to construct a maximum likelihood classifier, which was then applied to the full image, associating each pixel to a single ROI. That image was used to look up percent cover values for each bottom-type, producing final maps for coral cover, turf-bare cover, etc.

For accuracy assessment, for each ROI pixel (total of 1,634 pixels), actual benthic cover was compared against predicted benthic cover at levels of 0%, 0–10%, 10–20%, 20–30%, etc. These values together comprise an error matrix with actual cover as columns and predicted cover as rows. Correct classifications fall along the main diagonal of the matrix, while misclassifications are off-diagonal. Dividing each matrix element by its column total, then multiplying by 100, converts the matrix of pixel counts to classification rates. Classification accuracy was very good for all levels of each bottom-type; the lowest correct classification rate was 88.9% for turf-bare at 50–60% cover. The high accuracy indicates that the maps are a good representation of benthic community structure on the Kahekili reef. The error matrices for coral and turf-bare are shown in Exhibit 36.

The remote sensing maps corroborate spatial trends identified throughout this Report. Turf-bare is clearly high nearshore and low offshore (Exhibit 37), and coral follows the opposite trend (Exhibit 38). We know these patterns follow habitat zonation at Kahekili. Most importantly, the locations of the freshwater seeps have no bearing on the spatial pattern of either turf-bare or coral.

EXHIBITS

The exhibits accompanying this report will be used, as will excerpts from the documents referenced in this Report, data relied on in this Repor,t and data and documents relied on by Dr. Smith and Plaintiffs' other experts as appropriate.

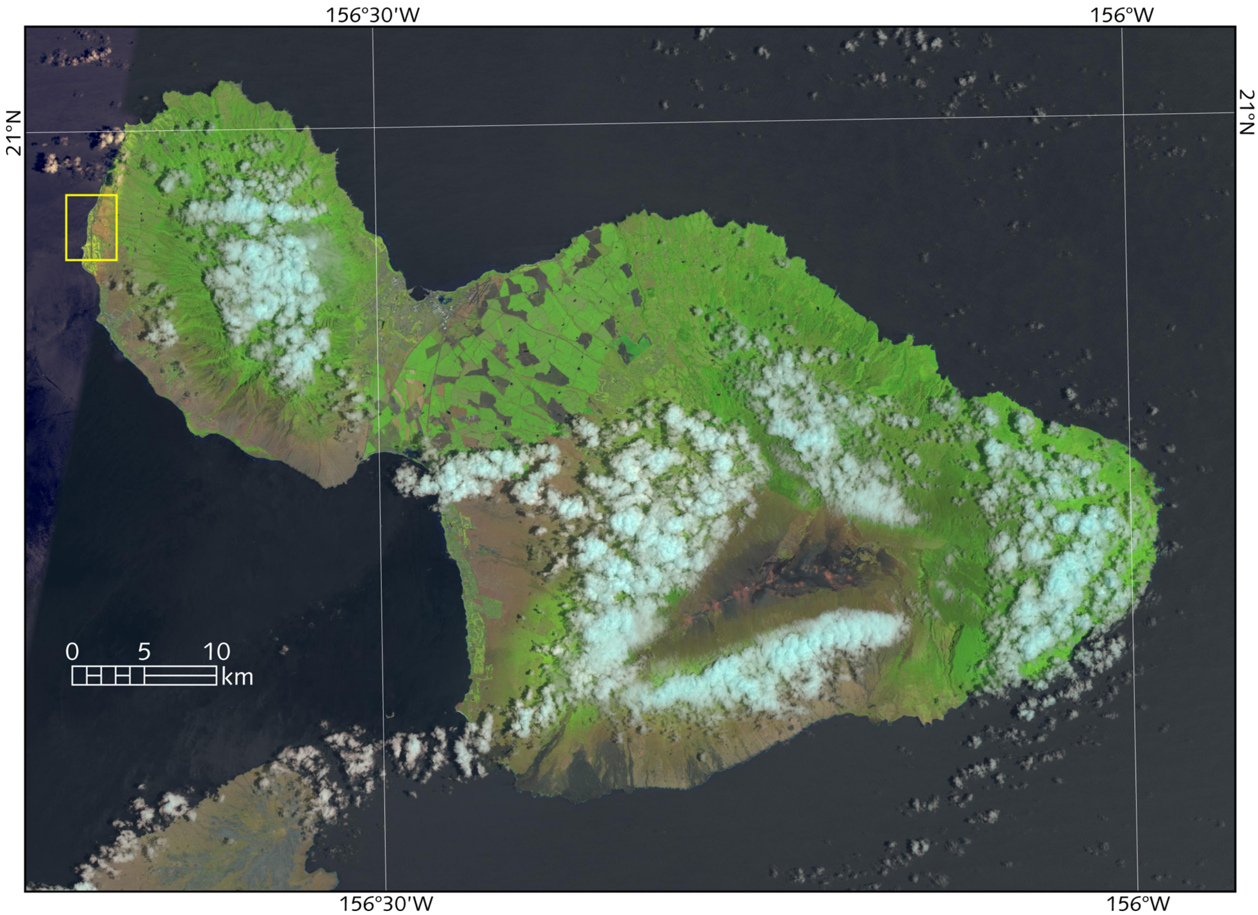


Exhibit 1. Landsat 8 scene of Maui, Hawaii. Wider Kahekili area is outlined in yellow box, which is also the extent of the map in Exhibit 2.

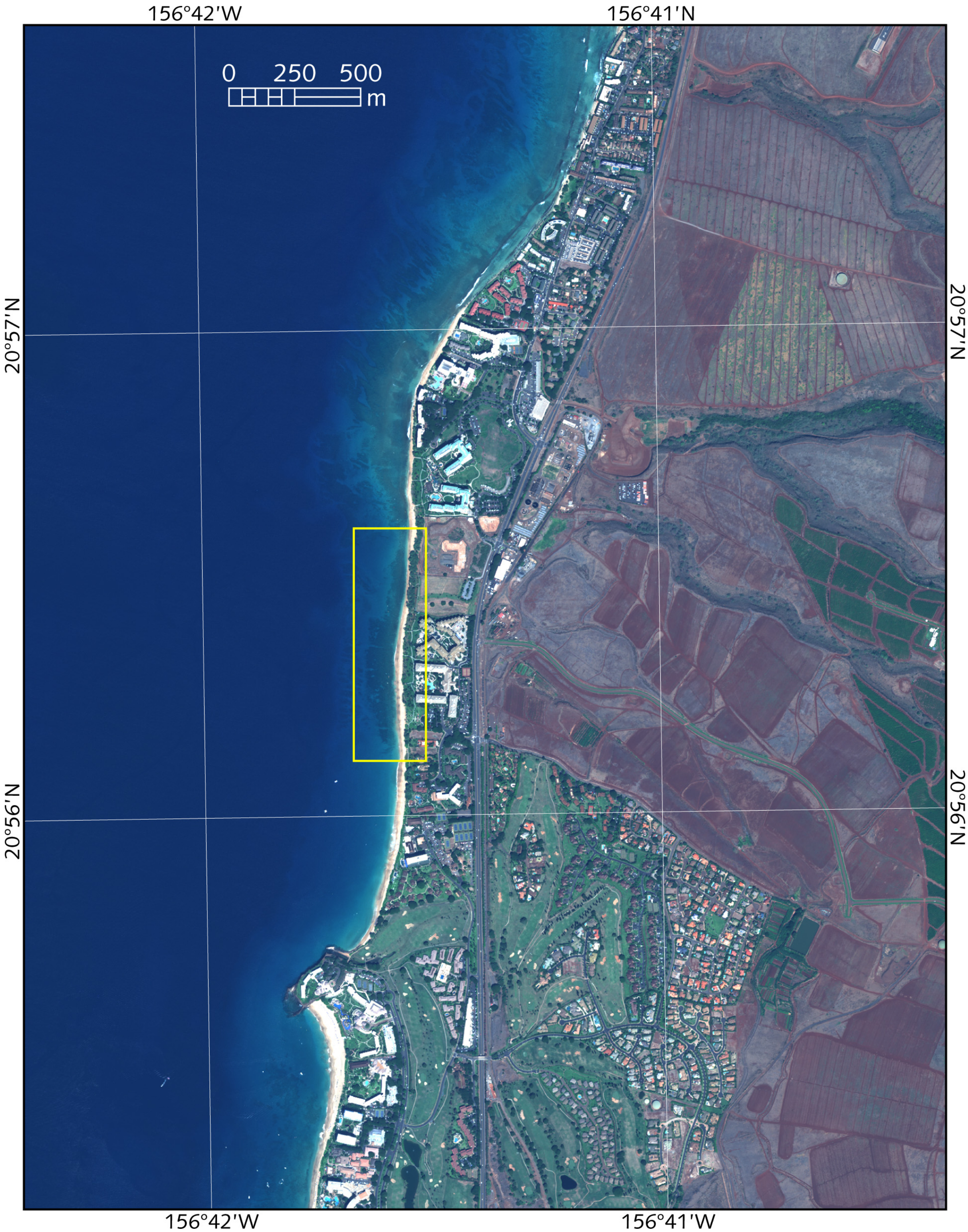


Exhibit 2. Wider Kahekili area. Fringing reefs appear as darker, brownish areas just seaward of beach, interspersed with extensive submerged sand patches. Yellow rectangle highlights Kahekili reef proper, and shows extent of the map in Exhibit 3. Image source: DigitalGlobe.

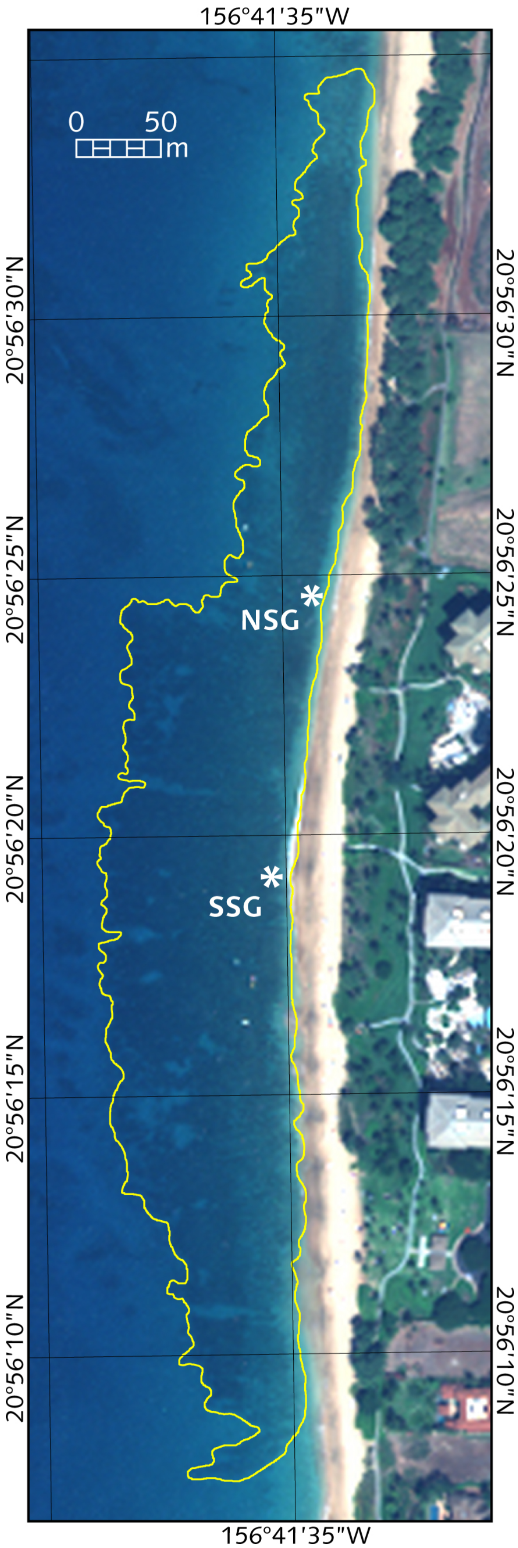


Exhibit 3. Kahekili reef proper. Yellow polygon outlines reef area (visually interpreted from the image). White asterisks indicate locations of north seep group (NSG) and south seep group (SSG). Image source: DigitalGlobe.

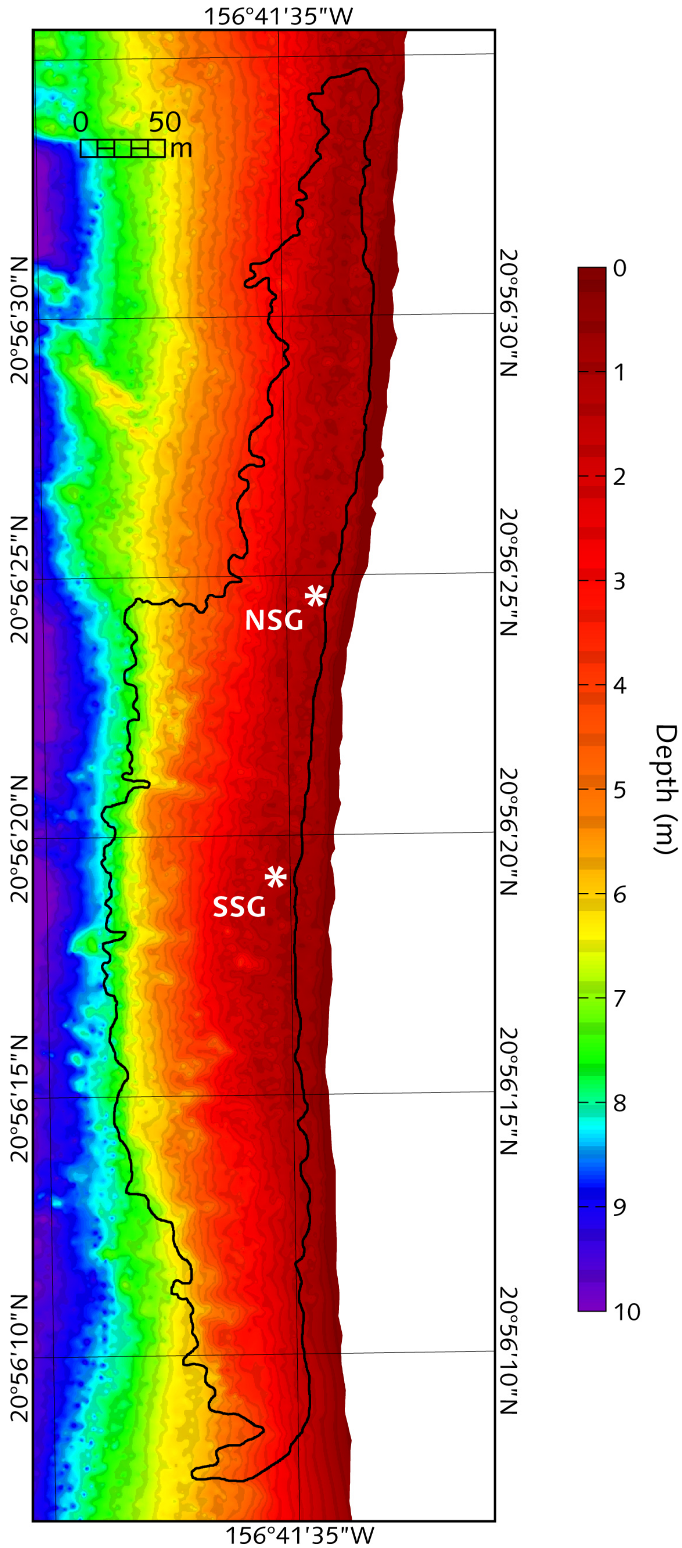


Exhibit 4. Bathymetry of Kahekili reef. Black polygon outlines reef area (as in Exhibit 3). Land area is masked in white. White asterisks indicate locations of north seep group (NSG) and south seep group (SSG). Data source: US Army Corps of Engineers.

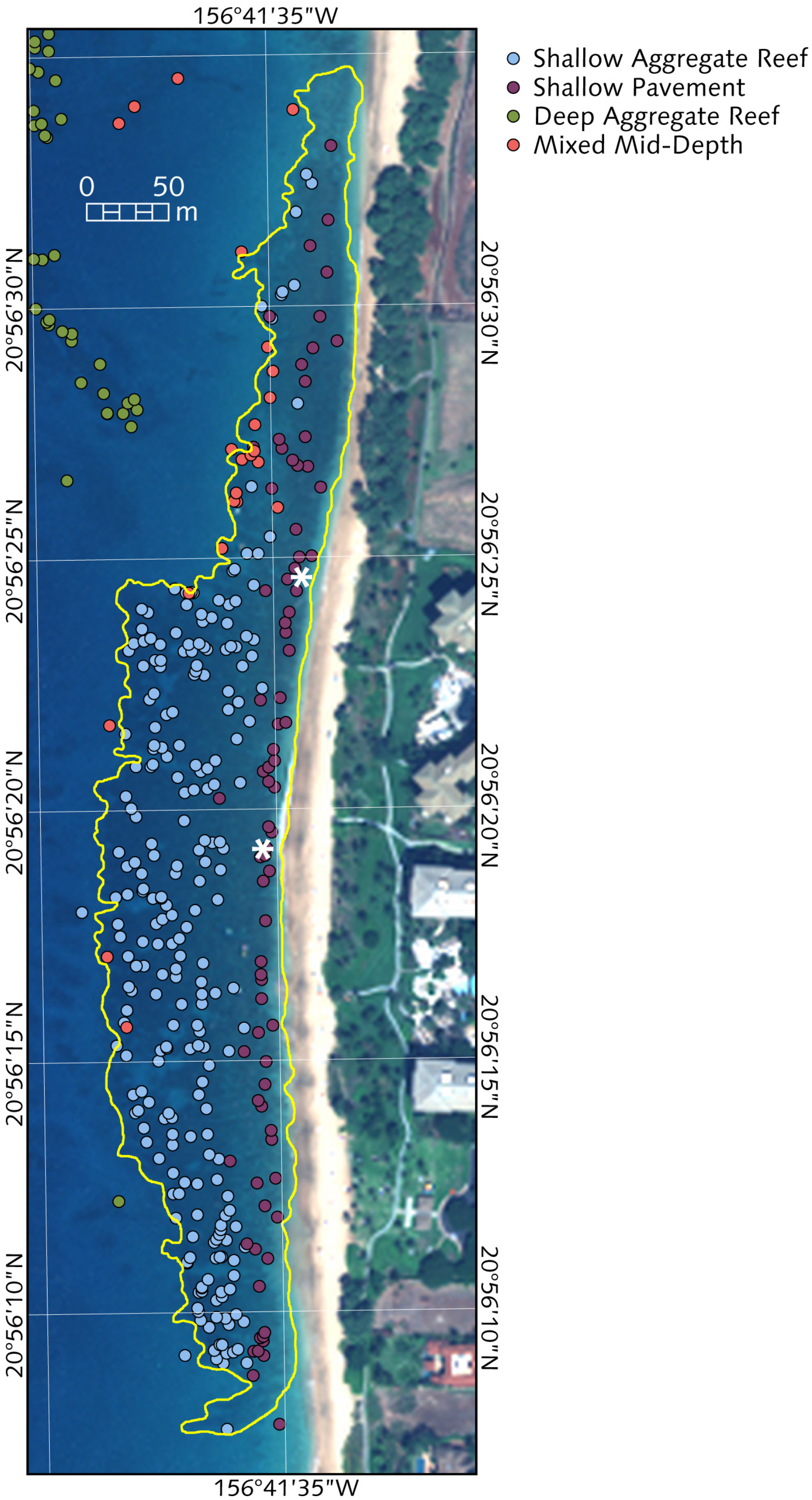


Exhibit 5. Distribution of habitats on Kahekili reef in DAR-CRED data. All survey rounds are plotted. Seeps are shown as white asterisks.

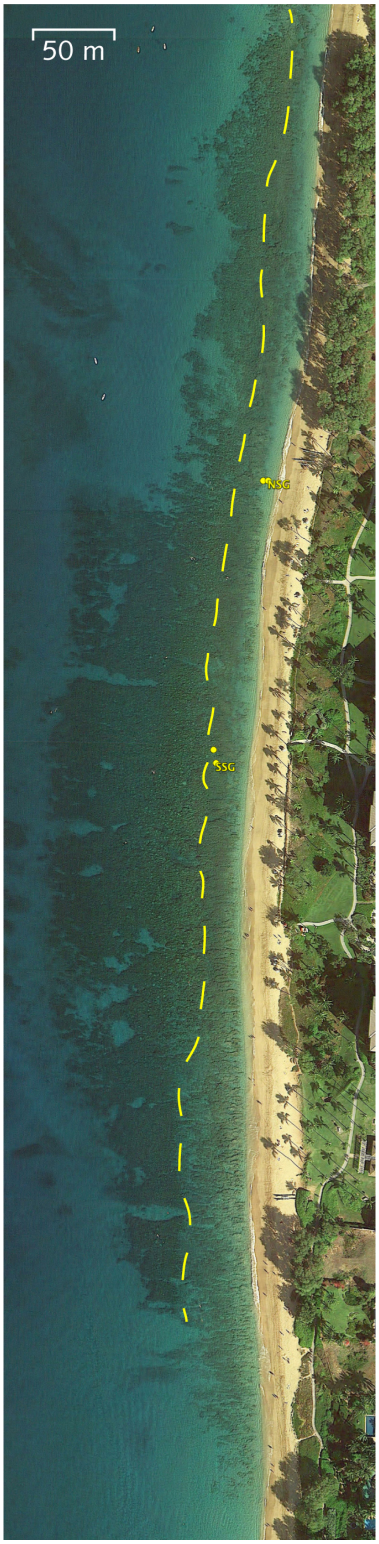


Exhibit 6. Approximate boundary between shallow pavement and shallow aggregate reef habitats on Kahekili reef. Boundary is estimated visually. Seep groups are labeled. Image source: Google Earth.

Survey Round	Survey Period	Number of Records
KA0801	Jan 2008	38
KA0808	Aug 2008	32
KA0909	Sep 2009	30
KA1009	Oct 2010	26
KA1103	Mar 2011	39
KA1109	Sep 2011	31
KA1204	Apr 2012	24
KA1209	Sep 2012	34
KA1304	Apr 2013	23
KA1309	Sep 2013	26
KA1404	Apr 2014	27

Exhibit 14. Dates and number of records (transects) on Kahekili reef for each DAR-CRED survey round.

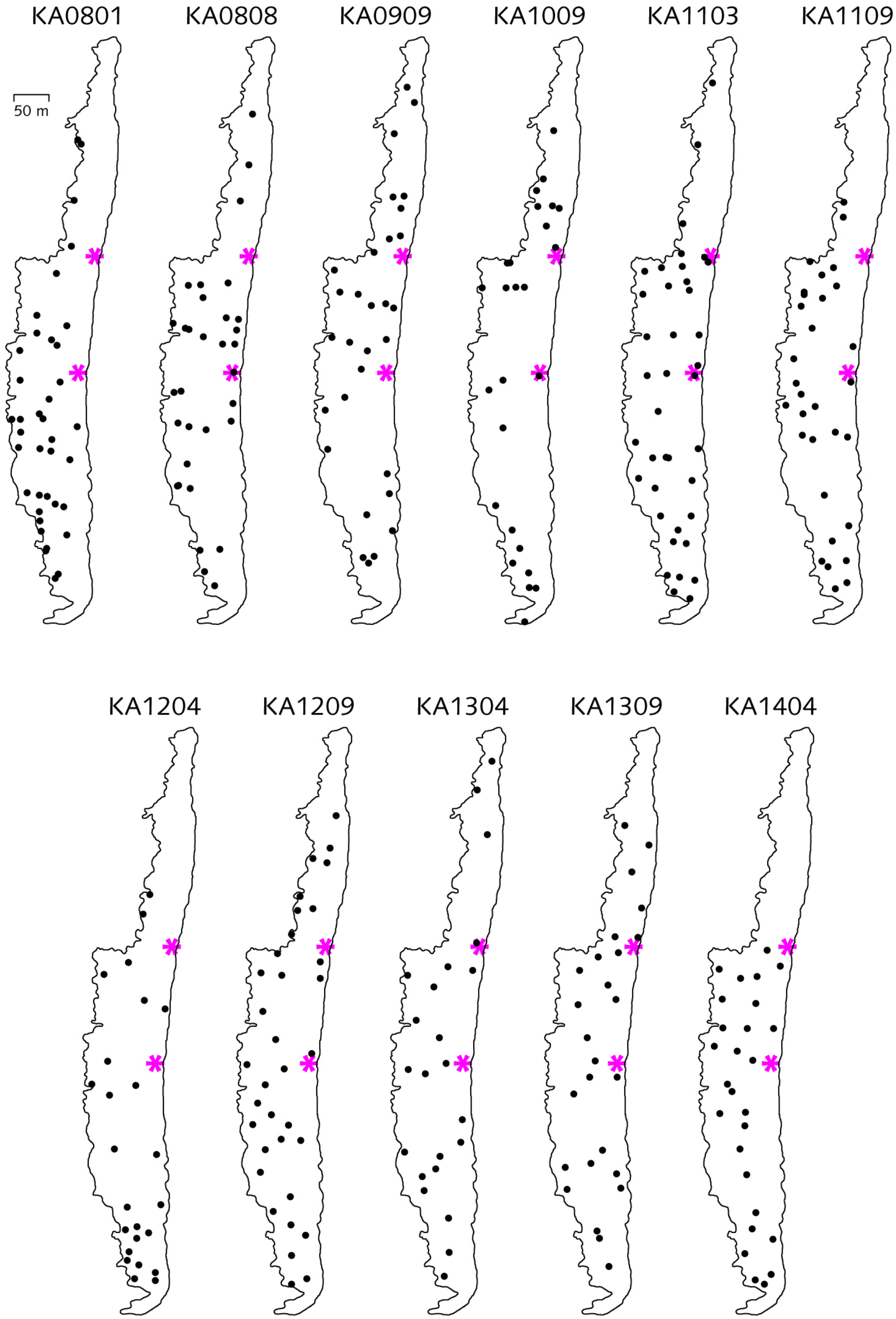


Exhibit 15. Location (black dots) for each transect during each survey round. Black polygon outlines reef area (as Exhibit 3). Magenta asterisks show locations of NSG and SSG.

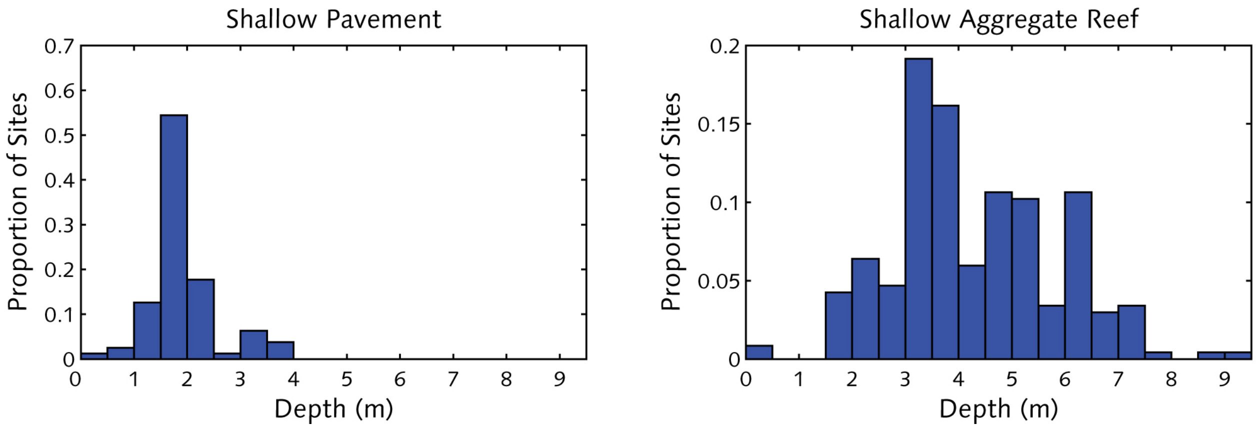


Exhibit 16. Depth distributions for shallow pavement and shallow aggregate reef habitats at Kahekili. Bar height indicates proportion of sites at given depth. Within each plot, the sum of all bar height equals one. Note that the shallow aggregate reef site at 0 m depth is likely an incorrect data entry in the DAR-CRED data set.

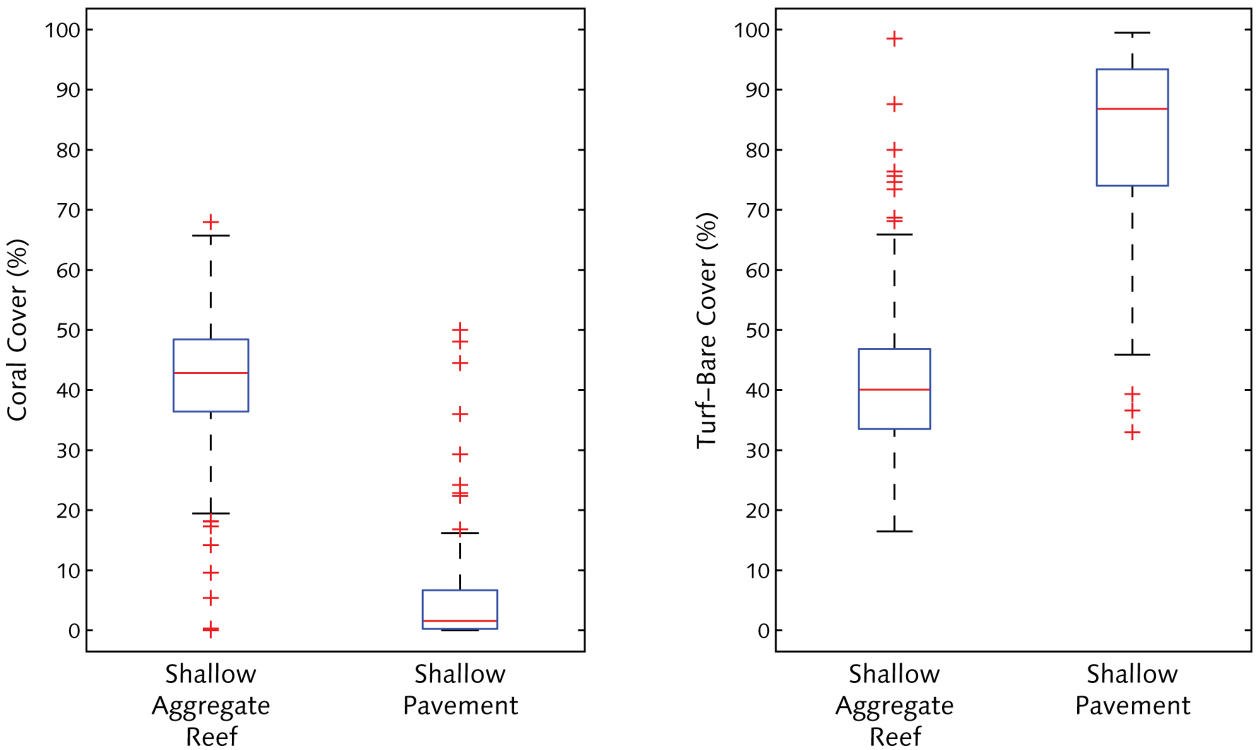


Exhibit 17. Box plots showing percent cover for coral (left) and turf-bare (right) within the two predominant habitat zones at Kahekili. In a box plot, the horizontal red line indicates the median, blue boxes indicate the 1st and 3rd quartiles, black whiskers indicate minimum and maximum extent of data points that are not outliers, and red crosses indicate statistical outliers. Coral cover is much higher in the shallow aggregate zone than in the shallow pavement zone. Turf-bare shows the opposite trend.

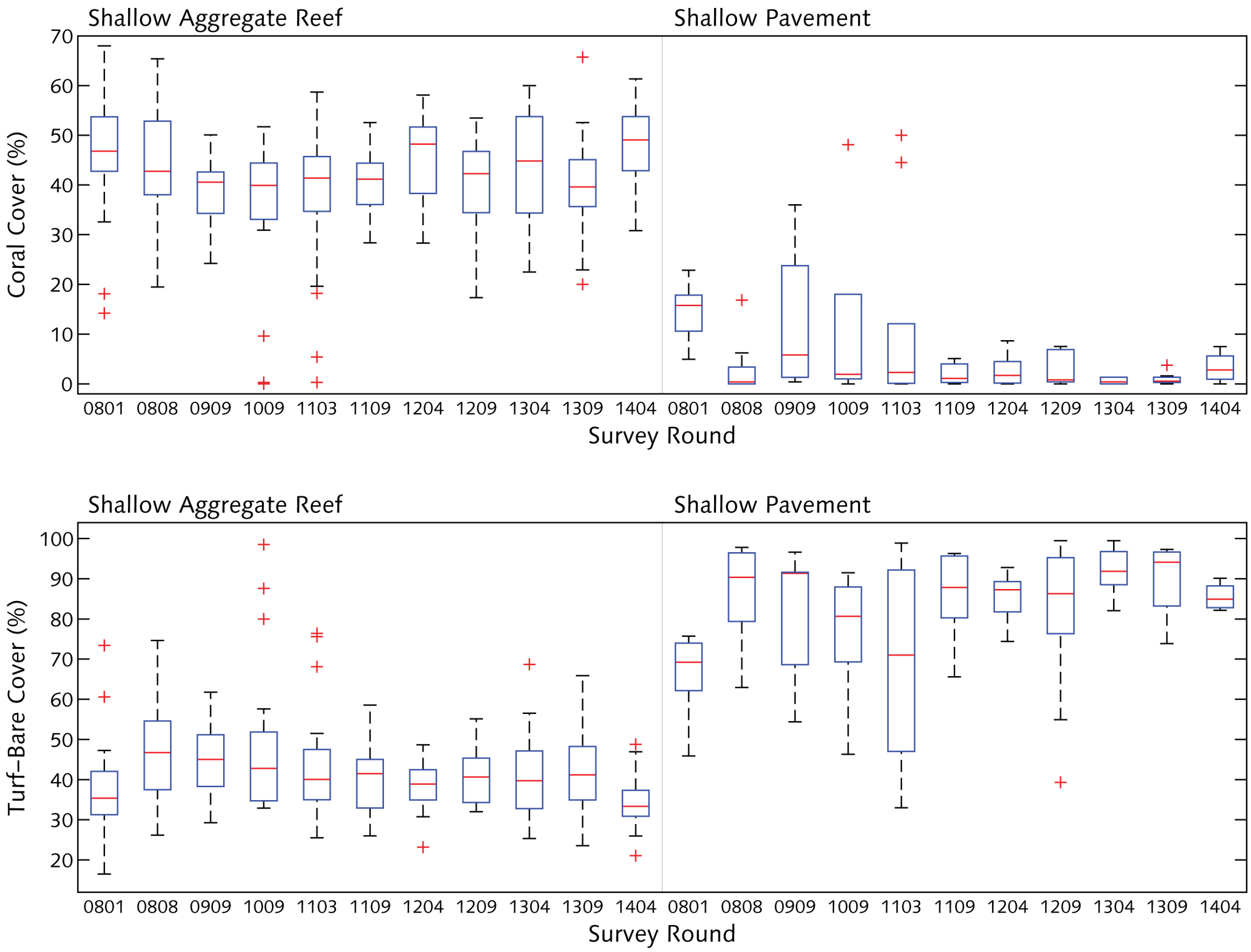


Exhibit 18. Box plots showing percent cover for coral (top) and turf-bare (bottom) within the shallow aggregate reef (left) and shallow pavement (right) habitats at Kahekili. The same trends are Exhibit 9 are apparent, but there is also survey-to-survey variation. However, that inter-survey variation is not as great as the inter-habitat variation.

	Benthic cover vs. distance to nearest seep, controlling for distance to shore		Benthic cover vs. distance to shore, controlling for distance to nearest seep	
Survey Round	Coral	Turf-Bare	Coral	Turf-Bare
KA0801	−0.40	−0.90	0.45	0.42
KA0808	0.48	−0.25	0.13	−0.02
KA0909	−0.19	0.05	0.74*	−0.80*
KA1009	−0.64	0.64	0.54	−0.62
KA1103	−0.21	0.22	−0.18	−0.08
KA1109	0.80	−0.91*	−0.70	0.86
KA1204	−0.70	−0.31	0.95*	−0.38
KA1209	−0.24	−0.70	0.79*	−0.16
KA1304	−0.10	0.18	0.31	−0.34
KA1309	0.15	−0.61	−0.54	−0.57
KA1404	0.96	−0.87	−0.93	0.97

Exhibit 19. Partial correlation coefficients comparing coral and turf-bare cover in the shallow pavement zone against distance to either seeps or shore, while correcting for the other distance. There are very few statistically significant correlations (indicated by *), which effectively means that, within the shallow pavement zone, neither seeps nor shore influence the spatial distribution of coral and turf-bare.

	Benthic cover vs. distance to nearest seep, controlling for distance to shore		Benthic cover vs. distance to shore, controlling for distance to nearest seep	
Survey Round	Coral	Turf-Bare	Coral	Turf-Bare
KA0801	−0.01	0.02	0.20	−0.03
KA0808	−0.50*	0.29	−0.42	0.33
KA0909	−0.32	−0.25	0.11	−0.19
KA1009	−0.12	0.10	0.08	−0.07
KA1103	0.31	−0.24	0.26	−0.32
KA1109	−0.34	0.08	−0.07	−0.08
KA1204	−0.26	0.08	0.01	−0.38
KA1209	0.05	−0.44	0.04	−0.29
KA1304	−0.40	0.39	−0.13	−0.38
KA1309	0.12	0.13	−0.05	−0.32
KA1404	−0.32	0.31	0.09	−0.05

Exhibit 20. Partial correlation coefficients comparing coral and turf-bare cover in the shallow aggregate reef zone against distance to either seeps or shore, while correcting for the other distance. There is a signle statistically significant correlation (indicated by *), which effectively means that, within the shallow aggregate reef zone, neither seeps nor shore influence the spatial distribution of coral and turf-bare.

	Benthic cover vs. distance to nearest seep, controlling for distance to shore		Benthic cover vs. distance to shore, controlling for distance to nearest seep	
Survey Round	Coral	Turf-Bare	Coral	Turf-Bare
KA0801	0.04	−0.06	0.27	−0.42*
KA0808	−0.02	−0.08	0.56*	−0.53*
KA0909	−0.07	−0.20	0.63*	−0.70*
KA1009	−0.04	−0.02	0.43*	−0.43*
KA1103	0.04	−0.05	0.48*	−0.49*
KA1109	−0.04	−0.17	0.70*	−0.71*
KA1204	0.04	−0.24	0.73*	−0.80*
KA1209	0.20	−0.54*	0.73*	−0.75*
KA1304	0.02	−0.03	0.67*	−0.81*
KA1309	0.22	−0.16	0.68*	−0.75*
KA1404	−0.08	0.10	0.62*	−0.61*

Exhibit 21. Partial correlation coefficients comparing coral and turf-bare cover for the entire Kahekili reef against distance to either seeps or shore, while correcting for the other distance. There is effectively no correlation between benthic cover and distance to the seeps. Conversely, there is nearly all correlations are statistically significant (indicated by *) between benthic cover and distance to shore. Moreover, all coral correlations are positive, indicating increase of coral cover with distance from shore, and all turf-bare correlations are negative, indicating decrease of turf-bare cover with distance from shore. This is the effect of habitat: shallow pavement is near shore and shallow aggregate reef is farther from shore.

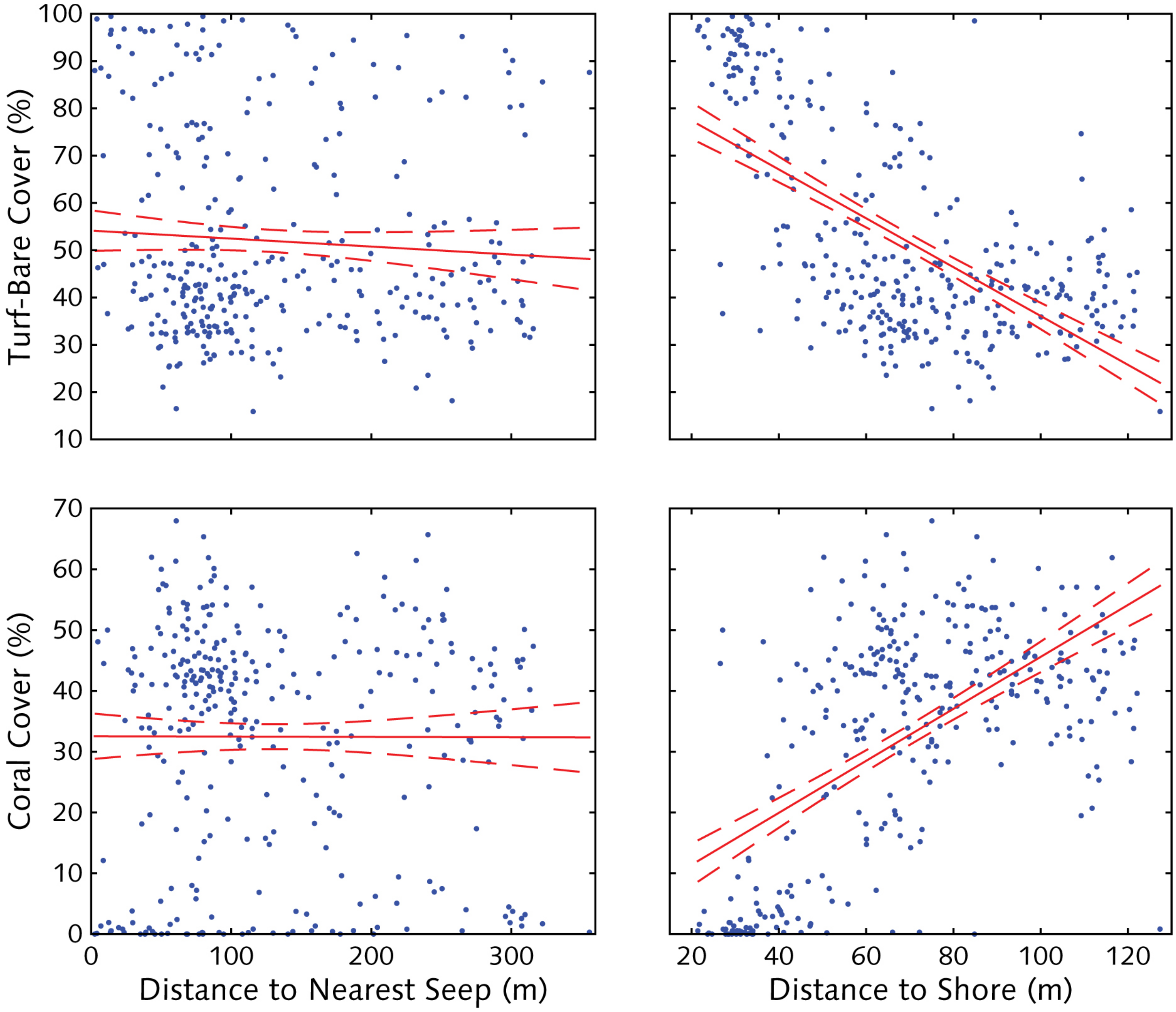


Exhibit 22. Relationship of turf-bare (top) and coral (bottom) cover with distance to nearest seep (left) and distance to shore (right). Blue dots are data points, solid red lines are least-squares regression lines, and dashed red lines are ±95% confidence intervals on the regressions. These plots pool all data points from all habitats and survey rounds. Neither turf-bare nor coral cover changes with increasing distance from the nearest seep, indicating that the seeps have no effect on either benthic type. Turf-bare and coral cover have strong negative and positive relationships, respectively, with distance to shore.

	Benthic cover vs. distance to nearest seep, controlling for distance to shore		Benthic cover vs. distance to shore, controlling for distance to nearest seep	
Survey Round	Pseudo-F	p	Pseudo-F	p
KA0801	2.84	0.029*	2.65	0.071
KA0808	0.25	0.846	12.53	0.001*
KA0909	0.90	0.442	16.08	0.000*
KA1009	1.72	0.184	1.99	0.158
KA1103	0.41	0.817	8.19	0.001*
KA1109	1.53	0.195	21.30	0.000*
KA1204	0.75	0.539	25.36	0.000*
KA1209	7.48	0.000*	18.86	0.000*
KA1304	0.65	0.551	16.05	0.001*
KA1309	0.45	0.754	16.82	0.000*
KA1404	0.78	0.497	10.86	0.001*

Exhibit 23. Results of partial redundancy analysis relating benthic community structure to either distance to seeps or distance to shore while correting for the other distance. Redundancy analysis is a multivariate form of correlation that is able to consider all benthic types at once, as opposed to a single type such as coral or turf-bare. Results are presented as a pseudo-F statistic and corresponding p-value. Statistically significant p-values are indicated by *. Benthic community structure is effectively not correlated with distance to seeps, but it is correlated with distance to shore.

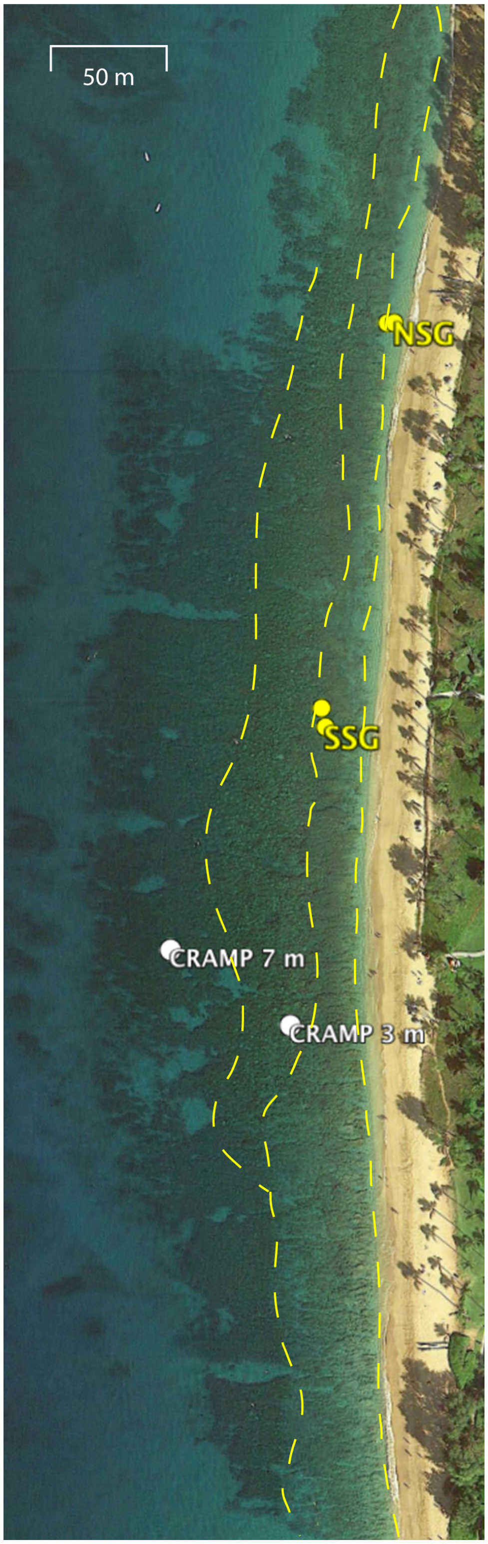


Exhibit 24. Aerial photograph of Kahekili reef showing locations of seep groups and CRAMP transect sites. Habitat zonation is clearly present. Dashed yellow lines depict (visually interpreted) boundaries between habitat zones. See Exibit B for labels. Source: Google Earth.

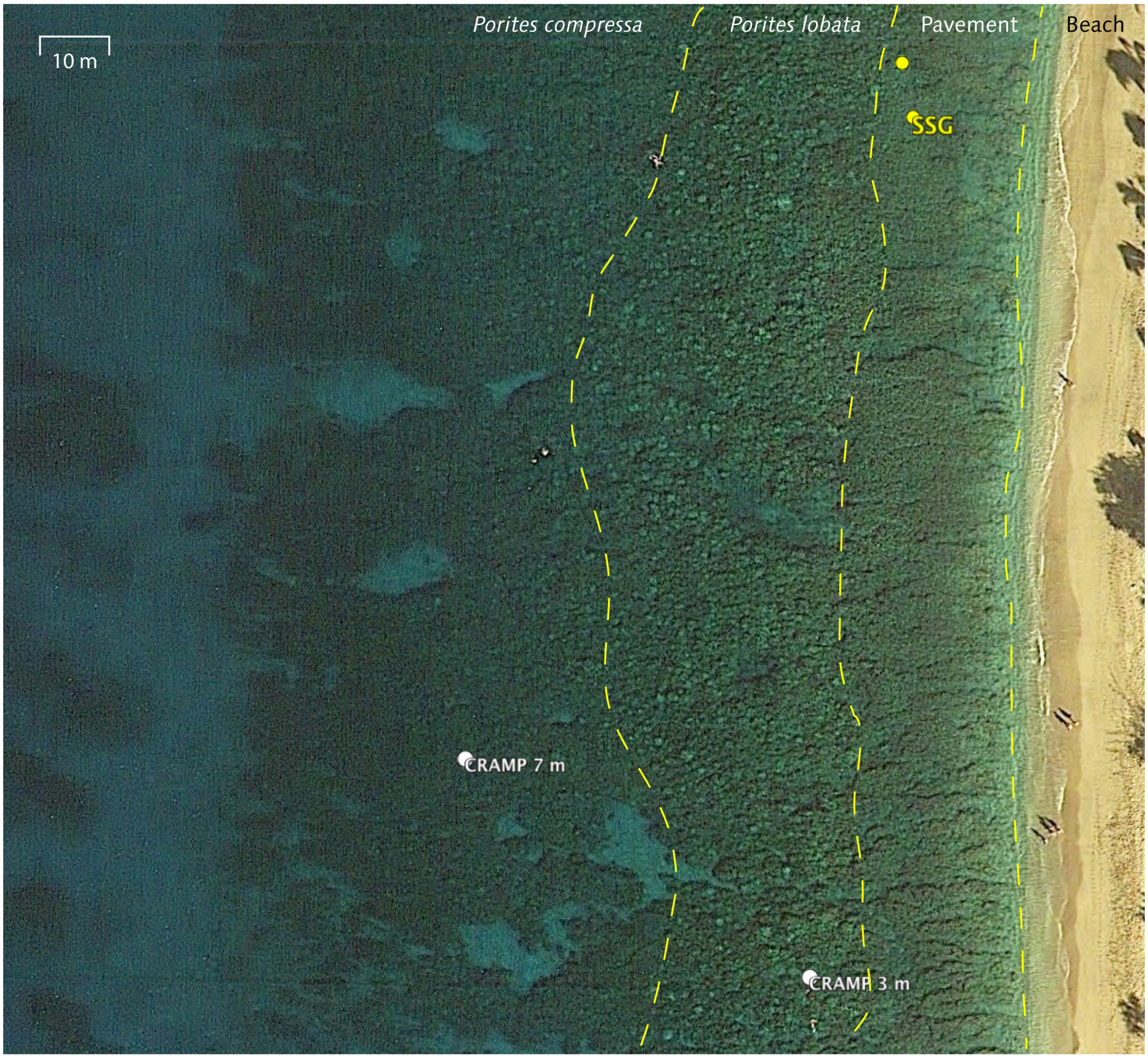


Exhibit 25. Close-up of Kahekili reef in vicinity of south seep group and CRAMP transect sites, illustrating clear habitat zonation. Approximate habitat boundaries are delineated by dashed yellow lines. The *Porites lobata* and *Porites compressa* zones are both within the DAR-CRED habitat "shallow aggregate reef." Source: Google Earth.

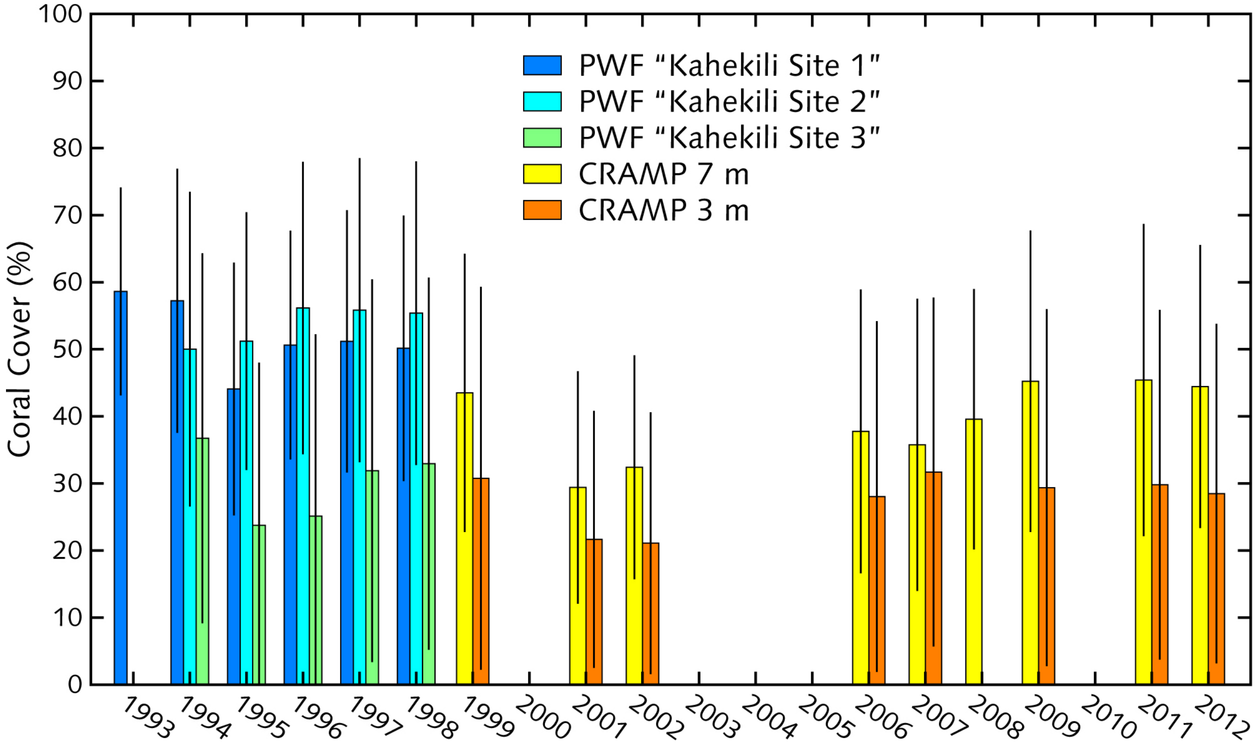
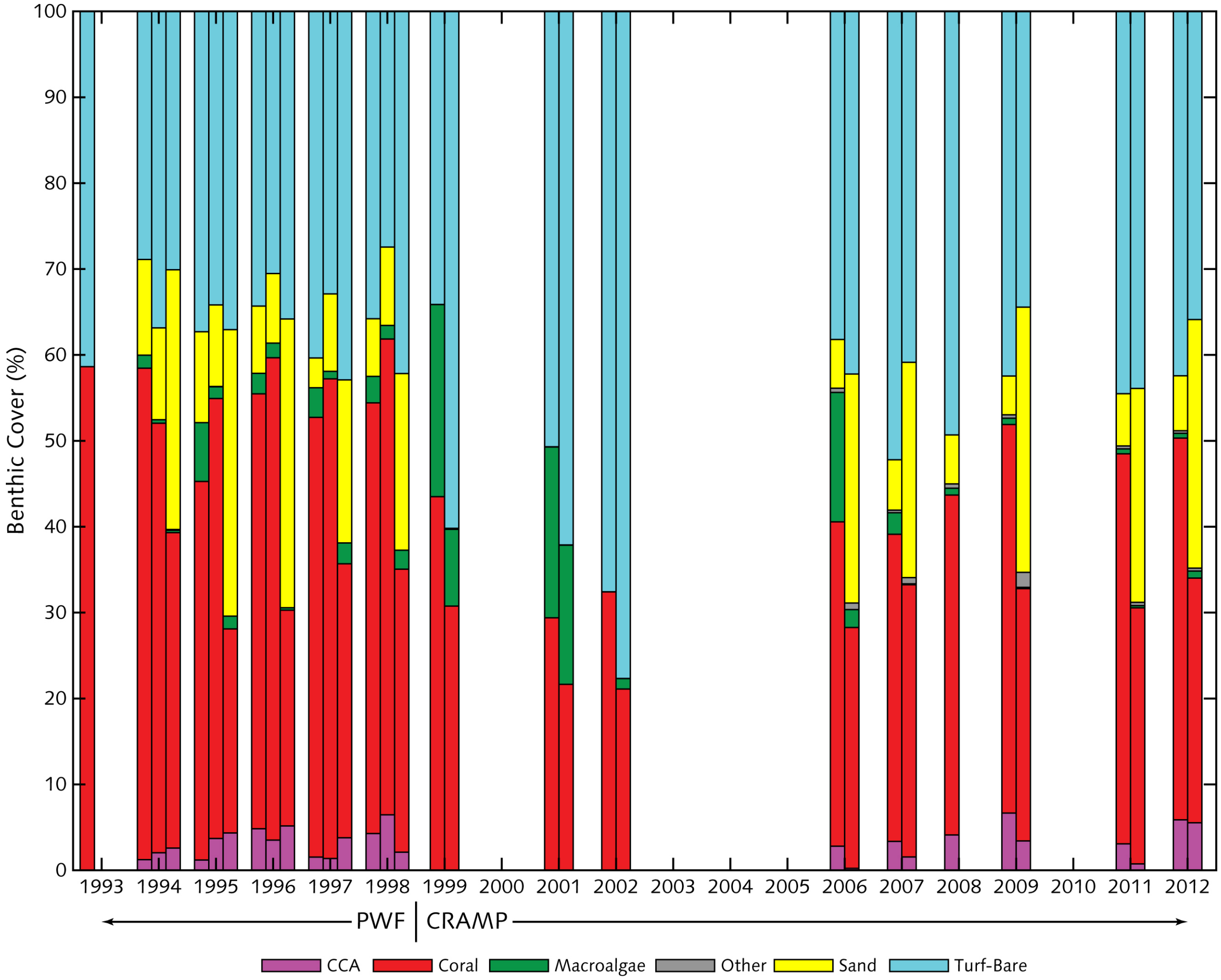


Exhibit 26. Coral cover data from Pacific Whale Foundation (PWF) and Coral Reef Assessment and Monitoring Program (CRAMP) for Kahekili reef. These are the data available from the NOAA Coral Reef Information System (CORIS) website. PWF "Kahekili Site 3" and CRAMP 3 m site are both in the shallow pavement zone.



Exibit 27. Benthic cover data from Pacific Whale Foundation (PWF) and Coral Reef Assessment and Monitoring Program (CRAMP) for Kahekili reef. These are the data available from the NOAA Coral Reef Information System (CORIS) website. In the PWF section, the left bar in each year represents "Kahekili Site 1," the middle bar in each year represents "Kahekili Site 2," and the right bar in each year represents "Kahekili Site 3." In the CRAMP section, the left bar in each year represents the 7 m site, and the right bar represents the 3 m site. PWF "Kahekili Site 3" and CRAMP 3 m site are both in the shallow pavement zone.

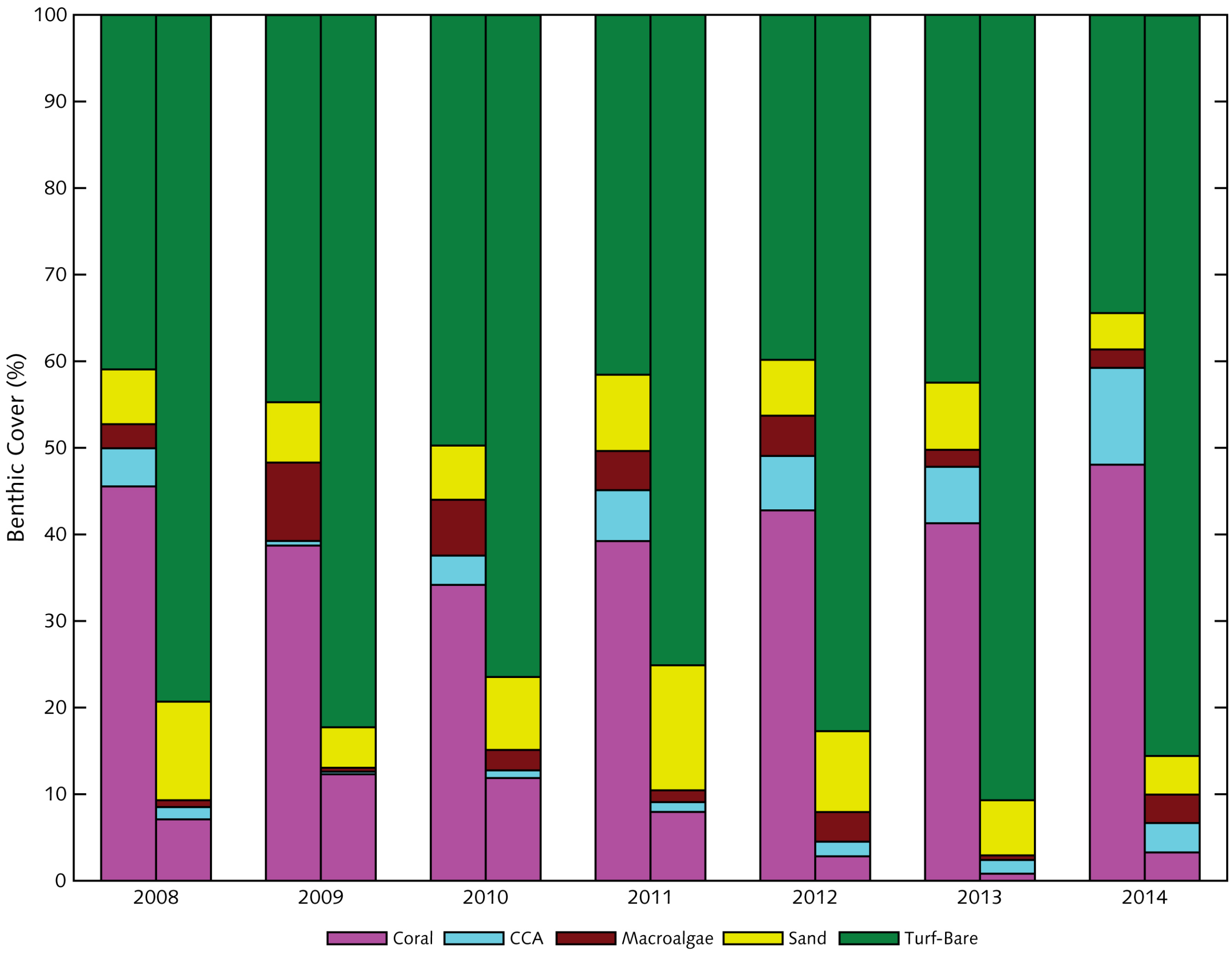


Exhibit 28. Benthic cover for Kahekili reef from DAR-CRED data set. For each year, left bar represents shallow aggregate reef habitat, and right bar represents shallow pavement habitat.

	Shallow Aggregate Reef		Shallow Pavement	
Year	Coral	Turf-Bare	Coral	Turf-Bare
2008	45.5	40.9	7.1	79.3
2009	38.7	44.7	12.3	82.3
2010	34.2	49.7	11.9	76.4
2011	39.2	41.6	8.0	75.1
2012	42.8	39.8	2.8	82.7
2013	41.3	42.5	0.8	90.7
2014	48.1	34.4	3.3	85.5

Exhibit 29. Percent cover of coral and turf-bare by year and by habitat, as given by the DAR-CRED data.

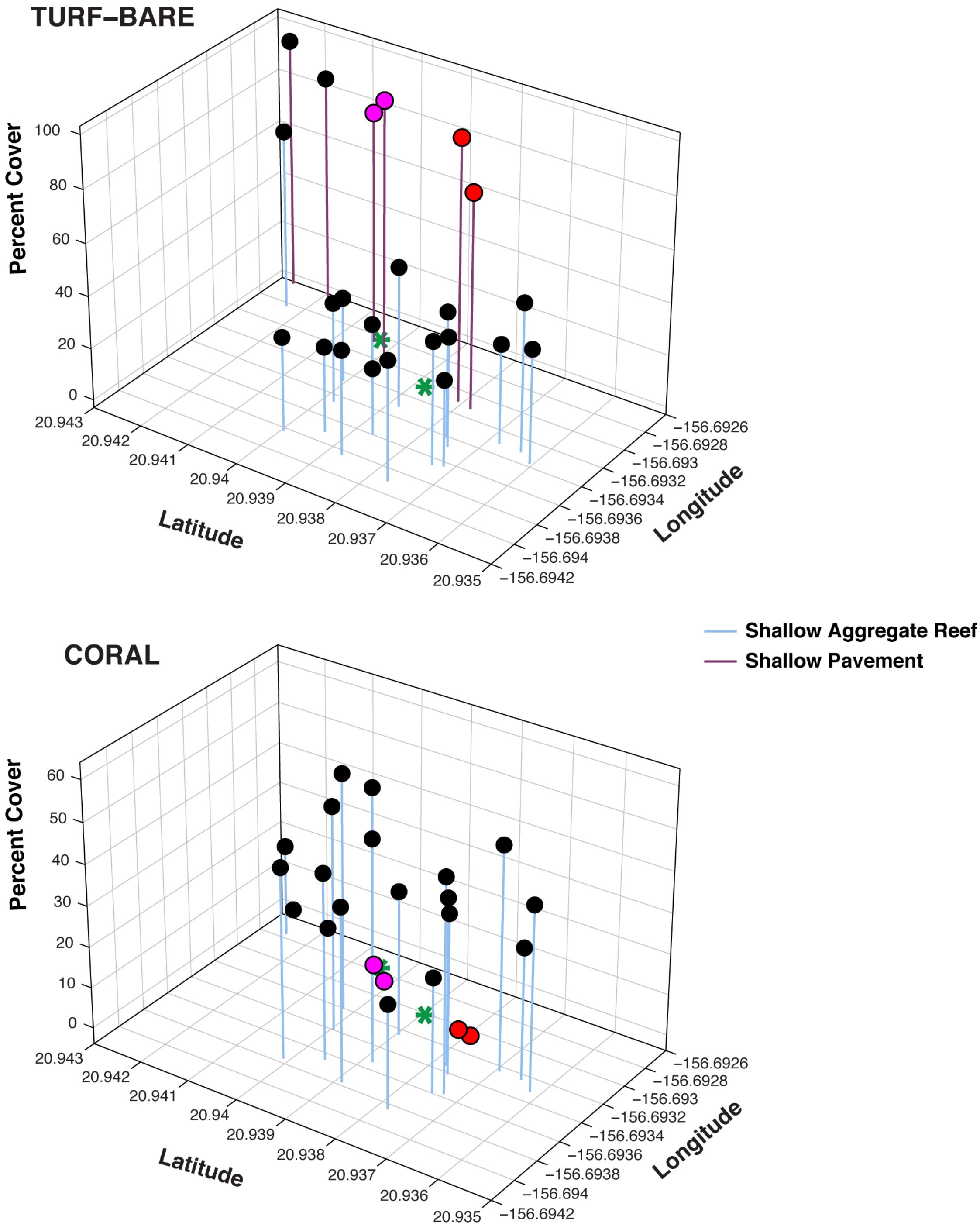


Exhibit 30. Turf-bare and coral cover at Kahekili reef. These data are from a NOAA/CRED survey in April 2013. Stem lengths show cover value (dots with no stems have zero cover), and stem colors show habitat of survey site. Pink and red dots are sites near north and south seep groups, respectively, according to Smith. Green asterisks show locations of seep groups. High turf and low coral occurs in shallow pavement zone, while high coral and low turf occurs in shallow aggregate reef zone.

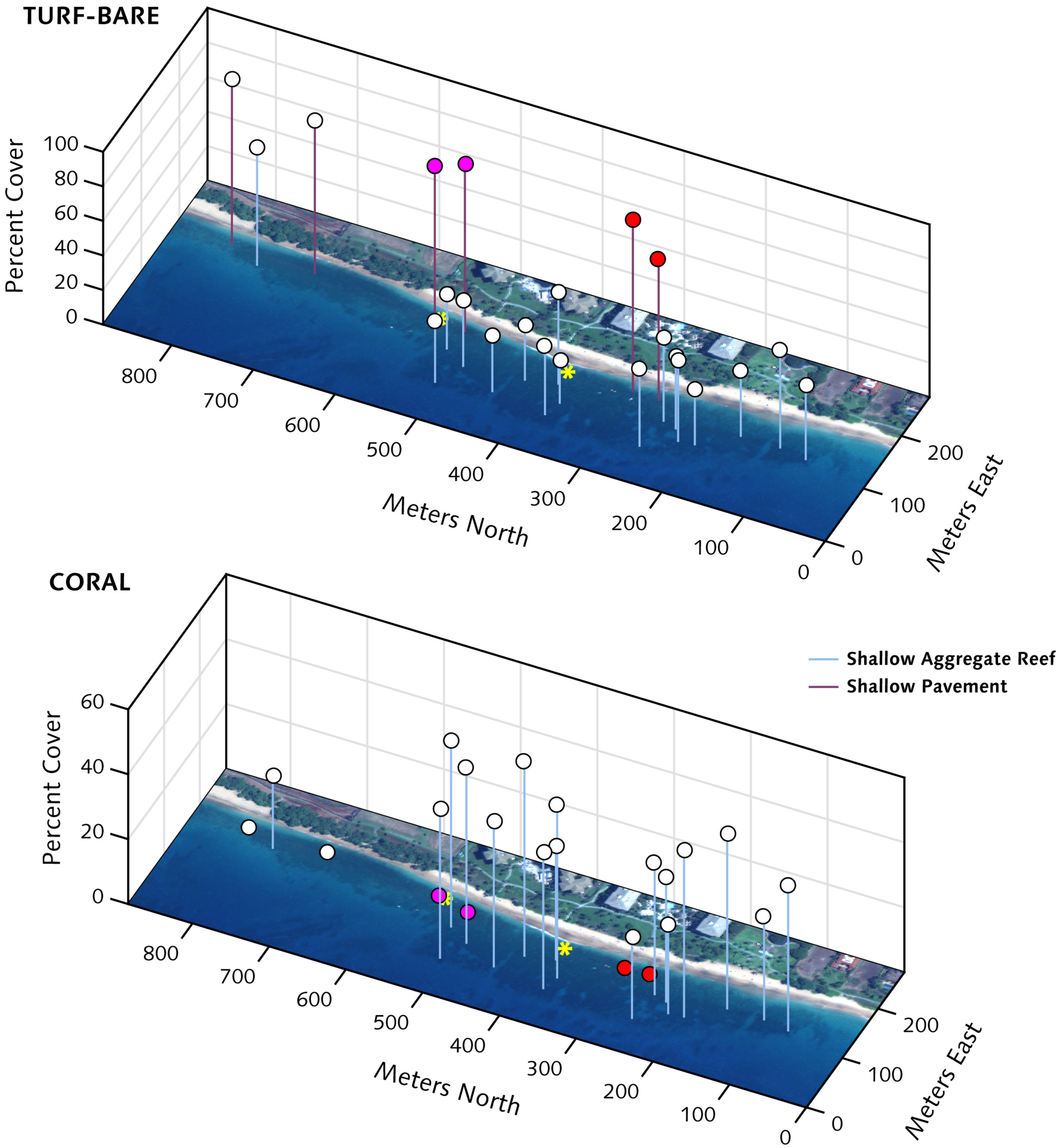


Exhibit 31. Same as Exhibit 30, with two exceptions. First, data are overlaid on satellite image of Kahekili reef, which gives important context. Second, distances are scaled equally in horizontal directions. Seep groups are denoted by yellow asterisks.

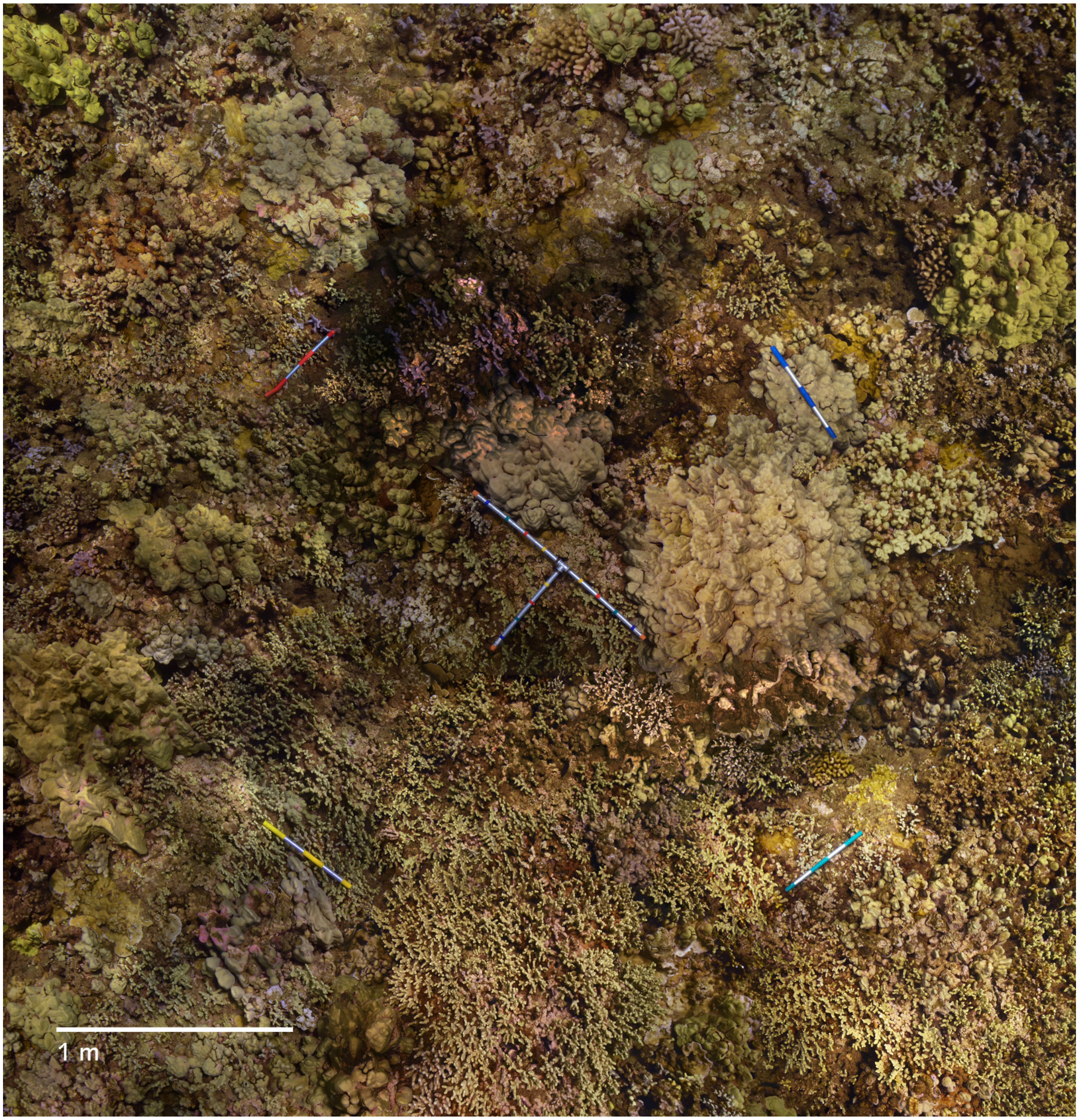


Exhibit 32. Example photomosaic of reef area at Kahekili.

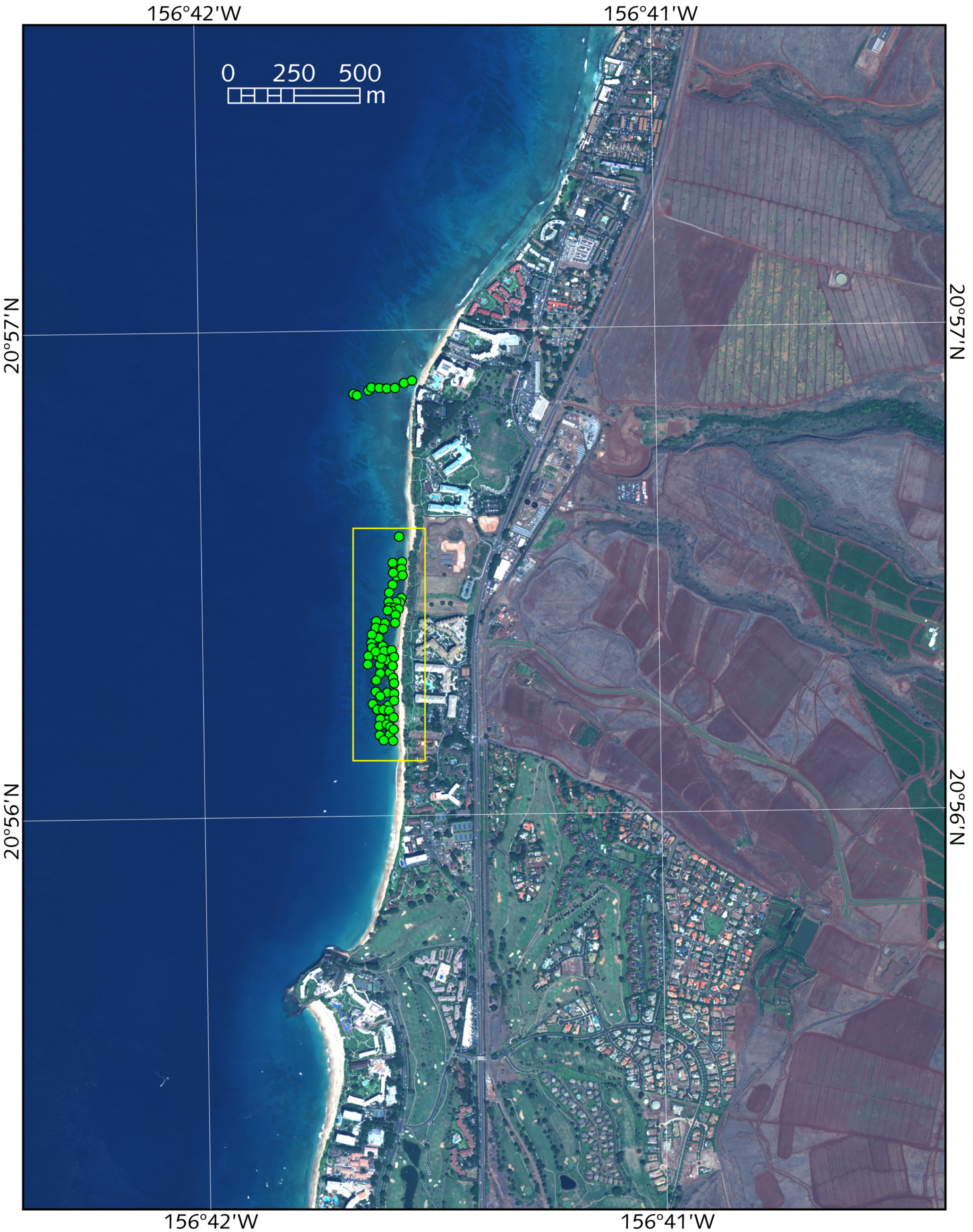


Exhibit 33. Wider Kahekili area, showing August 2014 survey sites. Not shown are four survey sites ~1 km to the south.

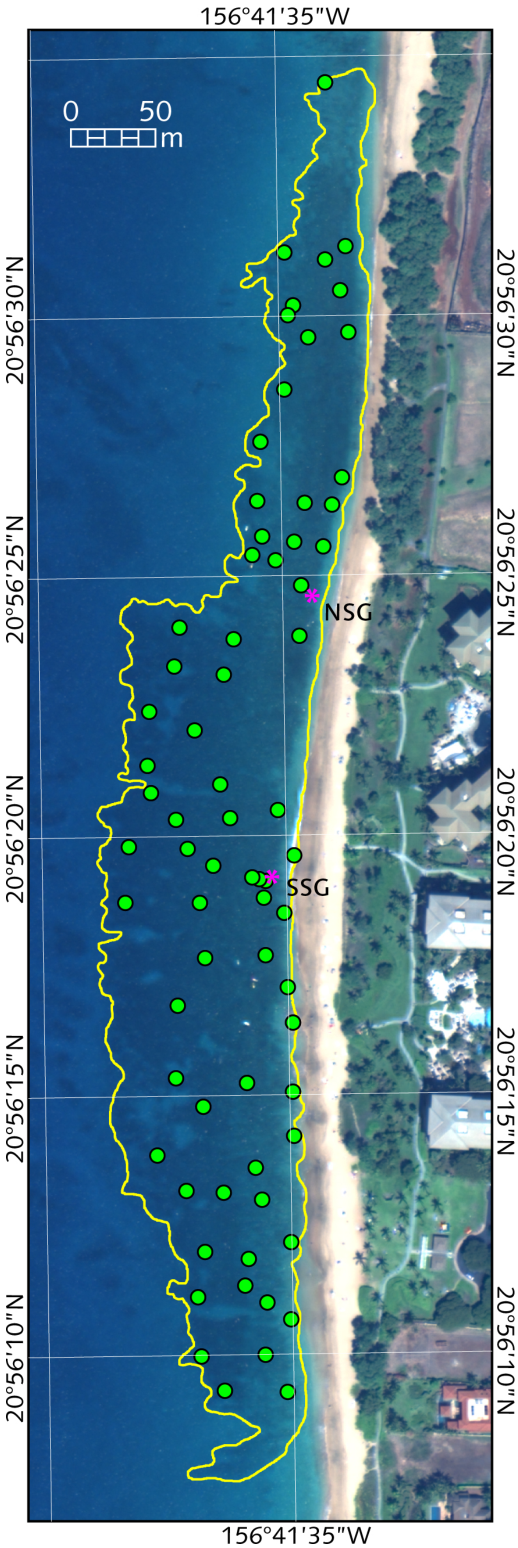


Exhibit 34. Kahekili reef proper. Yellow polygon outlines reef area (visually interpreted from the image). Pink asterisks indicate locations of north seep group (NSG) and south seep group (SSG). Green dots show locations of August 2014 survey sites.

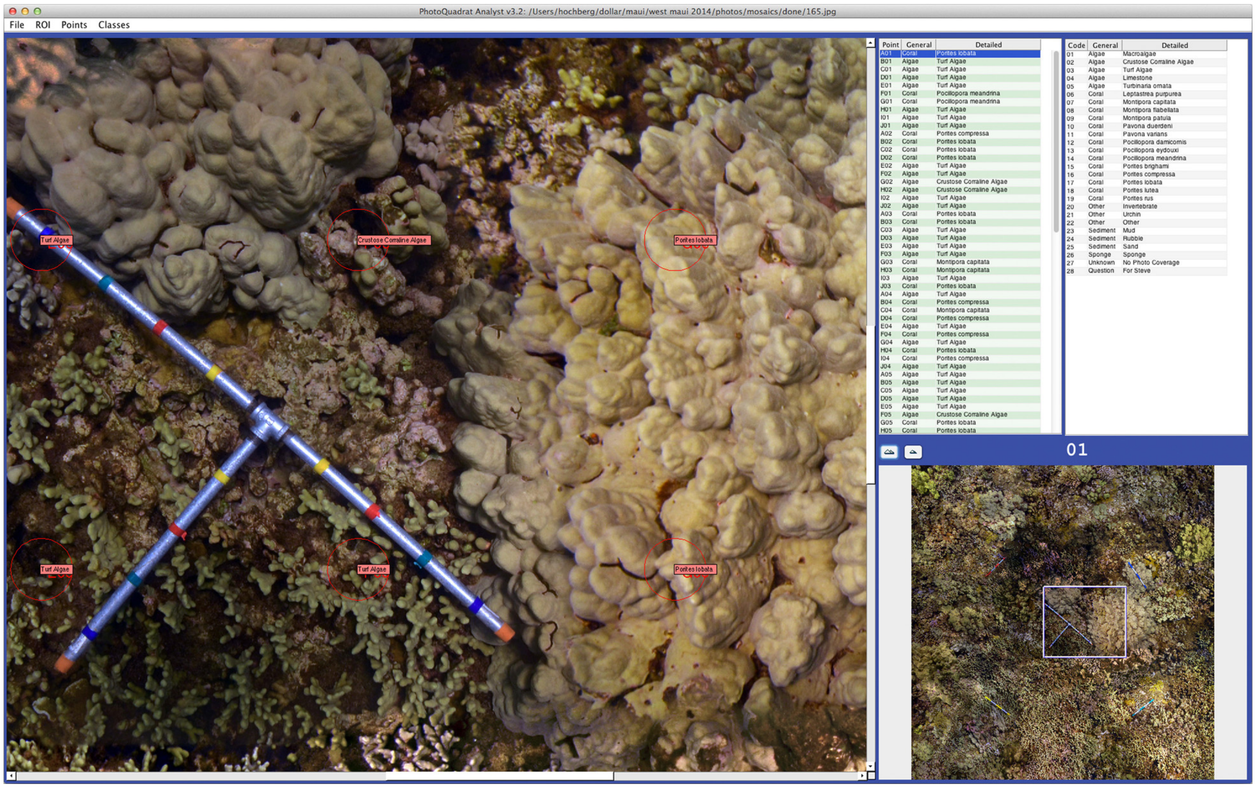


Exhibit 35. Example point-counting procedure. Full photomosaic is shown at bottom-right. Zoomed-in portion is in main window. Right-hand table shows list of available identifications. Left-hand table shows actual point assignments.

		ACTUAL CORAL COVER									
		p = 0	0 < p ≤ 10	10 < p ≤ 20	20 < p ≤ 30	30 < p ≤ 40	40 < p ≤ 50	50 < p ≤ 60	60 < p ≤ 70	70 < p ≤ 80	80 < p ≤ 90
PREDICTED CORAL COVER	p = 0	98.1	1.4	0	0	0	0	0	0	0	0
	0 < p ≤ 10	1.2	97.6	0.7	0.6	0	0.4	0	0	0	0
	10 < p ≤ 20	0	0.3	96.6	2.4	0	1.1	0	0	0	0
	20 < p ≤ 30	0.8	0.7	2.1	95.2	1.4	1.1	0	0	0	0
	30 < p ≤ 40	0	0	0	0.6	95.7	0	1	0	0	0
	40 < p ≤ 50	0	0	0.7	1.2	2.9	95	2.4	5	0	0
	50 < p ≤ 60	0	0	0	0	0	0.7	94.7	0	3.8	0
	60 < p ≤ 70	0	0	0	0	0	1.1	1	95	0	0
	70 < p ≤ 80	0	0	0	0	0	0	1	0	96.2	0
	80 < p ≤ 90	0	0	0	0	0	0.7	0	0	0	100

		ACTUAL TURF COVER								
		10 < p ≤ 20	20 < p ≤ 30	30 < p ≤ 40	40 < p ≤ 50	50 < p ≤ 60	60 < p ≤ 70	70 < p ≤ 80	80 < p ≤ 90	90 < p ≤ 100
PREDICTED TURF COVER	10 < p ≤ 20	100	0	0	0.7	0	0	0	0	0
	20 < p ≤ 30	0	94.8	2.6	0.7	0	0	0	0	0
	30 < p ≤ 40	0	1.6	94.8	0.4	2.2	0	0	0	0
	40 < p ≤ 50	0	3.6	2.2	95.7	0	0	0.5	0	0
	50 < p ≤ 60	0	0	0.4	0.7	88.9	0.6	0.5	0	0
	60 < p ≤ 70	0	0	0	0.7	4.4	97.1	1.5	0.7	0.9
	70 < p ≤ 80	0	0	0	0.7	4.4	1.8	96.9	0	0.3
	80 < p ≤ 90	0	0	0	0.4	0	0	0.5	98.6	0.6
	90 < p ≤ 100	0	0	0	0	0	0.6	0	0.7	98.2

Exhibit 36. Classification error matrices for remote sensing component of August 2014 survey. Values are classification rates (%). For example, pixels that actually have coral cover 30–40% are correctly classified 95.7% of the time, while 1.4% of the time they are incorrectly classified as coral cover 20–30%.

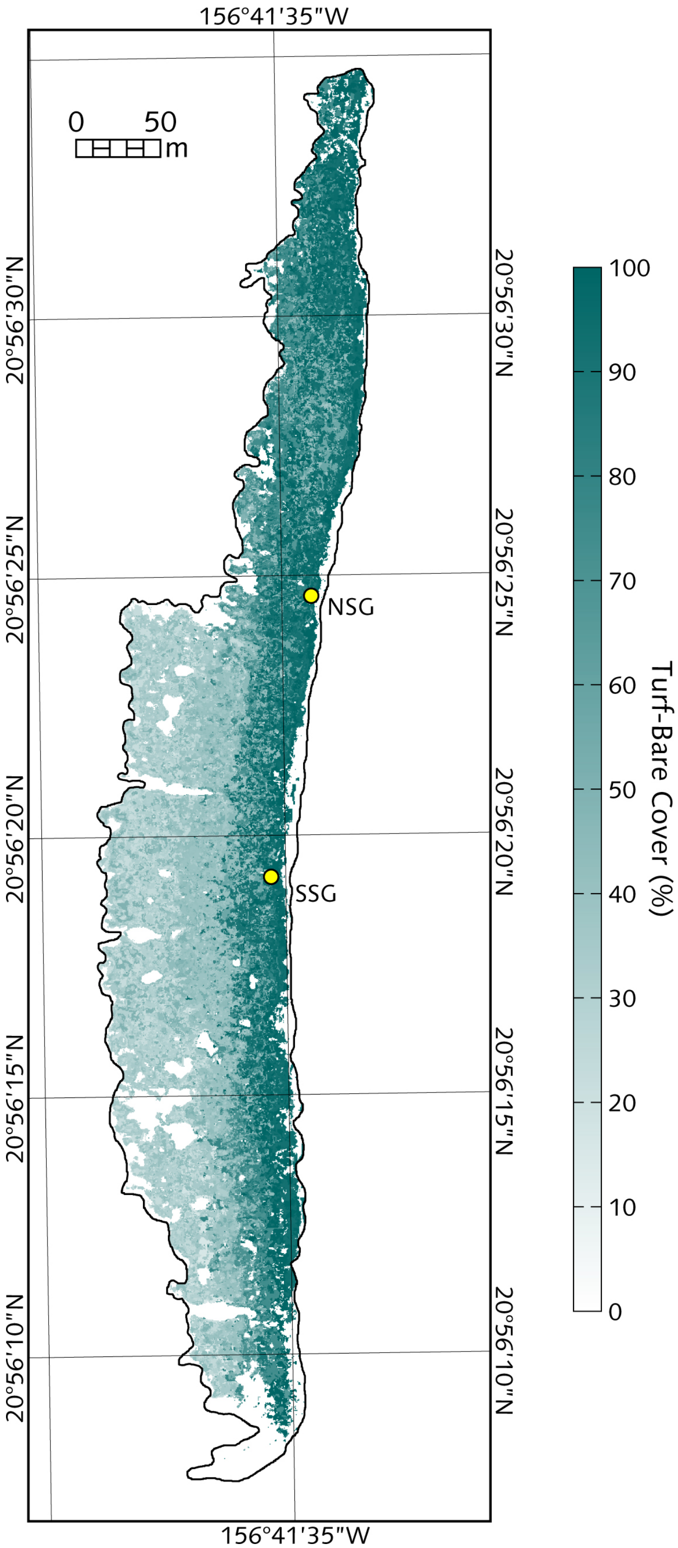


Exhibit 37. Remote sensing map product showing distribution of turf-bare cover on Kahekili reef. Seep groups are marked with yellow dots.

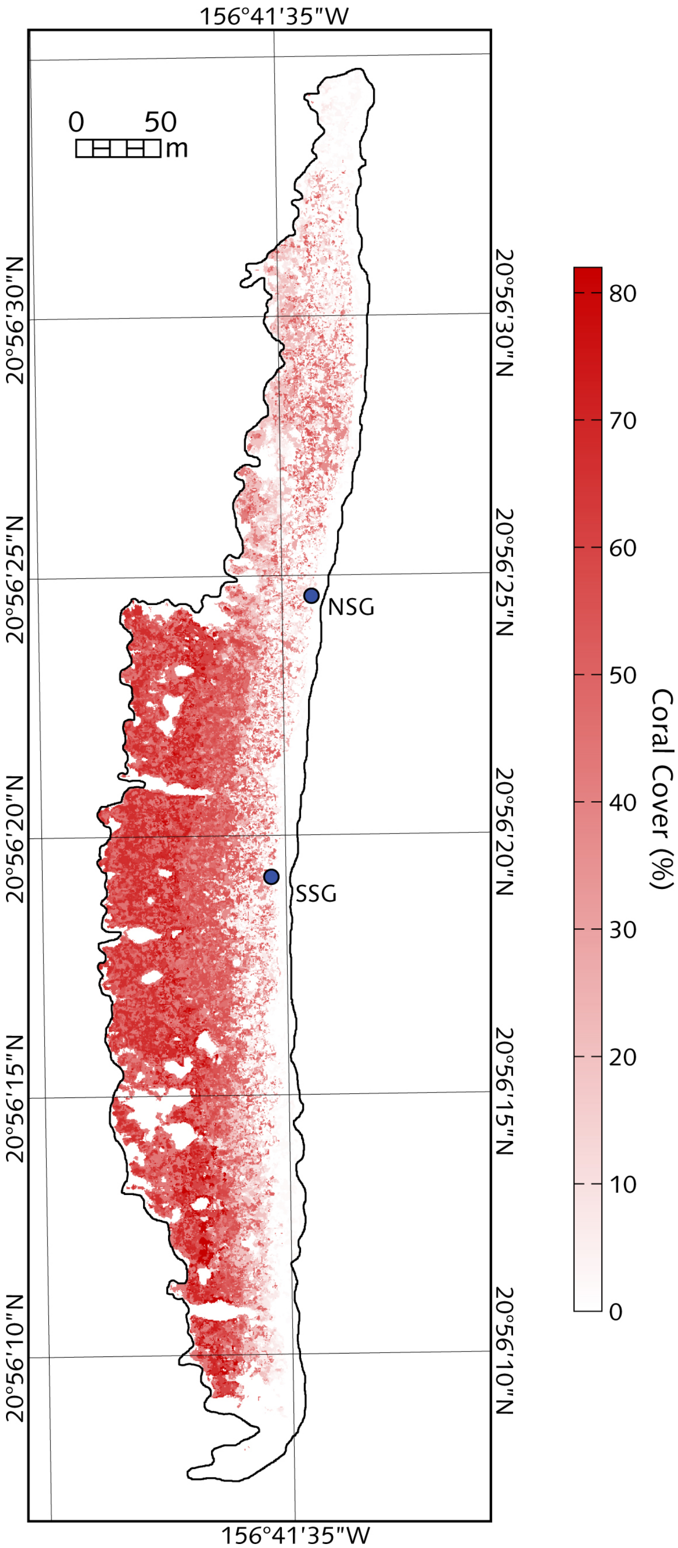


Exhibit 38. Remote sensing map product showing distribution of coral cover on Kahekili reef. Seep groups are marked with blue dots.

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WITNESS QUALIFICATIONS, INCLUDING A LIST OF PUBLICATIONS
See §1 and attached curriculum vitae.

LIST OF ALL OTHER CASES IN WHICH, DURING THE PREVIOUS FOUR YEARS, THE WITNESS TESTIFIED AS AN EXPERT AT TRIAL OR BY DEPOSITION
None.

STATEMENT OF THE COMPENSATION TO BE PAID FOR THE STUDY AND TESTIMONY IN THIS CASE
Expert will be paid $175 per hour worked for case analysis and depositions and $200 per hour worked for trial testimony.

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CURRENT RESEARCH INTERESTS

1. Ecology and bio-optics of shallow water organisms, communities, and systems
2. Organism-, community- and ecosystem-scale biogeochemical responses to stressors, especially those related to climate change
3. Connection between genetic, taxonomic, functional, and bio-optical diversity
4. Remote sensing of shallow waters for application to ecosystem studies and conservation at local, regional and global scales

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2002 PhD, Oceanography, University of Hawaii
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2008–2011 Assistant Professor, Oceanographic Center, Nova Southeastern University
2002–2008 Assistant Researcher, Hawaii Institute of Marine Biology, University of Hawaii

PUBLICATIONS (Google Scholar statistics as of January 6, 2015: Citations = 1444; h-index = 17; i10-index = 18; Times Cited in parentheses following citation)

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Book Chapters (times cited as of January 6, 2015 in parentheses following citation)

1. Phinn SR, Hochberg EM [*sic*], Roelfsema C (2013) Visible and Infrared Overview. In: Goodman JA, Purkis SJ, Phinn SR, (eds.) *Coral Reef Remote Sensing: A Guide for Mapping Monitoring and Management*. Springer, The Netherlands pp. 3-28 (1)
2. Hochberg EJ (2011) Remote sensing of coral reef processes. In: Dubinsky Z, Stambler N (eds.) *Coral Reefs: An Ecosystem in Transition*. Springer, The Netherlands pp 25-35. (7)
3. Andréfouët S, Hochberg EJ, Chevillon C, Muller-Karger FE, Brock JC, Hu C (2005) Multi-scale remote sensing of coral reefs. In: Miller RL, Castillo CED, McKee BA (eds.) *Remote Sensing of Coastal Aquatic Environments: Technologies, Techniques and Applications*. Springer, The Netherlands pp 299-317. (22)

EDITORSHIPS

2014–Pres. Associate Editor, *Frontiers in Marine Science: Coral Reef Research*

2014–Pres. Lead Guest Editor, *Remote Sensing of Environment* Special Issue for the Hyperspectral Infrared Imager (HyspIRI)

2011–Pres. *Remote Sensing of Environment* Editorial Board, Member

GRANTS AND CONTRACTS

1. *Pending* 2014–2019 CORAL: COral Reef Airborne Laboratory. Role: PI. NASA: $20,522,000.
2. 2014–2015 Marine Environmental Program FY2014–2015. Role: PI. Bermuda Department of Environmental Protection: $150,000
3. 2013–2014 Marine Environmental Program FY2013–2014. Role: PI. Bermuda Department of Environmental Protection: $150,000
4. 2012–2017 Continued assessment of the marine environment and coral reefs in the vicinity of the Seabright Point sewage outfall. Role: PI. City of Hamilton, Bermuda: $280,436
5. 2012–2013 Assessment of benthic and fish community response to removal of thruster walls at Heritage Wharf, Dockyard, Bermuda. Role: PI. Bermuda Ministry of Public Works: $26,882
6. 2012–2013 Marine Environmental Program FY2012–2013. Role: PI. Bermuda Department of Environmental Protection: $150,000
7. 2011–2012 Marine Environmental Program FY2011–2012. Role: PI. Bermuda Department of Environmental Protection: $150,000
8. 2011–2012 Guantánamo, Cuba marine surveys and photomosaicking technology evaluation. Role: PI. US Navy via TEC: $100,347
9. 2010 HyspIRI Sun Glint Sub-Group (Chair Activities). Role: PI. NASA/JPL: $12,408
10. 2010–2011 Coral reef resource surveys for Apra Harbor and four watersheds in southwestern Guam in support of the Marine Corps relocation to Guam. Role: PI. US Navy via TEC: $252,858
11. 2009–2010 Assessment of benthic community structure in the vicinity of the proposed turning basin and berthing area for carrier vessels nuclear (CVN) Apra Harbor, Guam. Role: PI. US Navy via TEC: $220,904
12. 2006–2008 University of Hawaii participation in the Hyperspectral Imager for the Coastal Ocean (HICO). Role: PI. ONR: $300,000
13. 2006–2007 Integration of Pacific bathymetric data: Assessment of the quality and usefulness of estimated depths derived from Ikonos satellite images when integrated with multibeam bathymetric data. Role: Co-PI (PI: JS Ferguson). NOAA: $130,000
14. 2004–2008 Empirical radiative transfer corrections for deterministic coral reef remote sensing. Role: PI. NASA: $297,790
15. 2004 Hyperspectral Imager for the Coastal Ocean (HICO) Coral Reef Mapping. Role: Co-PI (PI: MJ Atkinson). ONR: $322,765
16. 2003–2005 Mapping benthic habitats of the Main Eight Hawaiian Islands. Role: Co-PI (PI: MJ Atkinson). NOAA/Science and Technology International: $1,300,000 (est.)
17. 2000–2005 CRESPO: Coral Reef Ecosystem Spectro-Photometric Observatory. Role: Graduate Assistant (PI: MJ Atkinson). NASA: $291,000
18. 2000–2003 Calibration support for Hawaiian coral reef mapping. Role: Graduate Assistant (PI: MJ Atkinson). NOAA: $273,261
19. 1998–2001 Hyperspectral remote sensing of coral reefs in a tropical estuary. Role: Graduate Assistant (PI: MJ Atkinson). NASA: $225,998

INVITED LECTURES

1. 2010 – Using Remote Sensing and Optics to Study Coral Reef Ecology and Biogeochemistry. Florida International University, October 27
2. 2009 – Using Remote Sensing and Optics to Study Coral Reef Ecology and Biogeochemistry. Smithsonian Marine Station, February 6

3. 2008 – Reef Assessment Using Remote Sensing and In Situ Optics. Southeast Florida Coral Reef Initiative Technical Advisory Committee, November 6
4. 2007 – Coral Reefs and Light. Carnegie Institute of Washington, Department of Global Ecology, Stanford University, November 6
5. 2005 – Coral Reefs: Views from 4 mm to 400 km. NASA Ames Research Center, July 11

CONFERENCE PAPERS AND PRESENTATIONS

1. 2014 – Hochberg EJ. Seasonally variable coral pigment response to and anticipation of changes in temperature and light. Ocean Optics XXII, Portland, ME, October 26–31
2. 2014 – Hochberg EJ. Light-use efficiency for coral reefs. 2014 Ocean Sciences Meeting, Honolulu, HI, February 23–28
3. 2013 – Hochberg EJ. Spectral Imaging of Coral Reefs: Inversion, Classification, & Modeling Ecosystem Function. 2013 HyspIRI Science and Application Workshop, Pasadena, CA, October 15–17
4. 2013 – Hochberg EJ. Coral Reef Products for HyspIRI. 2013 HyspIRI Science Symposium, NASA Goddard Space Flight Center, Greenbelt, MD, May 29–30
5. 2012 – Hochberg EJ. Hyperspectral remote sensing of coral reefs: Inversion, classification, and modeling ecosystem function. International Geoscience and Remote Sensing Symposium, Munich, Germany, July 22–27
6. 2012 – Hochberg EJ. Optical indices for coral pigments and reef community light-use efficiency. 12th International Coral Reef Symposium, Cairns, Australia, July 9–13
7. 2011 – Hochberg EJ. Coral Reef Remote Sensing Science Objectives and Requirements. 2011 HyspIRI Science Workshop, Washington, D.C., August 23–25
8. 2011 – Hochberg EJ, et al. Characterization of Glint and Its Impact on HyspIRI Aquatic Science. 2011 HyspIRI Science Workshop, Washington, D.C., August 23–25
9. 2011 – Hochberg EJ. Coral Reefs, Climate Change, and Remote Sensing. 2011 HyspIRI Science Symposium, NASA Goddard Space Flight Center, Greenbelt, MD, May 17–18
10. 2010 – Hochberg EJ. HyspIRI Sunglint Subgroup: Glint Characterization, Determination of Impacts on Science, and Potential Mitigation Approaches. 3rd HyspIRI Science Workshop, Pasadena, CA, August 24–26
11. 2010 – Hochberg EJ. Remote Sensing of Productivity and Calcification of the Florida Keys Reef Tract. International Geoscience and Remote Sensing Symposium, Honolulu, HI, July 25–30
12. 2010 – Hochberg EJ, Dollar SJ. A Coral Reef Habitat Index Derived from Satellite Multispectral Imagery and LIDAR Data. 2010 Ocean Sciences Meeting, Portland, OR, February 22–26
13. 2009 – Hochberg EJ. Sun Glint Correction + HyspIRI for Coral Reef Science. 2nd HyspIRI Science Workshop, Pasadena, CA, August 11–13
14. 2009 – Dunagan S, Baldauf B, Finch P, Guild L, Hochberg E [*sic*], Jaroux B, Johnson L, Lobitz B, Sandor-Leahy S, Shepanski J. Small Satellite and UAS Assets for Coral Reef and Algal Bloom Monitoring. 33rd International Symposium on Remote Sensing of the Environment, Stresa, Italy, May 4–8
15. 2008 – Hochberg EJ, Atkinson MJ. Remote Sensing of Coral Reef Biogeochemistry Based on Optical Absorptance and Light-Use Efficiency. 11th International Coral Reef Symposium, Ft. Lauderdale, FL, July 7–11
16. 2007 – Hochberg EJ. Coral reef benthic productivity based on optical absorptance and light-use efficiency. Ocean Color Research Team Meeting, Seattle, WA, April 11–13
17. 2006 – Hochberg EJ, Atkinson MJ. Water Column Radiative Transfer Compensations for Coral Reef Remote Sensing. Joint Workshop on NASA Biodiversity, Terrestrial Ecology, and Related Applied Sciences, University of Maryland, Adelphi, MD, August 21–25

18. 2004 – Mosher TJ, Mitchell ML, Lucey PG, Hochberg E [*sic*]. Hyperspectral Imaging of Coastal Regions from the ISS. Fourth International Asia-Pacific Environmental Remote Sensing Symposium, Honolulu, HI, November 8–12
19. 2004 – Hochberg EJ, Apprill A, Atkinson MJ, Bidigare RR. Bio-optical modeling of photosynthetic pigments in corals. Ocean Optics 17, Fremantle, Australia, October 25–29
20. 2004 – Hochberg EJ, Apprill A, Atkinson MJ, Bidigare RR. Bio-optical modeling of photosynthetic pigments in corals. 10th International Coral Reef Symposium, Okinawa, Japan, June 28–July 2
21. 2004 – Hochberg EJ, Atkinson MJ. Spectral reflectance of coral, algae and sand and implications for coral reef remote sensing. Ocean Research Conference, Honolulu, HI, February 15–20
22. 2003 – Hochberg EJ. Sea surface glint correction for high resolution images of aquatic environments. 30th International Symposium on Remote Sensing of Environment, Honolulu, HI, November 10–14
23. 2002 – Hochberg EJ. Capabilities of remote sensors to classify basic coral reef community-types. 7th International Conference on Remote Sensing of Marine and Coastal Environments, Miami, FL, May 20–22
24. 2000 – Hochberg EJ, Atkinson MJ. Spectral reflectance characteristics of coral reef benthic communities. 9th International Coral Reef Symposium, Bali, Indonesia, October 23–27
25. 1998 – Hochberg EJ, Atkinson MJ, Holasek RE. Airborne hyperspectral remote sensing of a coral reef in Kaneohe Bay, Oahu, Hawaii. 5th International Conference on Remote Sensing for Marine and Coastal Environments, San Diego, CA, October 5–7

PROJECTS AND REPORTS

1. Hochberg EJ (2014) Evaluation of NOAA-CRED benthic monitoring data for Kahekili, Maui, Hawaii. Prepared for County of Maui
2. Hochberg EJ, Noyes T (2013) Continued Assessment of the Marine Environment and Coral Reefs in the Vicinity of the Seabright Point Sewage Outfall: Year 1 Report. Prepared for the Corporation of Hamilton, Bermuda
3. Hochberg EJ (2013) Assessment of Benthic and Fish Community Response to Removal of Thruster Walls at Heritage Wharf, Dockyard, Bermuda. Prepared for Bermuda Ministry of Works and Engineering
4. Hochberg EJ (2012) Coral Reef Surveys at Guantánamo Bay Naval Station, 2011 and 2012. Prepared for CardnoTEC, Inc. and Dept. of the Navy, Scientific Diving Service
5. Hochberg EJ, Bruce CF, Green RO, Oaida BV, Minnett PJ, Muller-Karger FE, Gentemann C, Mobley CD, Zimmerman RC, Park YJ, Turner W, Goodman J, Gao BC, Knox RG, Middleton EM, Turpie KR, Ungar S (2011) HyspIRI Sun Glint Report. Prepared for Jet Propulsion Laboratory, National Aeronautics and Space Administration
6. Dollar SJ, Hochberg EJ (2010) Mitigation site surveys and evaluations of watersheds of southwestern Guam and Apra Harbor; Assessment of Coral Reef Resources. Prepared for TEC, Inc. and Dept. of the Navy, Navy Facilities Engineering Command, Pacific Base Development
7. Dollar SJ, Hochberg EJ (2009) Assessment of Benthic Community Structure in the Vicinity of the Proposed Turning Basin and Berthing Area for Carrier Vessels Nuclear (CVN) Apra Harbor, Guam. In: Habitat Equivalence Analysis and Supporting Studies. Prepared for TEC, Inc. and Dept. of the Navy, Navy Facilities Engineering Command, Pacific Base Development

PEER REVIEW ACTIVITIES (2000-2014, number of reviews in parentheses if greater than one)

Journals/Conference Proceedings (107 Total)

- 9th International Coral Reef Symposium
- 11th International Coral Reef Symposium
- *Bulletin of Marine Science* (4)
- *Canadian Journal of Remote Sensing*
- *Coral Reefs* (18)
- *Environmental Biology of Fishes*
- *Galaxea*
- *Geocarto*
- *Global Ecology and Biogeography*
- *IEEE Transactions on Geoscience and Remote Sensing* (3)
- *Indian Journal of Marine Science*
- *International Journal of Remote Sensing* (11)
- *ISPRS Journal of Photogrammetry and Remote Sensing*
- *Journal of Applied Remote Sensing* (3)
- *Journal of Experimental Marine Biology and Ecology* (3)
- *Journal of Geophysical Research - Planets* (2)
- *Journal of Sedimentary Research*
- *Limnology and Oceanography* (2)
- *Limnology and Oceanography: Methods*
- *Marine Ecology-Progress Series* (3)
- *Marine Pollution Bulletin*
- *Methods in Ecology and Evolution*
- *Photogrammetric Engineering and Remote Sensing* (3)
- *Remote Sensing* (2)
- *Remote Sensing of Environment* (38)

Research Proposals (50 Total)

- Australian Research Council (3)
- International Foundation for Science
- Marine Science and Technology Foundation (6)
- NASA Postdoctoral Program
- National Aeronautics and Space Administration (23)
- National Oceanic and Atmospheric Administration (2)
- NOAA Undersea Research Center
- National Oceanographic Partnership Program (6)
- National Park Service
- National Science Foundation (3)
- Schmidt Ocean Institute (2)
- University of Hawaii Sea Grant College Program

PROFESSIONAL SERVICE, SOCIETIES AND ACTIVITIES

2010	NIMBioS Investigative Workshop: Modeling Reef Ecosystems, 21–23 July, Knoxville, TN
2009–2011	Chair of the HyspIRI Sunglint Subgroup
2009	EPA Coral Reef Decision Makers Workshop, 17–18 June, Key West, FL
2008	Awarded NASA Senior Fellow (declined due to conflicting schedule)
2008	NASA Coastal Habitats Workshop, 5–7 August, UC at Santa Barbara
2007	NASA Ocean Color Research Team Meeting, 11–13 April, Seattle
2001–2006	World Bank/Global Environment Fund Coral Reef Targeted Research Working Group on Remote Sensing, Member

PROFESSIONAL SOCIETIES

2007–Pres.	American Geophysical Union, Member
2005–Pres.	American Society of Limnology and Oceanography, Member
2004–Pres.	International Society for Reef Studies, Member