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Technical Report 189

Baseline assessment of the coral reef habitat in Kaloko-Honokōhau National Historical Park adjacent to the proposed Honokohau Harbor expansion and development, Kona Kai Ola, 2006-2007

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ABSTRACT

Coral reefs are ecologically and economically important ecosystems, but highly susceptible to impacts of coastal development and, therefore, indicative of environmental degradation. A detrimental impact of coastal development is the stimulation of a benthic community shift to algal dominance from coral dominance. To identify reef degradation before it has advanced too far to be readily reversed, it is important that a sound monitoring program is initiated and maintained, and that procedures are in place to rapidly take mitigation measures if coral-reef condition metrics indicate negative change. In 2006, at the southern boundary of Kaloko-Honokōhau National Historical Park, 530 acres of public land were proposed to be developed into a mixed-use development that includes an almost 300% expansion of the existing Honokohau Small Boat Harbor. This proposed large-scale development has the potential to affect cultural and natural resources in Kaloko-Honokōhau NHP. A baseline study of the reefs in the vicinity of Honokohau Harbor was undertaken in order to generate a reliable and comprehensive assessment of the current (pre-harbor expansion) condition of the benthic communities within the Park. The study is comprised of three coral reef areas close to the Honokohau Small Boat Harbor and two reference sites presumed to be unaffected by onshore development. An overview of the current state of the benthic habitat for each site is presented, focusing on coral cover, algal cover, species composition, coral health, and macro-invertebrate abundance. Average coral cover across all sites was 47.4% ± 6.4 SD and macroalgae were virtually absent (<0.5%). Coral cover at the five sites ranged between 31% and 58%, which is well within the range typically found on the west coast of Hawai‘i. Dominant macro-invertebrates were large urchins, which are important herbivores. Additionally, individual coral colonies were identified to monitor coral mortality. A similar study is being conducted at the northern boundary of the Park where a residential development and a golf course are under construction. The results of both studies will be comparable, and provide baseline useful in monitoring for potential impacts of these nearshore developments.

INTRODUCTION

Threats to Coral Reef Ecosystems

A healthy reef is a complex three-dimensional structure providing habitat, food and shelter for numerous marine species (Connell 1978), and, as such, they sustain biodiversity and boost the local economy through dive/snorkel tourism and fishing (Cesar and Beukering 2004). Coral reefs also protect shorelines and coastal inhabitants from high seas and severe storms. Reefs are under threat of natural and anthropogenic impacts (Wilkinson 2004). Natural threats include global warming, which can result in bleaching of the corals as they loose their associated zooxanthellae. Bleaching occurred on Hawaiian reefs in 2005, which co-existed with an abnormal high ocean temperature (Jokiel and Brown 2004). Anthropogenic impacts are commonly identified as a major contributor to the observed global decline of coral reef ecosystem health (Bruckner et al. 2005). Coral reefs are at the receiving end of watersheds and are therefore subject to multiple threats from both land-use practices in the adjacent watersheds and from coastal developments and activities that provide easier access to exploitable marine resources (Waddell 2005). Significant impacts of onshore development on coral reefs would likely arise through some combination of increased terrestrial run-off, increased input of nutrients (in terrestrial run-off or in groundwater), and/or reduction in number of reef herbivores (e.g. the grazing fish and invertebrates that help to maintain the competitive advantage of corals over potentially overgrowing algae). Direct effects of terrestrial runoff (e.g., sediments, nutrients, contaminants, and freshwater inputs) have been identified as among the most significant threats to Pacific marine habitats (Birkeland 1997, Porter et al. 2005, Fabricius 2005). Land-derived sediments and associated increases in the input of nutrients and pollutants can lead to increased coral mortality (e.g. Nowlis et al. 1997), decreased coral growth (Fabricius 2005), shallower depth distribution limits (Fabricius 2005) and reduced coral recruitment (Fabricius 2005). Reefs have some resistance against detrimental effects from terrestrial run-off and have some degree of resilience after exposure to natural events. However, once deterioration sets in and is not halted in time, recovery may be impossible (Williams et al. 2007a).

Macroalgal growth is influenced by both nutrients (resources) and grazing pressure (consumers) (Littler and Littler 1984, Smith et al. 2001, Thacker et al. 2001). Nutrients are typically low in coral reef ecosystems, and groundwater is an important source for supplying new nutrients (Street et al. 2008). A change in nutrient concentration in the groundwater could therefore have serious impacts to coral reef ecosystems by promoting algal growth, potentially leading to harmful algal blooms (Smith and Smith 2006). While increased nutrients and reduced grazer populations are both important contributors to algal blooms, a recent meta-analysis of nutrient-enrichment and herbivore-reduction manipulative studies concluded that the effects of a decline in herbivores has tended to be stronger than the effect of nutrient enrichment, and therefore that a reduction of herbivores has greater potential than eutrophication to drive coral-to algal-phase shifts (Burkepile and Hay 2006). However, both are potentially of concern.

The NPS has a clear mandate for coral reef monitoring and management. On July 11, 1998 President Clinton signed Executive Order 13089 – Coral Reef Protection. This executive order mandated all federal agencies to provide for implementation of measures needed to research, monitor, manage, and restore affected ecosystems, including, but not limited to, measures reducing impacts from pollution, sedimentation, and fishing. The US Coral Reef Task Force was established in 1998 followed by the passage of the Coral Reef Conservation Act in 2000. In the State of Hawaiʻi, coral reef monitoring and management is also a priority. In 1998, the Hawaiʻi Coral Reef Initiative Research program was established to conduct public awareness programs on threats to coral reef ecosystems and in 2004 Hawaiʻi Division of Aquatic Resources (DAR) launched the outreach campaign, "Hawaiʻi's Living Reef" Program. Within the National Park system, the Inventory and Monitoring (I&M) Program has selected Marine Benthic Communities as a "Vital Sign" for long term monitoring in all the parks of the Pacific Island Network (Brown et al. 2006). The NPS has a mandate to protect the natural and cultural resources within Kaloko-Honokōhau National Historical Park including its coastal waters with nearshore coral reef ecosystems. The long-term monitoring by the I&M program will complement the park management efforts by establishing monitoring programs for benthic communities, fish communities, and water quality. These programs will compile solid baseline data, be able to reliably detect change, and will be comparable with other parks in the Pacific Islands (NPS 2014a, 2014b).

Documented Phase Shifts or State Changes on Hawaiian Coral Reefs

Degradation of nearshore resources in Hawaiʻi is a growing concern (Friedlander et al. 2005). While local causes of degradation vary on a case-by-case basis, factors assumed to have led to declines include anthropogenic impacts from coastal development (increased sedimentation, nutrients and pollution), and severe reduction of herbivores on the reefs (Friedlander et al. 2005). Spatial and temporal variation in Hawaiian coral reef communities is being monitored by the Hawai‘i Coral Reef Assessment and Monitoring Program (CRAMP), which has been monitoring 60 permanent reef sites since 1999. Temporal trends from 1999 to 2002 showed a decline in coral cover at the islands of O‘ahu and Maui where human population density is high, and at Moloka‘i where inadequate watershed management has led to extreme erosion and sedimentation of the reefs (Jokiel et al. 2004). Coral cover over that time period stayed approximately the same at Hawai‘i Island where human population is relatively low, and at Kaho‘olawe Island, where a re-vegetation program was implemented and all grazing animals were removed. At the island of Kaua‘i, also with relatively low human population, coral cover increased between 1999 and 2002 (Jokiel et al. 2004). Similarly, a recent summary of CRAMP and Hawai‘i DAR’s nine long-term monitoring sites around Maui Island revealed that nearly a quarter of all living coral has been lost over the previous decade, with strong indications that human impacts have been responsible. The study found that coral cover consistently declined adjacent to populated areas, but that remote or offshore sites showed increased or sustained high coral cover over the length of the study (Williams et al. 2007b).

Blooms of alien invasive algal species are now a major concern on all of the populated Main Hawaiian Islands with the exception of Big Island (Rodgers and Cox 1999, Conklin and Smith 2005, Smith et al. 2002). The seriousness of invasive algal blooms is demonstrated by several highly visible and costly cases in O‘ahu, and west and central Maui—in the latter of which, blooms of *Hypnea musciformis* adjacent to Kīhei beaches have been estimated to cost Maui County $20 million per year through direct clean-up costs and loss of revenue from degraded habitats (Carlton 2001, Cesar and Beukering 2004). The most thoroughly documented case study of reef decline in Hawai‘i comes from Kāne‘ohe Bay on the island of O‘ahu, where increased nutrient-rich sewage discharge into the bay facilitated the growth of the macroalga *Dictyosphaeria cavernosa*, resulting in a coral to algal phase shift (Smith et al. 1981, Jokiel et al. 1993, Stimson and Larned 2000).

Vulnerability of a reef to detrimental effects from terrestrial run-off is related to the physical, hydrodynamic, spatial and biological properties of the area (Fabricius 2005). For example, enclosed bays (e.g. Kāne‘ohe Bay) and wide shallow areas with poor circulation (e.g. Kīhei shallow reefs) tend to retain pollutants and nutrients, and have more potential for regular re-suspension of sediments (Smith et al. 1981). Herbivorous fish populations are, as described above, another key factor affecting reef condition. The degraded reefs in O‘ahu are heavily overfished, hence have very low grazer populations and that have almost certainly contributed to those reefs’ vulnerability to algal blooms (Williams et al. 2007a). On the west coast of Hawai‘i, fish populations remain relatively healthy, most reef areas are close to deep waters, and there are strong currents in nearshore waters (Presto et al. 2007), all factors that have probably contributed to West Hawai‘i reefs resistance and resilience to degradation. However, coastal developments are increasing on Hawai‘i Island, and a recent study of developments in Kohala and north Kona indicated that developments were associated with increased levels of nutrients in adjacent waters, and concluded that West Hawai‘i reefs may be approaching their tolerance level for nutrient concentrations (Wiegner et al. 2006). Already, nutrient concentrations in Honokōhau Bay have exceeded state standards for total nitrogen and nitrate-nitrogen (NO_3-N) (MRC 2000, Ziemann 2006, Department of Health 2008), and therefore there is certainly scope for any additional nutrient impacts of the proposed harbor development to lead to significant environmental impacts. Additionally, the reefs in the Harbor area are at risk from increased fishing pressure due to the proposed expansion of the harbor. Consequent decreases in herbivore stocks have the potential to stimulate coral-to-algal phase shifts.

Development around Kaloko-Honokōhau National Historical Park

The human population of Hawaiʻi Island has increased 24% between 1990 and 2000 and is predicted to increase another 46% by 2020 (CensusScope 2008). As a result of ongoing development, water withdrawal has increased since 1978 (Oki et al. 1999). At the time of this study, 13 projects (Fig. 1) are underway, planned, or proposed upslope of and in the vicinity of Kaloko-Honokohau NHP, as well as infrastructure improvements on water transmission lines, sewer systems, and roads.

Adjacent to the Park's northern boundary, a residential and golf course development is under construction. Upslope of the Park are planned and existing light industrial parks, and residential areas. A closed landfill, a metal scrap yard, and the Kealakehe wastewater treatment plant are upslope to the south. The treatment plant releases approximately 1.35 million gallons per day (mgd) of treated wastewater. The projected capacity for the plant is 5.31 mgd (Parsons et al. 2008). Adjoining the Park's southern boundary, the State of Hawaiʻi Board of Land and Natural Resources (BLNR) and the Department of Hawaiian Homelands (DHHL) provisionally approved a development agreement with Jacoby Development, Inc. (JDI) for approximately 530 acres of public land for a mixed-use development project "Kona Kai Ola" (Oceanit 2006). The proposed development would contain fifteen and a half acres of state-owned shoreline property within the Kaloko-Honokōhau National Historical Park legislated boundary (Fig. 2). The planned development would construct a new 45-acre marina basin with a minimum of 800 additional boat slips (273 exist presently), mixed light industrial, commercial and resort components, including timeshares, hotels, and interconnected water lagoons flowing out into the existing harbor. Additional research in response to comments on the draft environmental impact statement showed likelihood of detrimental impacts to the water quality and the benthic community close to the harbor due to change in hydrology as a result of the 45-acre marina basin and the proposed water features (Oceanit 2007). In the final Environmental Impact Statement, an alternative was included with a smaller scale version of the proposed marina (25 acres) with the same orientation, perpendicular to the existing harbor, and a reduction in the water features (Oceanit 2007).

Study Objectives

The NPS in cooperation with the University of Hawaii (UH) initiated a systematic baseline assessment of coral reef resources vulnerable to impacts arising from adjacent development (Marrack et al. 2014, this study). The objective of this study was to generate a baseline of the present composition and condition of the coral reef ecosystem in the proximity of the harbor. This effort includes an assessment of the abundance (percent cover of the benthic substrata) of sessile benthic macroinvertebrate (e.g., corals, sponges, urchins) and algal assemblages (including large fleshy macroalgae, crustose coralline, and turf algae) at randomly selected hard bottom sites at 10 meters depth in high coral cover areas. An additional objective was to survey current health of randomly selected individual *Pocillopora meandrina* colonies, a common coral species susceptible to water quality changes and found at all sites at similar depths.

This baseline study will serve as a comparison point for future assessment of changes in the Park's southern-area coral reef community over time and related to harbor development. Results from Marrack et al. (2014) indicate that the study design and survey methods are robust and have a good probability of correctly identifying $\geq$10% absolute change in coral cover over time.

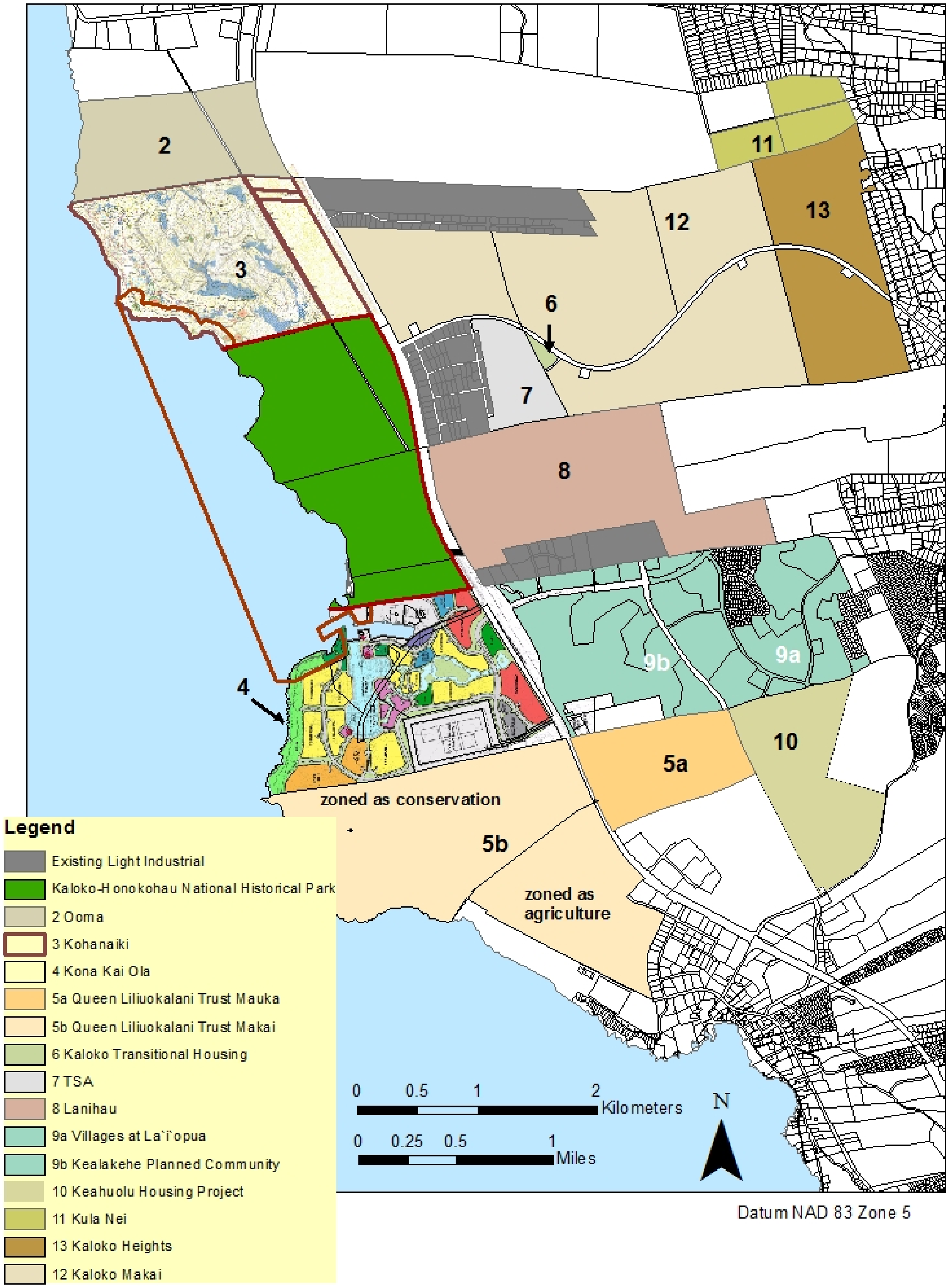

Figure 1. Planned and proposed development in the vicinity of Kaloko-Honokōhau NHP, 2007.

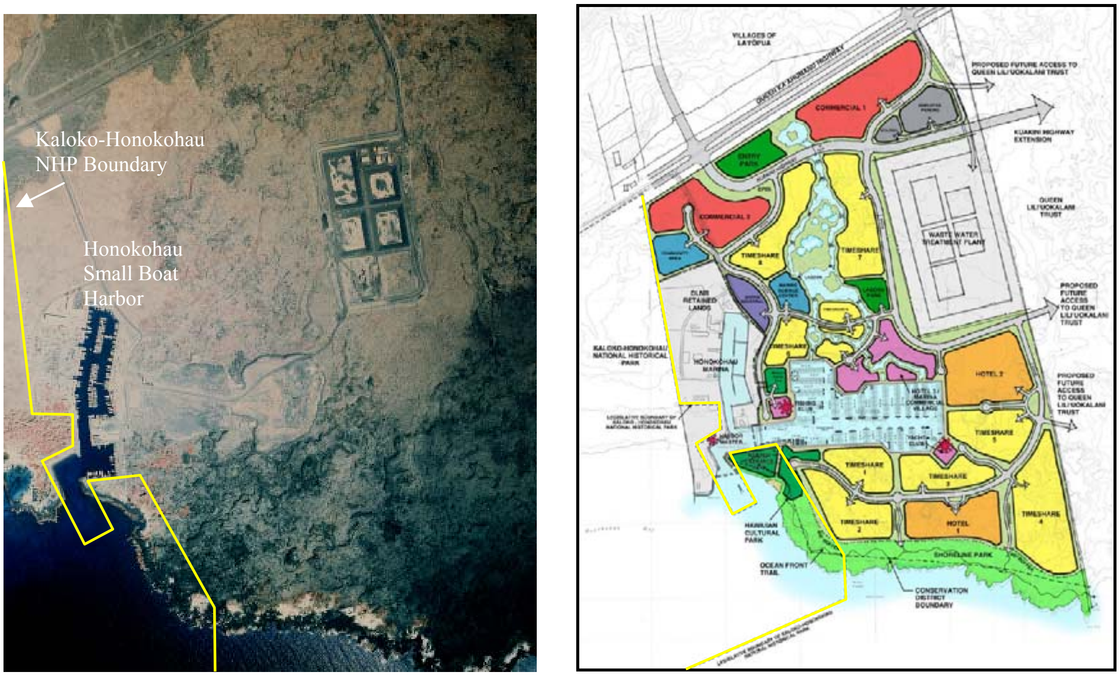

Figure 2. Left: an aerial photo downloaded from Google earth in 2006 of the current harbor area and Right: the master plan of the proposed Kona Kai Ola Marina Resort (from Oceanit 2006).

METHODS

Survey Design

The benthic survey design is based on the coral reef inventory protocols devised and tested by Virgin Islands National Park (Miller et al. 2007) and the NPS Inventory & Monitoring (I&M) Program for the Pacific Island Network (Brown et al. 2006). For the baseline study in the harbor area, we have replicated the methodology used by Marrack et al. (2014) and followed I&M protocols for macro-invertebrate surveys and coral mortality assessment. Future monitoring results will be used to identify changes to the benthic community structure over time.

The indicators selected for the baseline studies (Marrack et al. 2014, this study) are purposely the same as for the NPS Inventory and Monitoring Vital Sign Monitoring Program to facilitate compilation of datasets. They are relatively easy to measure and provide information on the condition of the reef ecosystem suitable for quantifying change over time. Indicators are benthic community, coral mortality, and macro-invertebrate abundance.

Benthic Community: Permanent photoquadrats are a precise and quantitative method to document temporal change in benthic communities (Brown et al. 2006). Archived photographs are created for future reference, and percent cover of coral and algae can be precisely determined using analytical approaches. Additionally, long-term monitoring of the abundance of different invertebrate and algal taxa or assemblages can reveal changes in community composition which are responsive to variation in certain environmental stressors or drivers. For example a shift from turf to macroalgae can be indicative of a decrease in herbivore pressure while a shift from corals to crustose coralline algae could be a sign of nutrient increase (Littler and Littler 1984).

Coral Mortality**:** Coral growth rate and survival are meaningful indicators of coral reef health and tend to be affected by water quality, thus net growth or mortality is a kind of time-integrated measure of environmental condition and therefore a potential useful indicator of stress (Lesser 2004). Any change in the extent or impact of diseases on corals would generally lead both to coral mortality and to sub-lethal effects (reduced growth, reproductive output, increased vulnerability to other stressors); hence coral condition gives useful information in additional to that generated by percent cover surveys, and has some scope for providing early warning of stress before coral mortality is too far advanced. Coral bleaching is a stress reaction caused by many factors including environmental degradation (Buchheim 1998) and ocean temperature rise due to global warming. In October 2005, bleaching occurred in West Hawaiʻi and *Pocillopora meandrina* appeared highly susceptible. *P. meandrina* is present at all study sites, and we have therefore selected this coral species as an indicator species for the coral mortality study.

Macro-invertebrate abundance: One of the dominant macro-invertebrate groups on the reefs in Kaloko-Honokōhau NHP is sea urchins. Sea urchins are herbivores and therefore help to maintain corals' competitive advantage over algae on healthy reefs. A reduced urchin population can lead to an increase in algal cover as has been observed and extensively documented in the Caribbean (e.g. Lessios et al. 1984, Hughes 1994). After the mass mortality of *Diadema antillarum,* algal abundance increased, coral cover decreased, and these degraded conditions persisted throughout the Caribbean due to a reduction in grazing pressure (Williams and Polunin 2001). Sea urchin density is therefore a good leading indicator of a possible shift in the coral-algal balance. Additionally, the crown of thorns sea star (*Acanthaster plancii*) is a coral predator. There is no reason to believe that local abundance is driven by small-scale environmental factors, but given their potentially severe impacts on coral reefs, their abundance should be monitored sufficiently, at least so that any substantial outbreaks can be detected.

Study Area

Kaloko-Honokōhau NHP's marine waters are extensively reviewed by Hoover and Gold (2005) and they give a detailed description of the water quality and associated biological resources. Here, we highlight the results of recent water quality and benthic community studies of immediate relevance to the baseline study of the harbor reefs.

Water Quality

Kaloko-Honokōhau NHP's waters are designated by the State of Hawaiʻi as Class AA pristine waters and are subject to numeric criteria for water quality parameters (HAR §11-54). As the leeward coast of Hawaiʻi has a dry climate and there are no fluvial inputs, freshwater input to the coast is almost entirely comprised of submarine groundwater discharge (Paytan et al. 2006). Data from grab samples in 2000 (MRC 2000) and 2006 (Ziemann 2006) show that state water quality standards for nitrate-nitrogen (NO_3-N) was exceeded in Honokōhau. Honokōhau Bay was listed by the State of Hawaii as an impaired water body for elevated nutrients in 2006 under section 303(d) of the Clean Water Act (Department of Health 2008). Knowledge of quantity and fate of this brackish groundwater discharge is important for predicting the input of these components (nutrients and pollutants) to the coral reef ecosystem. Radium isotope quartets have proven to be very effective tracers in the study of submarine groundwater discharge (Paytan et al. 2006).

The harbor is a prominent discharge location of subterranean groundwater (Johnson et al. 2006). With tracers and nutrient long-term studies it was found that a significant amount of groundwater builds up in the harbor, discharges through the harbor mouth into the ocean and gets distributed due to mixing in the coastal area (Presto et al. 2007, Street et al. 2008, Grossman et al. 2010, Knee et al. 2008). This groundwater proved to be an important source for new nutrients. The addition of extra nutrients resulted in high nutrient concentrations (> 6 mmol N m^{-2} d^{-1}, > 0.25 mmol P m^{-2} d^{-1}) in the nearshore ocean, an order of magnitude higher than marine waters surrounding the park (Street et al. 2008). Historical data showed that nutrients increased with the increase in population size and the subsequent land development since the 1990s, and presently cause a chronic stress to the coral ecosystem just outside of the harbor mouth (Parsons et al. 2008).

Benthic Cover

The Department of Land and Natural Resources' Division of Aquatic Resources (DAR) has established 26 monitoring sites along the west coast of Hawai'i Island. Every three to five years they conduct benthic cover photo-transect surveys with the most recent surveys prior to this study completed in 2003. DAR's survey sites are located on reef areas with relatively large amounts of *Porites compressa* cover in the 10-15 m depth range (their initial focus was on aquarium fish for which that is prime habitat). Each site has four permanent 25-m transects and per transect 25 photoquadrats are analyzed using Coral Point Count with excel extensions (CPCe) digital image analysis software developed by the National Coral Reef Institute (Kohler and Gill 2006). Mean coral cover per site in 2003 surveys ranged from 16.5% to 57.0% with a coast wide average of 37.4% (± 11% SD) (Table 1). At their Honokōhau site, which lies within our Harbor North study site, coral cover was 48.3% and turf algal cover 18.5%. The dominant coral species, by cover, across all sites surveyed by DAR was *Porites lobata* (mean cover of 22.0%) followed by *P. compressa* (10.6%), the mean cover of all other species comprised ≤ 1%. The DAR Honokōhau site had similar coral species composition. One striking result was the high octocoral cover, *Sarcothelia edmondsoni* (previously named *Anthelia sp.*), in the vicinity of Honokōhau harbor and Kailua Bay. The reason for this high cover is still unknown (Cotton 2004).

In 2005, the NPS Inventory and Monitoring program conducted benthic photo-transect and fish surveys in order to compare fish assemblages with habitat utilization patterns in Kaloko-Honokōhau, and off Pu'uhonua o Hōnaunau NHPs and two other national park units (Beets et al. 2010). Their focal groups were algal and coral cover. Random 1-m^2 quadrats were placed along a 25-m transect line and substrate type of 25 random intercept points per quadrat was identified. As their survey method comprised also of sandy areas, overall coral cover was lower than estimated by DAR who specifically surveys in high coral cover areas. In agreement with the DAR survey, octocoral cover was found to be very high (10%). Coral cover off Pu'uhonua o Hōnaunau NHP was higher than in Kaloko-Honokōhau with less sandy areas and about the same amount of turf. Macroalgae cover was higher compared with KAHO, almost 1%.

Cheryl Squair of University of Hawai'i-Mānoa Department of Botany conducted a qualitative and quantitative algal survey at 10 m and 20 m for NPS I&M program in 2006 (unpublished). From the preliminary results, we obtained a species list of algae encountered in the park and off Pu'uhonoua o Hōnaunau NHP. Appendix IV a and b includes algal species found at random

Table 1: Benthic composition results of different studies in west Hawai'i including Kaloko-Honokōhau NHP (KAHO) and Pu'uhonua o Hōnaunau NHP (PUHO). All data are % cover.

Survey Site	Coral	Turf Algae	Crustose Coralline	Macro algae	Sand	Sessile Invert	Other	Research Group
West Coast	37.4	42.0	7.0	1.5	3.1	1.6	7.4	DAR
Honokohau	48.3	18.5	6.8	0.6	1.7	11.6	12.4	DAR
KAHO	18.0	52.5	8.1	0.6	6.7	10.1	4.0	NPS-I&M
PUHO	38	50.0	7.7	0.9	3.2	0.5	0.2	NPS-I&M

sampling sites close to our transects at 10-and 20-m depths. (See Appendix Figure A4 for our transect locations and the algal survey sampling locations for the harbor area and PUHO.)

Fish

In 2005, a marine inventory survey was conducted for the NPS Inventory & Monitoring program (Beets et al. 2010) in four national park units, Kalaupapa National Historical Park on Moloka'i and Pu'ukoholā Heiau National Historic Site, Kaloko-Honokōhau NHP, Pu'uhonua o Hōnaunau NHP on the Island of Hawai'i. Apart from a marine vertebrate inventory including sea turtles and mammals, characteristics of marine fish assemblages (density, biomass, species richness, and diversity) was determined, and fish habitat utilization patterns were established. Reef fish surveys were conducted by swimming at a slow, constant speed along a 25-m transect looking 2.5 m at either side (survey area 125 m^2 per transect). Kaloko-Honokōhau and Pu'uhonua o Hōnaunau had similar fish assemblages in terms of density and abundance because of similar habitat and fishing pressure. Fish assemblages were highest at Kalaupapa probably due to habitat differences and low fishing pressure, and low at Pu'ukoholā Heiau where there are multiple anthropogenic impacts such as harbor construction and upland erosion. At Kaloko-Honokōhau and Pu'uhonua o Hōnaunau surgeon fish (Acanthuridae) and damselfish (Pomacentridae) made up the majority of the density. In Kaloko-Honokōhau the introduced ta'ape (*Lutjanus fulvus*) was the largest component of total fish biomass. This could be due to the large school (> 500 individuals) that is commonly present at the aggregate reef area (pers. obs) and will consequently heavily influence the total biomass. Few large piscivores were encountered, which was attributed to relatively high fishing pressure and corresponds with the DAR's results.

The DAR monitoring program also includes fish surveys at each of their 26 sites in West Hawai'i (DAR unpublished data). Fish surveys are conducted at least four times per year every year since 1999. At 14 of those sites, DAR conducts 'resource fish surveys', which focus on fish species that are main targets of commercial and recreational fishers. Resource-fish surveys consist of timed swims along a depth contour north and south from a fixed starting point at each site. Total area covered is generally around 240 m by 10 m per site per resource survey. Among all the DAR 'resource fish' sites along the west coast of Hawai'i Island, Honokōhau has the lowest biomass of 'resource fish'(Fig. 3 - mean of all eight surveys conducted in 2005-06). The relatively low fish stocks in the harbor area are probably due to proximity to the harbor and accessibility of the area to spear-fishers (Ivor Williams pers. comm.). The DAR data (Fig. 3) show low biomass at the Honokōhau site (indicated by arrow) compared with the other West Hawai'i sites.

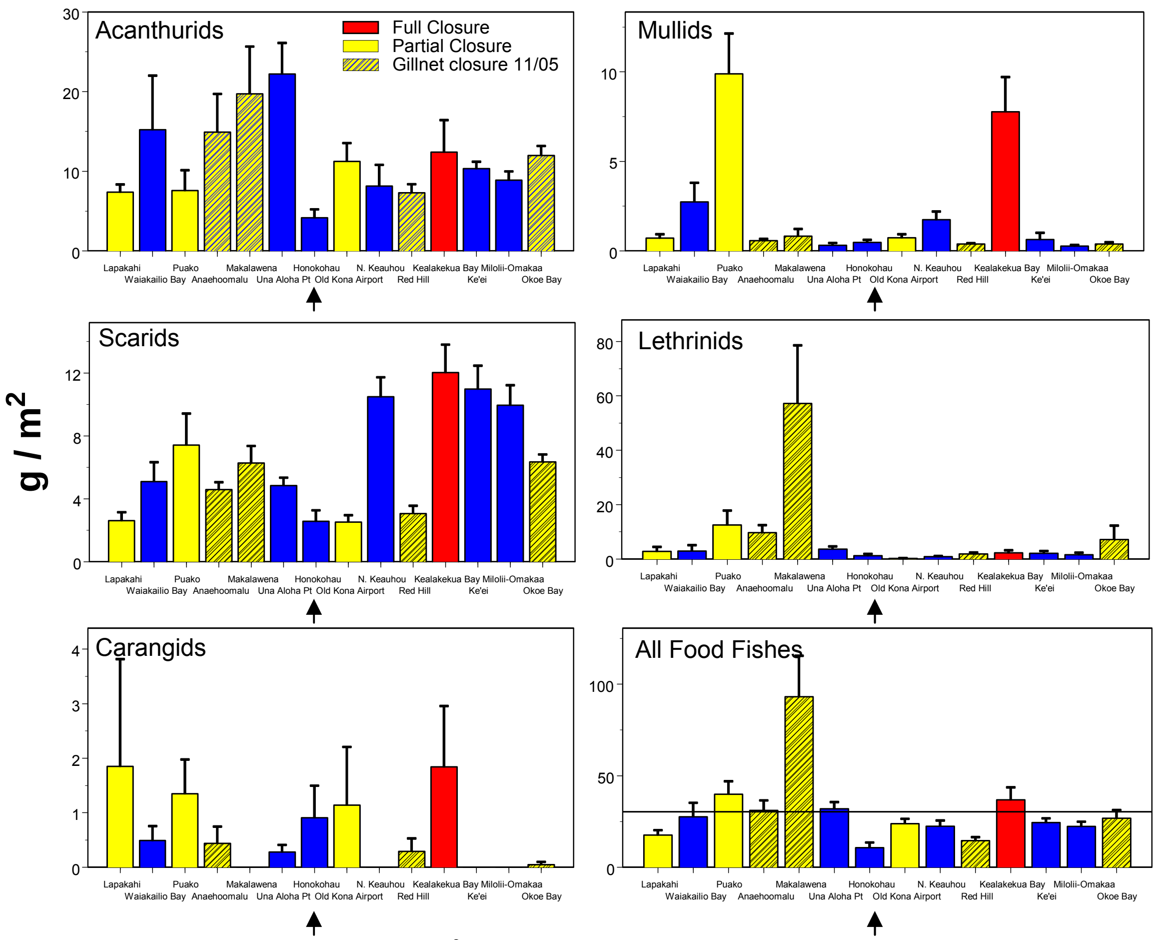

Figure 3. Mean (± SE) Biomass (g/m^2) of ‘resource fishes’ at 14 west Hawai‘i sites (x axis). Solid blue means areas open to fishing. Horizontal line in last figure represents mean biomass of all sites combined. Graph used with permission from DAR (DAR unpublished data), arrow indicates Honokōhau site located in Kaloko-Honokōhau National Historical Park.

Study Sites

Criteria to select appropriate study sites are summarized in Table 2. Based on the criteria, three sites were selected to represent the benthic habitat close to the harbor and the proposed development (Figs. 4 and 5). Control sites with a similar habitat were selected using the same criteria and are identical to those used for the baseline study in the northern portion of Park waters (Marrack et al. 2014). We are aware of the limitations these sites have as control sites, and we therefore refer to them hereafter as ‘reference sites’. Kaloko Cut Reference Site is in the central portion of the Park coastline offshore of “Kaloko Cut”, a shoreline feature south of Kaloko Fishpond where two intertidal lava-protrusions form a narrow “cut” in the coastline (Fig. 4, Fig. 6). The PUHO Reference Site is located offshore of Pu‘uhonua o Honaunau National Historical Park (Fig. 6). These reference sites have a colonized hard bottom with high coral cover at the 10-m depth contour and similar coral species composition as the study sites (Cochran et al. 2007). Kaloko Fishpond and Kaloko Cut are freshwater discharge sources. The near-surface flow is primarily oriented alongshore from south to north with a net onshore flow

(Storlazzi and Presto 2005). Development upslope of the Park will affect the groundwater quantity and quality, making this a less ideal reference site. However, this was the only site within the Park with similar habitat and as far away from current coastal development as possible. We included Pu‘uhonua o Honaunau as an additional reference site because coastal and upslope development is minimal and benthic habitat was similar (Cochran et al. 2007). Freshwater input within the study area was observed during field studies. Future data can also be compared for reference with DAR data of West Hawaii reefs as they monitor similar reef habitats (10-m depth, high coral cover) on a regular basis (every three years) and with the I&M annual benthic monitoring program that began in 2007.

Selected areas were visually inspected with snorkel gear. With a waterproof GPS unit (Trimble GeoXT in a dry bag), study site boundaries were determined and in the office, and representative polygons of the study sites were created using GIS program ArcMap 9.1 (Fig. 4). All reef areas are well defined and differ slightly in coral composition and topography and are therefore kept as separate sites. Coral cover estimates were taken from Gibbs et al. (2007) and Cochran et al. (2007), which have a 10 x 10 m resolution. The ‘Harbor South’ study area (approximately 230 m x 40 m) consists of volcanic pavement with more than 50% rocks and boulders. It is a narrow stretch of high coral cover (50 to 90%) tapering to the south. It is flanked by boulders to the east and a steep drop off to the west. There are no day-use mooring buoys and little shore diving in this area (Fig. 7 – top map). The ‘Aggregate Reef’ area is a small (approximately 90 m x 40 m) well-defined area bordered by boulders to the south (shore), a sandy channel to the east, a steep drop-off (ending at about 30-m depth) sandy area to the north, and a rubble area to the west. The main substrate is aggregate reef that is colonized by corals with an estimated cover of 90 to 100%. There are three day-use mooring buoys between the reef and the shoreline, and it is a popular site for shore diving (Fig. 7 – bottom map). The ‘Harbor North’ area stretches over a length of 420 m and a width of 70 m and borders the harbor channel to the south. It slopes off to the west and ends in a boulder area to the east. Substrate is volcanic pavement with sand channels and rubble patches. Transect lines were placed on top of ridges running perpendicular to shore, where estimated coral cover is 90 to 100%. There are four mooring buoys located in this area (Fig. 8). Kaloko Cut Reference Site at 10-m depth, is also small (approximately100 m x 40 m) and consists of volcanic pavement with an estimated 50 to 90% coral cover. Shore diving is possible but not popular and there is one mooring buoy (Fig. 6, – top map). The “PUHO Reference Site” is 1.7 km long and 125 m wide with volcanic pavement as substrate and coral cover is low (10 to 50%). Some areas have 10 to 50% rocks and boulders. There are no mooring buoys but some boat diving, anchoring, and snorkeling occurs (Fig. 6– bottom map).

To document the present benthic community composition in the study areas, video tracks at each study site were made about 1 to 1.5 m above the substrate using a Sony PC 110 digital video camera recorder in a Mako PC 110 underwater housing with a GPS unit on the surface to follow the approximate path of the video track. Photos of the reef taken at oblique angles from each transect pin were also taken as overall impressions of the reefs at study sites.

Information on dive-use areas was determined based on proximity to mooring buoys and responses of 11 dive boat operators asked during informal interviews to rank study-area use by divers on a scale from 1-3 (light, moderate, heavy). We then ranked each transect site as low (1), medium (2), or high (3) diver impact, depending on the number of divers, the frequency of dive boats visiting that area, and the proximity to mooring buoys.

Table 2. Criteria for selecting study sites for the Harbor Baseline Benthic Survey.

Criteria	Comment
Proximity to proposed project area	The areas closest to the harbor mouth are likely most vulnerable to environmental impacts of the harbor expansion development.
High groundwater intrusion	Known points of outflow based on local knowledge, infrared aerial images and ongoing studies by the United States Geological Survey (USGS) and Stanford University were located. The prevailing nutrient-rich surface net flow in front of the harbor mouth runs alongshore from south to north (Storlazzi and Presto 2005) so a reef site north of the harbor was included. Based on the lay-out of the proposed development (Fig. 2) and a net southeast deep water flow, a reef area parallel to the new marina, north-south oriented was included.
High (>50%) coral cover	Detailed (10 x 10 m resolution) Benthic Habitat Maps created by USGS (Gibbs et al. 2007, Cochran et al. 2007) showed distinctive reef zones categorized by substrate and colonization. This map aided in the selection of homogeneous areas representative of reef zones categorized as volcanic pavement with more than 50% estimated coral cover at 10 m depth.
Low diver use	Diver use areas have been determined by proximity to popular mooring buoys and interviews with dive boat operators.

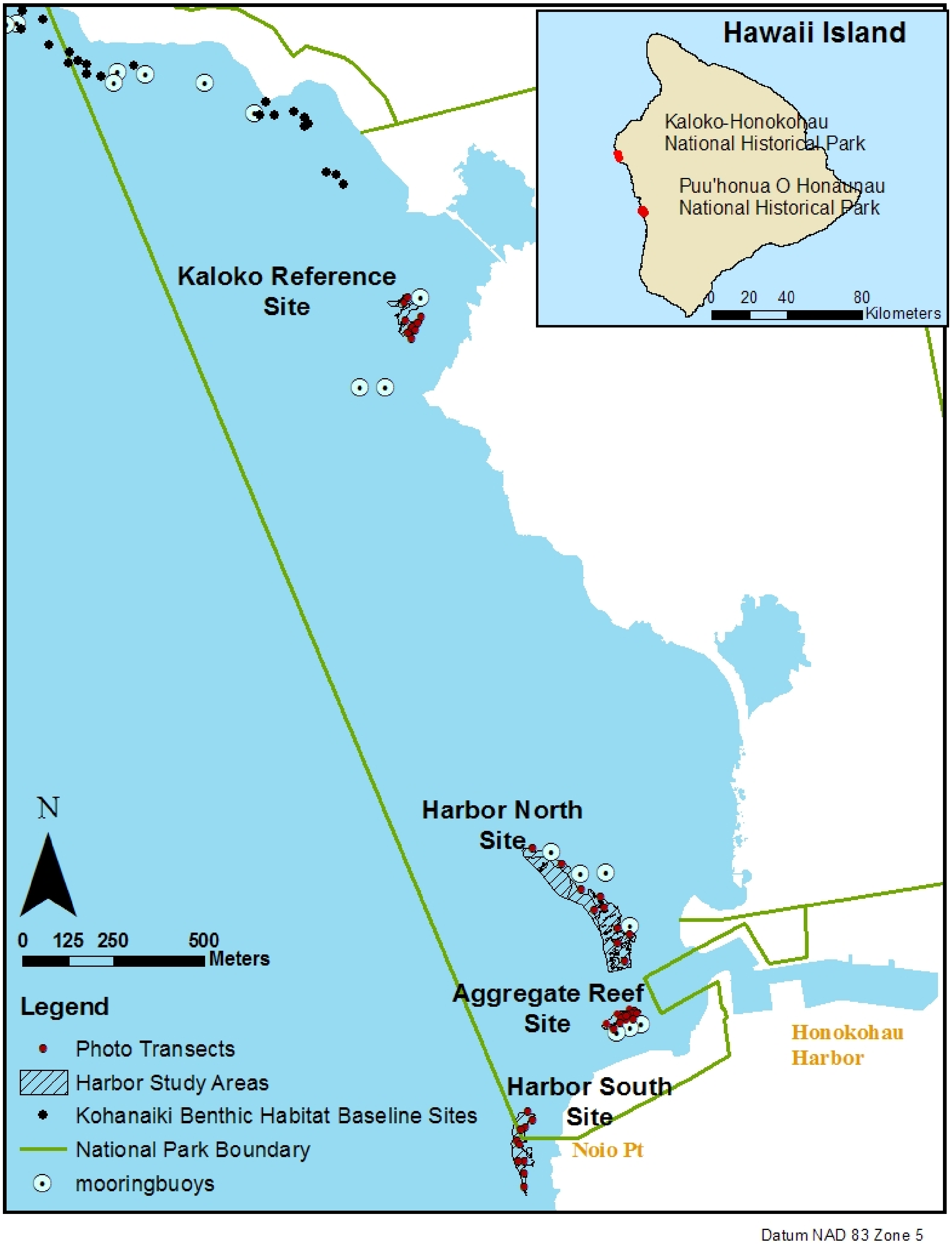

Figure 4. Selected study areas based on benthic habitat characteristics and random sampling locations for harbor benthic monitoring survey in Kaloko-Honokōhau National Historical Park, 2006-2007. Black dots in the northern part of the Park are the random sampling locations for the Kohanaiki benthic baseline survey (see Marrack et al. 2014).

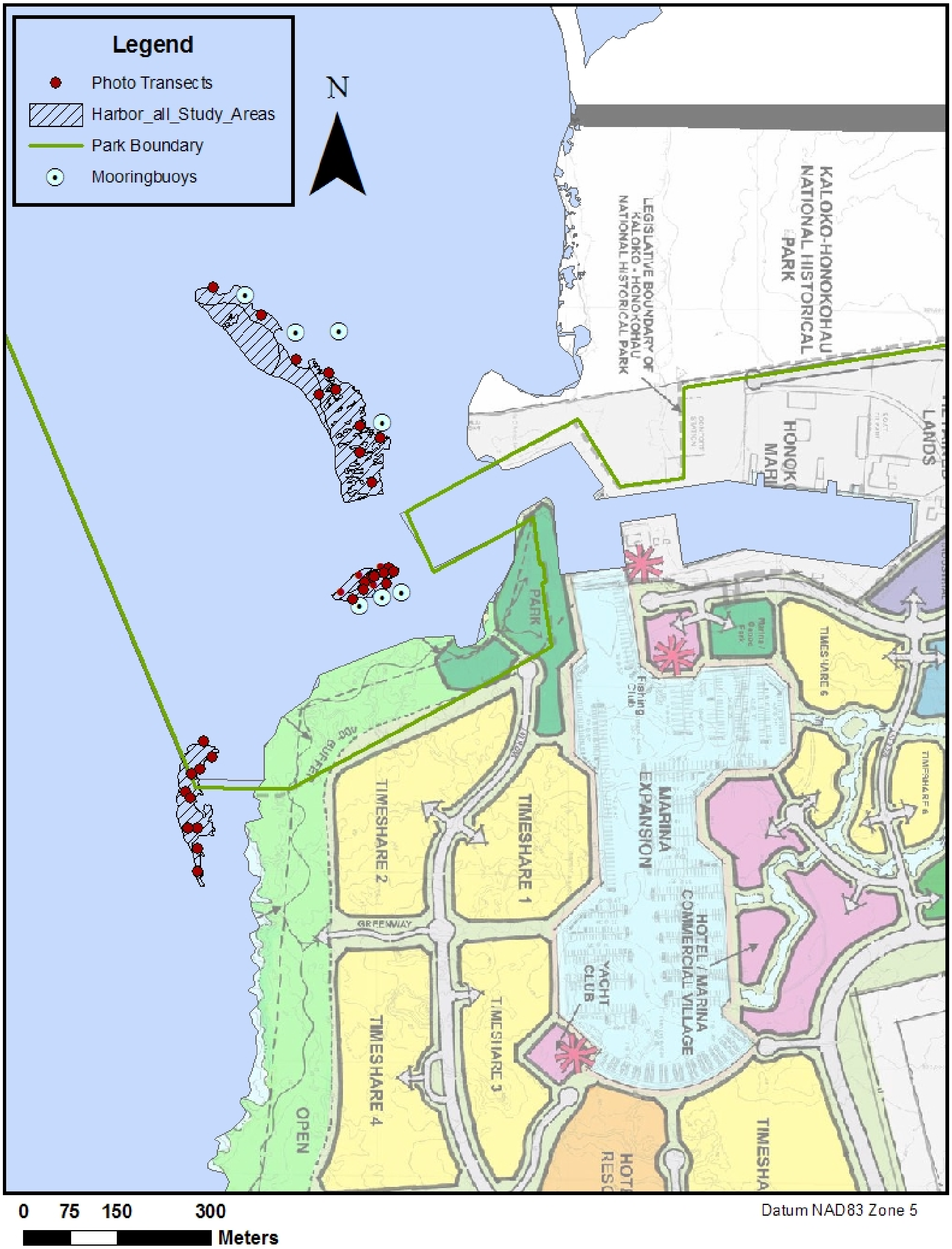

Figure 5. Selected study areas based on benthic habitat and random sampling locations for 2006-2007 harbor benthic monitoring survey in Kaloko-Honokōhau National Historical Park, in relation to the conceptual plan (Oceanit 2006) for the proposed harbor development Kona Kai Ola.

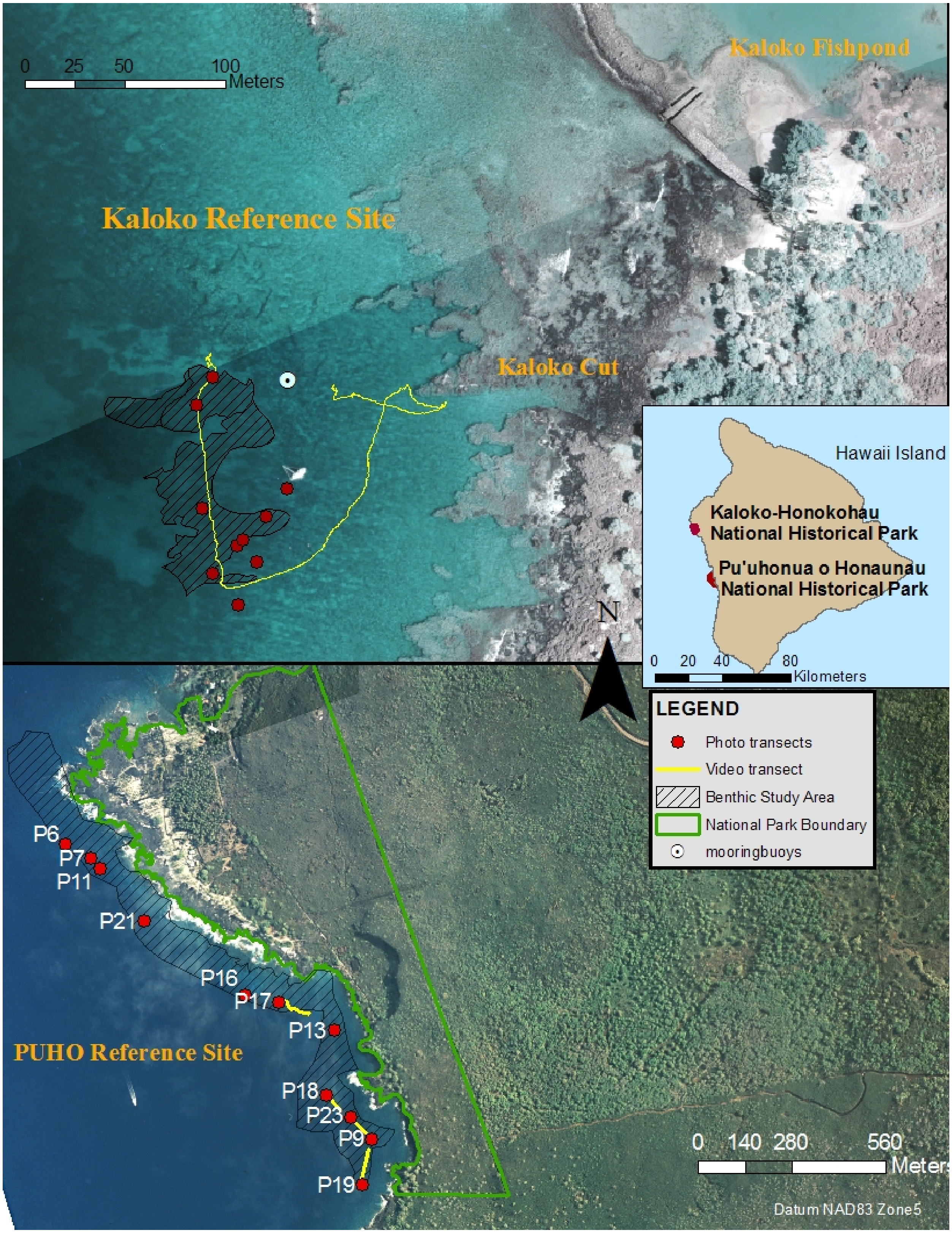

Figure 6. Kaloko Cut and Pu'uhonua o Hōnaunau NHP (PUHO) reference sites of benthic harbor survey with respectively 10 and 11 fixed random sampling locations at 10-m depth (2006 - 2007) and video track (2007).

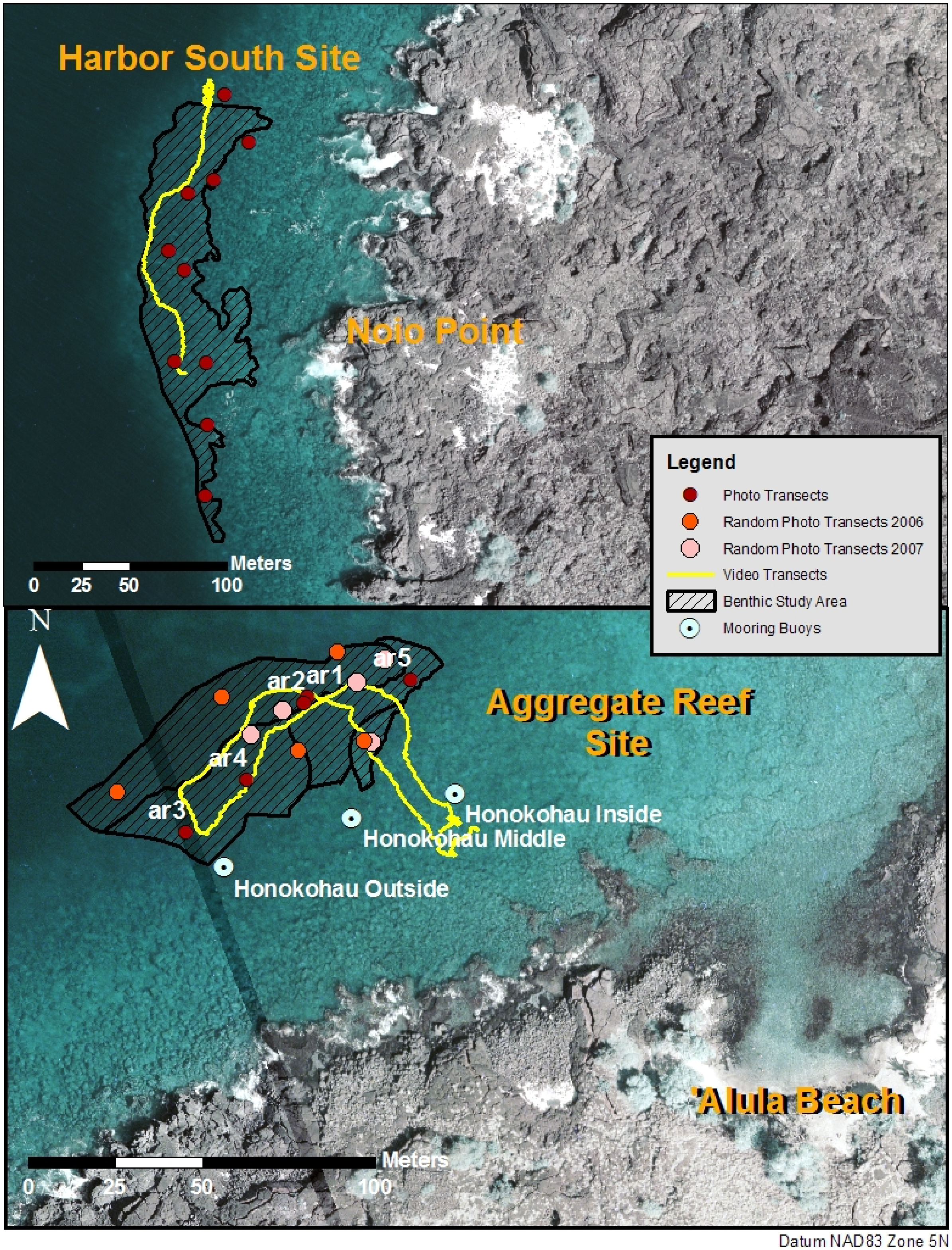

Figure 7. Harbor South (top) and Aggregate Reef (bottom) sites of benthic harbor survey with fixed and random sampling locations and video track in Kaloko-Honokōhau National Historical Park, 2006-2007.

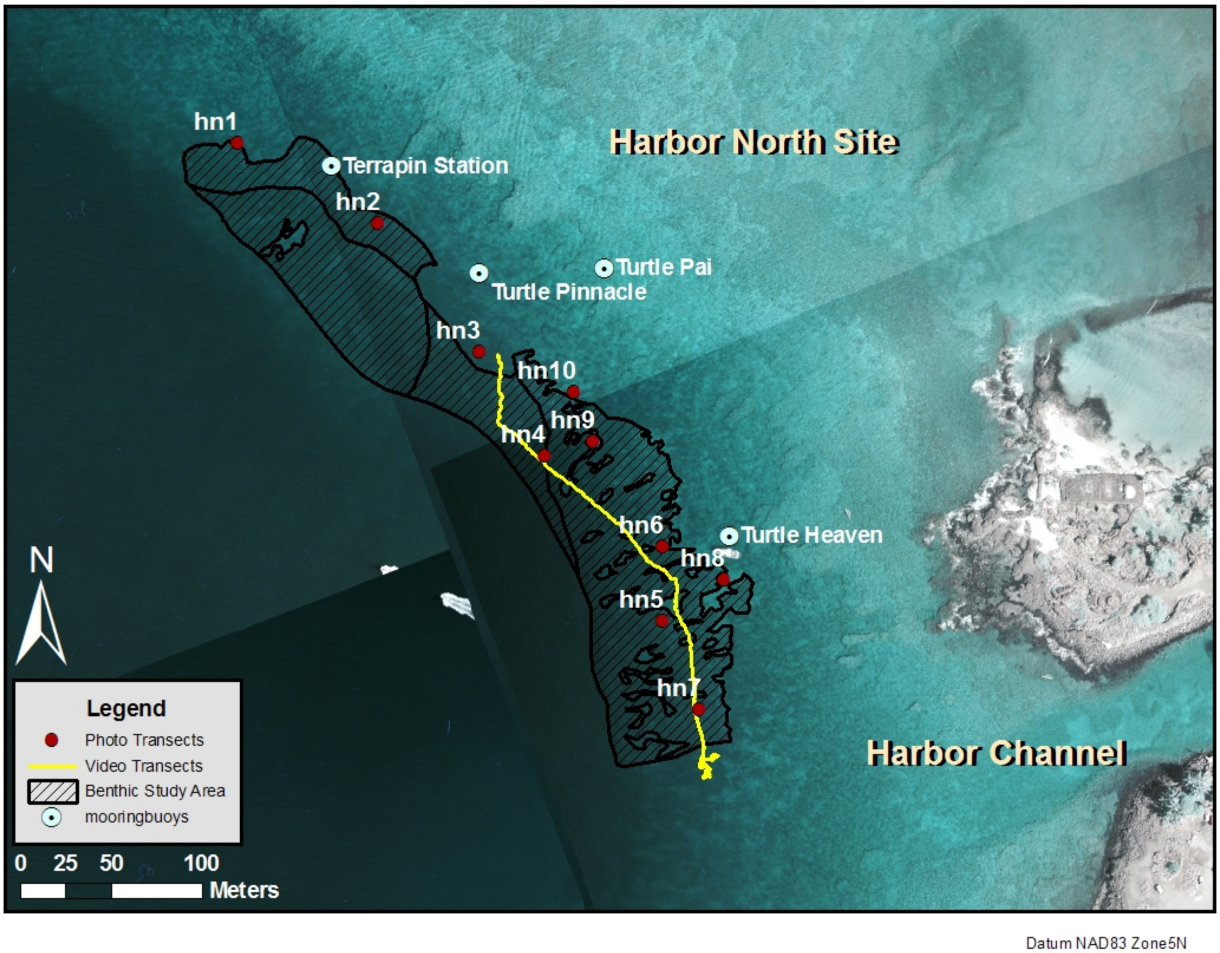

Figure 8. Harbor North site of benthic harbor survey with fixed sampling locations (2006 - 2007) and video track (2007).

Benthic Percent Cover Surveys

A pilot study was conducted to resolve optimal sample size to adequately characterize benthic cover. To determine statistical power we followed a technique developed by Bros and Cowell (1987) using the standard error of the mean. This method uses a Monte Carlo simulation procedure to generate a range of sample sizes versus sampling error (and therefore correlated with power). The sample size after which additional samples only lead to marginal decreases in standard error is taken as the most efficient level to achieve adequate survey power. For this study, pilot study results showed that ten, 10-m long transects with 10 photoquadrats per transect and 40 points per frame, gives a reliable value of the mean percentage of coral cover for a site (Appendix I). In accordance with those, we installed ten 10-m photoquadrat transects with start and end pins at each site. These transects are identified using GPS, compass directions from known markers such as mooring buoys, laminated photo identification sheets for transect features, and semi-permanent stainless steel pins installed with a small sledge hammer and affixed with a minimal amount of marine epoxy. Live coral has not been damaged during the placement of pins, as existing cracks within the basalt base rock were used. Sampling locations were randomly selected within the study sites using the NPS-developed ARCGIS extension AlaskaPak (Sarwas 2011). Location points in latitude and longitude and in UTM coordinates were downloaded into a GPS unit to navigate to in the field. Divers either used the Park's 22-ft vessel or shoreline entrances to access sampling locations. The field team, consisting of two divers and a snorkeler, navigated to the waypoints using the GPS unit, then descended to place a pin. Once a pin was installed by the divers, the snorkeler would record a new waypoint, to accurately record the transect location. The direction of each transect was perpendicular to the harbor outflow along a 10-m isobath, except in cases where that direction would traverse large sandy or rubble areas. In those situations, transects were run within the habitat polygon at a similar isobath strata. To minimize visual impacts in the 'aggregate reef' study area, which is small and highly used by divers, we used four existing pins (from University of Hawai'i - Hilo survey programs) as starting points and added one more. The other five transects are 'random' transects. Once a site was located, observers laid a transect line between the fixed pins making sure it was straight and tight. At 0.5-m intervals along each transect, 21 quadrats were photographed from a perpendicular angle above the substrate. An Olympus C7070 camera in an Olympus C7070 underwater housing was used. A metal rod attached to the housing kept the camera at the set distance from the substrate for each photograph. The length of the rod created a 0.50 m x 0.43 m photo quadrant when the camera was in the wide-angle setting.

Transects were surveyed twice during the baseline period. The first set of photographs was taken in August and September 2006 for the Aggregate Reef, Harbor North and Harbor South sites and in October, November and December 2006 for the two reference sites, Kaloko Cut and Pu'uhonua o Hōnaunau NHP. Image-frames were analyzed in the office. A second set of photographs were taken in April 2007 and have been archived. Image analysis was conducted using the National Coral Reef Initiative (NCRI) Coral Point Count with Excel extensions (CPCe) software (Kohler and Gill 2006) on non-overlapping photoquadrats. For the reference sites eleven (every other) non-overlapping digital photoquadrats were used for analysis per transect and twenty-one photoquadrats per transect for the three harbor sites. Each frame was analyzed using 40 randomly selected points in the program CPCe. Appendix II gives a complete list of all parameters recorded and the categorization in groups. Because turf, macroalgae and crustose coralline algae (CCA) are often used indicators for nutrient availability and grazing pressure (Littler and Littler 1984), they each form a main category. Percent cover values for each substrate category and coral species were derived by dividing the number of occupied points by the total number of identified points. Percent cover was tabulated for benthic categories: coral, crustose coralline algae, turf algae (≤ 1 cm canopy height or frond extension), fleshy macroalgae (> 1 cm canopy height or frond extension), blue-green algae (cyanobacteria), sand, and available substrate for colonization (rubble and bare rock). When a point landed on a mobile invertebrate, the tape, wand, or there was a shadow or hole, the benthic category was classified as unidentified (UNIDENT). Identification of species (when possible) was done for corals using Fenner (2005), algae using Abbot (1999) and Abbot and Huisman (2004), and invertebrates using Hoover (1998).

Observer variability of photo analysis was less than 7.5% and primarily caused by a difference in identification between turf and CCA. Only 2.5% in observer variability (1 point per frame) was due to coral cover error. We defaulted to turf when in doubt between turf and crustose coralline. If a point was on the border between coral and turf, we defaulted to coral. Octocoral might have been underestimated as it often was blurry because of water movement and could have been over-estimated as turf. When in doubt between *Porites lobata* and *P. lutea*, we defaulted to *P. lobata*. In our analysis, those two species are clumped together as "Massive Porites." We noted the presence of any disease, bleaching, and mortality encountered in the analysis of the photoquadrats. The identification of specific coral diseases requires specialized expertise that goes beyond the scope of this study.

Macroinvertebrate Survey

All mobile macro-invertebrates observed along the photoquadrat transects were identified using Hoover (1998). Individuals were counted while swimming along the length of the transect tape within a total width of 1.75 m. The number of boring urchins, *Echinometra mathaei*, was estimated by counting all individuals in a one or two-m^2 area dependent on the density, and multiplied to get an approximation of the total number in the 17.5-m^2 transect survey area. The number of crown-of-thorns seastar (*Acanthaster plancii*) was recorded. Recruits of urchins and *A. plancii* were noted with size estimates.

Coral Mortality Study

The first three individual *Pocillopora meandrina* coral colonies with a diameter of greater than 3 cm, located within 0.5 m on either site of the permanent transect, were photographed to facilitate re-location. Care was taken as to not damage any corals and only colonies with a diameter of more than 3 cm were considered. Colony location relative to the transect line was recorded (x being distance along, and y the distance perpendicular to the transect tape). At the three sites of the Honokōhau reef a total of 50 colonies were identified and an additional 50 colonies in the reference sites. Surveys included measurements of colony height, width, and length as well as information on the status of the colony (alive, half dead, or dead), and any blemishes were recorded. The length was the longest length of a coral colony; the width was the widest part perpendicular to the length axis. Each colony was photographed for comparison with future condition.

Data Analysis and Management

A one-way analysis of variance (ANOVA) was performed to test for differences among sites. Data were first tested for normality and equal variance using the Cochran's test. When necessary, data were transformed and then tested again. The criterion for significance for these comparisons was $P < 0.05$. When a statistical difference was identified, the multiple range test (using Fisher's least significant difference procedure) determined which means differed (Zar 1999).

Permanent records of the photoquadrats from 10-m transects and the underwater video are stored on computer (photos) or cassette (video), and are archived on CD's. Data collection and management will follow I&M coral reef inventory protocols. A Microsoft Access database has been created to store benthic community data, macroinvertebrate data, coral colony mortality data, and information on diver use for each transect.

RESULTS

Diver Usage of Study Sites

Diver usage of the research sites was based on the results of the informal surveys with commercial dive operators regularly utilizing park waters (Table 3). Three dive companies take an average of 4-6 divers/week, three companies take an average of 12-14 divers/week, two companies take an average of 24-36 divers/week, and three only take divers out occasionally. The number of clients varied between 2 and 36 per boat with an average of 11. Harbor South and Pu‘uhonoua o Hōnaunau are rarely visited by divers. Only one dive company mentioned going occasionally to Harbor South, they use SCUBA dive scooters and can cover a wide area. Their number of clients is however very small, two or three at a time. Nobody reported making the long journey to Pu‘uhonoua o Hōnaunau. Kaloko and Harbor North are moderately visited by dive operators. All dive operators mentioned frequent visits to the Aggregate Reef site especially when oceanographic conditions make other dive sites less pleasant due to high swells and/or strong currents. Kaloko Cut area (“Windows” dive site) and the areas close to mooring buoys in the Harbor North site were reported as moderately visited.

Table 3. Mean diver use score of all transects for each study site based on interviews with dive operators. 1 = low use, 2 = medium use and 3 = high use. PUHO = Pu‘uhonoua o Hōnaunau NHP

Location	Diver Use Score
Aggregate Reef	3
Harbor North	1.8
Harbor South	1
Kaloko	2
PUHO	1

Benthic Cover Characteristics

The most abundant substrate types at all five sites during the four-month study period were 'coral' and 'turf algae', which averaged 47.4% and 39.9% cover respectively. Coral cover ranged between 31% and 58% with the highest coral cover found in the Aggregate Reef and Kaloko sites. Turf algae cover ranged between 25.3% (Kaloko) and 60.7% (Harbor South). At the Harbor South and PUHO sites, turf was the dominant substrate type. Bare rock (no visible algae or invertebrate cover) was almost non-existent at all sites. Frondose macroalgal cover was very low (< 1%) with only a few dominant species. The coral/macro-algae ratio, which is sometimes used as an indication of a phase shift, was very high at all sites. Blue-green algae or cyanobacteria was a minor part of the benthic cover and was recorded mostly in Harbor South and at PUHO. The sessile invertebrate category was almost entirely made up of octocoral (*Sarcothelia edmondsoni*) and was most dominant in the Harbor North and Kaloko sites (Fig. 9, Table 4).

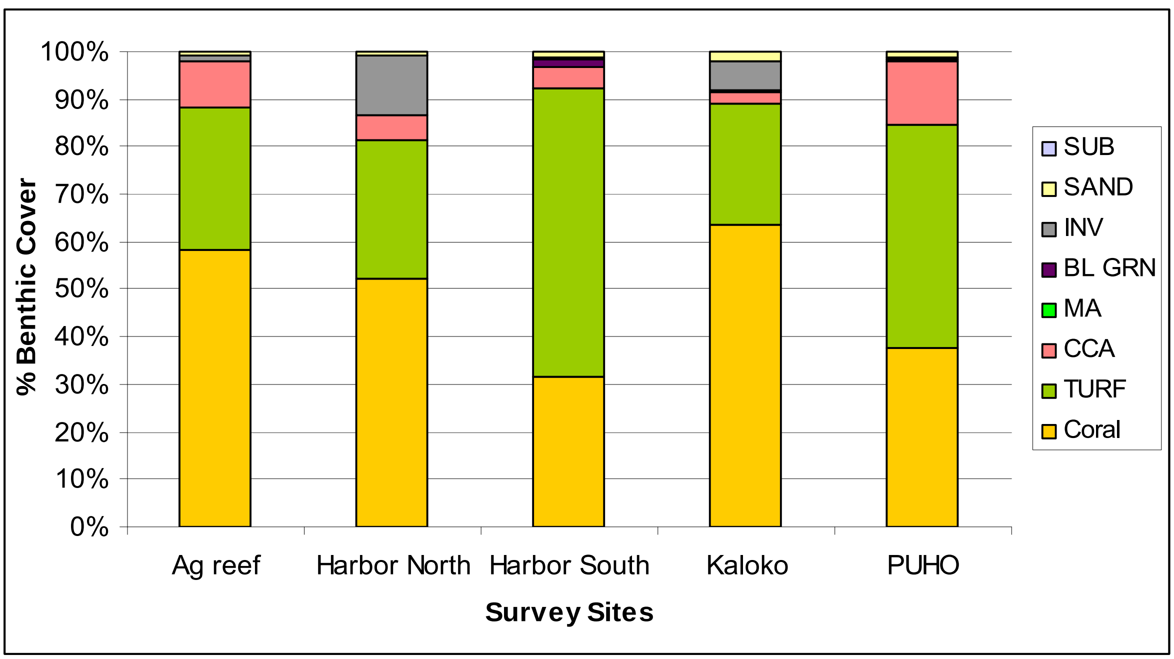

Figure 9. Benthic community composition at the three study sites and two reference sites (Kaloko Cut and PUHO) during August to December 2006. Data based on CPCe analysis of photoquadrats and represents average of 10 transects per site. SUB = available substrate for colonization; INV = sessile invertebrates; BL GRN = blue-green algae; MA = Macroalgae; CCA = crustose coralline algae.

Table 4. Habitat characteristics of all sites. Values are mean percent cover data with SD for ten transects at each site. The *algae* cover data is the total of turf, crustose coralline algae (CCA), and macro algae (MA) species. BL GRN = blue green algae or cyanobacteria; INV = sessile invertebrates; SUB = available substrate for colonization. Percentages cover corrected for unidentified points.

AVERAGE ± 1 SD	Coral	*Algae*	TURF	CCA	MA	BL GRN	INV	SAND	SUB
Aggregate reef	58.3 ± 5.5	*39.9 ± 6.8*	29.8 ± 3.9	10.0 ± 2.7	0.1 ± 0.1	0.0 ± 0.0	1.2 ± 2.0	0.6 ± 0.7	0.0 ± 0.0
Harbor North	52.4 ± 6.4	*34.2 ± 11.8*	29.1 ± 9.4	5.0 ± 2.1	0.1 ± 0.3	0.1 ± 0.2	12.3 ± 8.4	0.8 ± 1.0	0.1 ± 0.0
Harbor South	31.4 ± 7.4	*65.4 ± 10.5*	60.7 ± 8.3	4.7 ± 2.2	0.0 ± 0.1	1.4 ± 0.8	0.4 ± 0.4	1.2 ± 1.1	0.2 ± 0.0
Kaloko Reference	63.6 ± 13.9	*28.0 ± 15.4*	25.3 ± 13.5	2.7 ± 1.8	0.0 ± 0.1	0.1 ± 0.1	6.3 ± 5.8	2.0 ± 3.1	0.0 ± 0.0
PUHO Reference	37.8 ± 8.5	*60.7 ± 18.1*	46.9 ± 11.8	13.3 ± 5.5	0.5 ± 0.9	0.1 ± 0.2	0.1 ± 0.2	1.3 ± 1.5	0.0 ± 0.0

Coral Cover and Species Composition

Within the Harbor area, highest coral cover (58.3%) was found just outside and south of the harbor mouth at the Aggregate Reef site. *Porites lobata* (39.3%) and *P. compressa* (15.4%) were the primary coral species. Lowest coral cover (31.4%) was found off Noio Point (Harbor South site), where there are many boulders. The dominant coral species at the Harbor South site was *Pocillopora meandrina* (14.9%) closely followed by *Porites lobata* (13.9%). The area north of the harbor had a coral cover (52.4%) and composition similar to the Aggregate Reef with *Porites lobata* (36.2%) and *P. compressa* (15.1%) as the dominant corals species. The benthic composition in the reference sites was similar to the harbor sites (Table 4, Fig. 10, Fig. 11). The Kaloko Reference site showed the highest coral cover of all sites (63.6%). The dominant coral species was *Porites lutea* (27.6%) followed by *P. lobata* (24.5%) and *P. compressa* (11.5%). At the PUHO Reference Site, coral cover was low (37.8%) and comparable to Harbor South site. *Porites lobata* (25.3%) was the dominant coral species and some *P. compressa* (5.8%) and *Pocillopora meandrina* (3.9%) were identified. When the picture quality was slightly blurry, *P. lobata* may have been mistaken for *P. lutea*. In the analysis we have therefore clumped them as "Massive Porites". Coral species observed rarely (< 2% cover) were *Leptastrea bewickensis*, *Montipora capitata*, *M. patula*, *Pocillopora damicornis*, *Pavona duerdeni*, and *P. varians*.

Algae Cover and Species Composition

The highest algal cover (65.4%) was found at the Harbor South site, where many boulders are present, closely followed by PUHO Reference Site (60.7%). At all sites, algal species composition was predominantly turf, some crustose coralline algae (CCA), and very little macro-algae (Table 4, Fig. 10, Fig. 11). At Harbor South and Kaloko Reference site, turf accounted for respectively 93% and 90% of the total algae cover. The highest coralline algae cover was found at the PUHO site closely followed by the Aggregate Reef site. The PUHO Reference site also had the highest macroalgae cover. Identified macroalgal species per site were: *Dictyota* sp (0.01%) and *Asparagopsis taxiformis* (0.01%) at Harbor South site. At the Aggregate Reef site: Unidentified green algae (0.02%), *Dictyota* sp (0.01%), *Dictyosphaeria versluysii* (0.01%), and Unidentified red algae (0.01%). Harbor North site macroalgae consisted of a single species of *Asparagopsis taxiformis*, 0.13% ± 0.3 SD. Kaloko (Cut) Reference Site only had one transect where a gelatinous red macro-algae was identified (0.02% ± 0.1 SD). At the PUHO Reference site, macroalgal cover comprised of three species, unidentified red algae (0.44%), *Dictyota* sp (0.02%), and gelatinous red algae (0.02%). Cyanobacteria or blue-green algae were not encountered in the photo frames at the Aggregate Reef, in very low numbers (0.1%) at Harbor North, Kaloko and PUHO, and slightly higher at Harbor South (1.4%). Appendix III gives detailed information on the benthic cover of substrate types specified per transect.

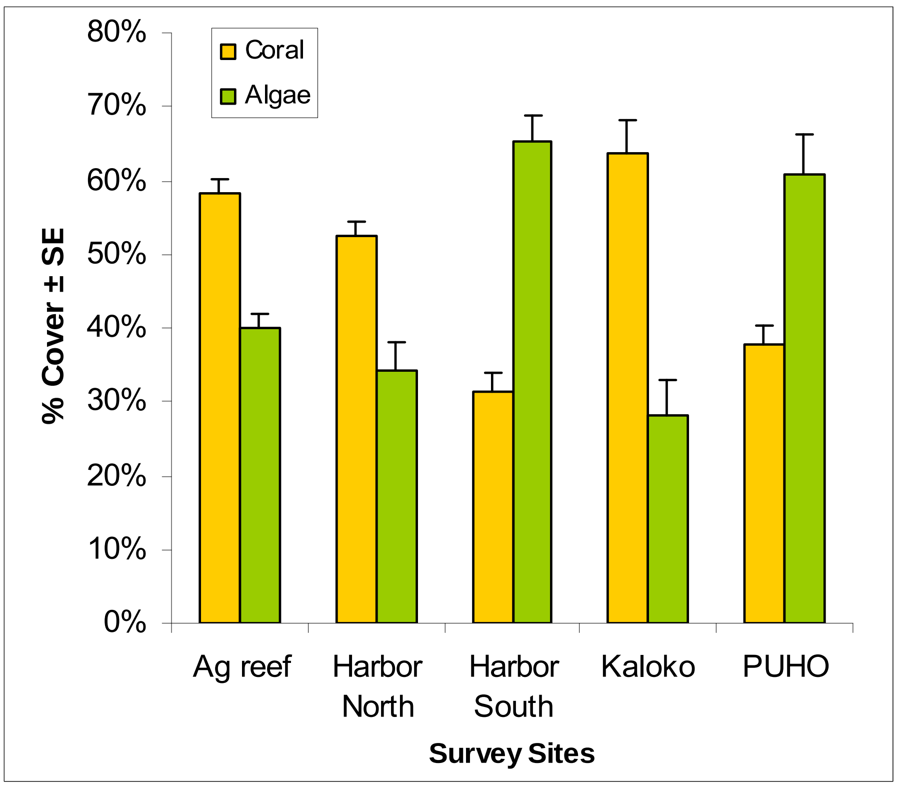

Figure 10. Mean percent coral and algal cover at three harbor sites and two reference sites (Kaloko (Cut) and PUHO) from August to December 2006. Algal cover is the total of turf, macro-algae and crustose coralline algae. Data based on CPCe analysis of photoquadrats and represents average of 10 transects per site. Error bars are standard error of the mean. Ag reef is Aggregate Reef harbor site.

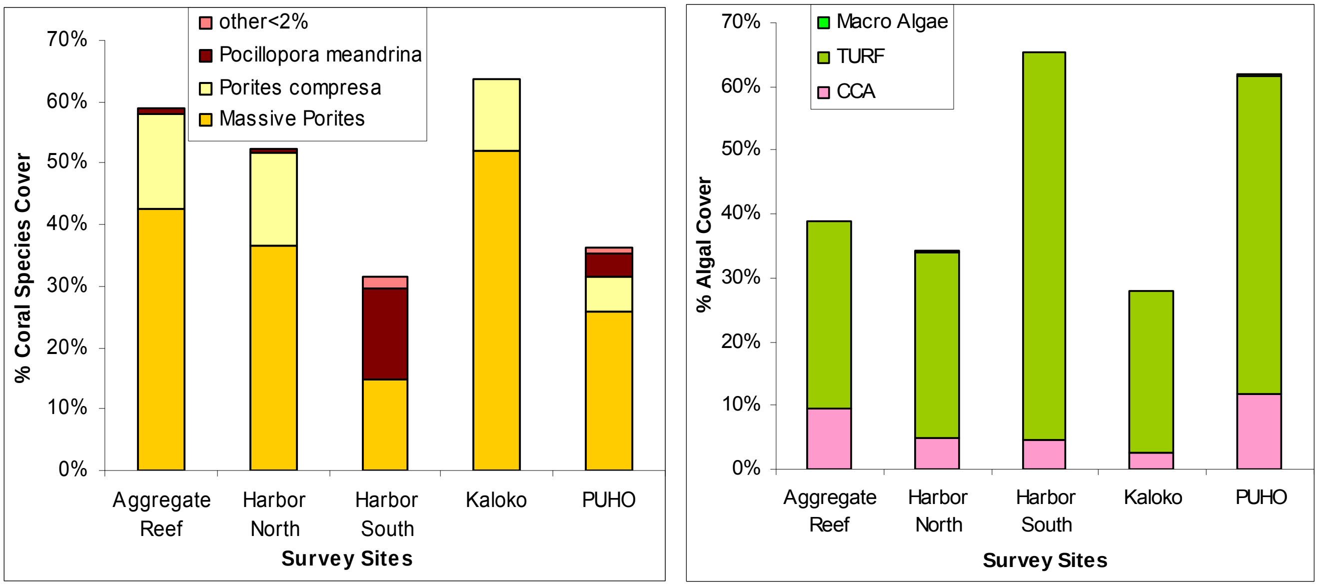

Figure 11. Composition of coral species (left) and algal categories (right) at each of the benthic survey sites. Kaloko (Cut) and PUHO are reference sites. CCA is crustose coralline algae. Massive Porites consist of *Porites lobata* and *P. lutea*.

Benthic cover data were significantly different among the sites. Percent substrate cover data of coral and crustose coralline algae formed a Poisson distribution and were therefore square root transformed prior to statistical analyses. A one-way ANOVA was used to detect statistical differences of coral cover, crustose coralline algae and turf algae (Table 5). All three substrate types showed a statistical significant difference between sites. Kaloko had the highest coral cover but similar to the Aggregate reef. Harbor North also showed a high coral cover, again similar to the aggregate reef but statistically different from Kaloko. Harbor South and the PUHO site had a similar and the lowest coral cover. The highest cover of turf was found in Harbor South where there are many boulders that serve as substrate for turf. The PUHO site followed in turf cover. The other three sites had similar turf cover. The PUHO site and Aggregate Reef had the highest cover of crustose coralline algae, followed by the two harbor sites and Kaloko had the lowest cover. Macro-algae were present in such low numbers that no statistical tests were deemed necessary.

Table 5. Statistical values of one-way ANOVA, *P* values representing statistical significance are in bold ($P \leq 0.05$). CCA = crustose coralline algae; SQRT = square root transformation.

Substrate type	**df**	***F***	***P***	**Multiple Range Test results**
SQRT(Coral)	4, 47	25.5	**0.0000**	Harbor South and PUHO formed a homogenous group. Aggregate reef formed a homogenous group with Harbor North and Kaloko, but Kaloko and Harbor North differed.
Turf	4, 47	23.4	**0.0000**	PUHO and Harbor North are different from the other three sites and from each other. Harbor South, Kaloko and Aggregate Reef formed a homogeneous group.
SQRT(CCA)	4, 47	21.1	**0.0000**	Kaloko differed from all other sites. Harbor North and South differed from PUHO and Aggregate reef

Invertebrates

Sessile invertebrate species other than corals were rarely encountered in the photoquadrats with the exception of octocoral (Fig 9: INV). The highest octocoral cover was at Harbor North site with 12.3% ± 8.4 SD, followed by Kaloko Reference Site (6.3% ± 5.8 SD), Aggregate Reef (1.3% ± 2.1 SD), and Harbor South (0.4% ± 0.4 SD). The lowest octocoral cover was found at the PUHO Reference Site (0.1% ± 0.1 SD). A one-way ANOVA on square-root transformed invertebrate data showed statistical significant differences among the sites ($F = 22.3$, $df = 4, 47$, $P = 0.000$). Other sessile invertebrates seen on transects in very low numbers were zooanthids, bryozoans, and sponges. Mobile invertebrates were classified as “unidentified” in the CPCe analysis because they obscure the benthic substrate. On transects, especially in the boulder-rich area of Harbor South, large numbers of shingly hoof shells (*Hipponix imbricatus*) were seen. Other species seen during the study were sea stars, sea cucumbers, mollusks, and urchins.

Other Substrate

Due to the selection of transects (omitting sandy patches) sand was uncommon, comprising less than 2% of the benthic habitat. Available substrate for colonization (bare rock and rubble) was even lower, with a maximum of 0.2% at Harbor South site. Turf or coral colonized most rock or dead coral. Appendix IIIc summarizes the percent cover of sessile invertebrate (octocoral), sand and available substrate at each site.

Coral Diseases and Bleaching

Pocillopora meandrina was a coral species that was often encountered as dead and found overgrown by turf. Recently dead coral, which could be any species that still showed polyp structure but had no pigment or turf algae growth, was only recorded for *P. meandrina*. Bleaching was minimal. Bleached tips were found on *Pocillopora meandrina* and *Porites lutea*. Totally bleached coral was only recorded for *P. meandrina*. Trematodiasis is commonly found on massive porites (*P. lutea* and *P. lobata*) throughout Hawai‘i and in our study as well. No other disease was observed in this study area. Of all random points that landed on coral during the photoquadrat analysis (16631) only 415 showed some form of blemish on the coral which corresponds to 2.5% (Table 6).

Table 6. Summary of disease or bleaching on corals at sampling locations during August to December 2006. Numbers represent number of encounters on all points per frames where coral was identified of all transects within a site. n is number of points identified as coral per site.

site	Dead *P. meandrina*	Recently dead coral	Bleached tips	Bleached	Trematodiasis	Other Disease
Aggregate reef (n=5141)	10	3	0	0	0	0
Harbor North (n=4369)	5	0	0	00	0	0
Harbor South (n=2605)	319	0	0	0	1	0
Kaloko (n=2730)	3	1	1	0	4	0
PUHO (n=1486)	63	0	1	4		0

Macroinvertebrate Survey

Large sea urchins were present at all sites with values ranging between 5 to 22 per belt transect (17.5 m^2). High numbers (> 40) of *Echinometra mathaei*, the small boring urchin, were also present at all sites, especially in the Aggregate Reef and Kaloko sites (Fig. 12). A single individual of the crown-of-thorns star was seen on only three transects, one in PUHO Reference site, one in Kaloko (Cut) Reference site, and one in the Aggregate Reef site but no recruits were observed. No sea urchin recruits of any species were observed on the transects. However, large numbers of recruits of *Tripnuestes gratilla* (collector urchin) were seen in the shallow, boulder area of Kaloko Cut.

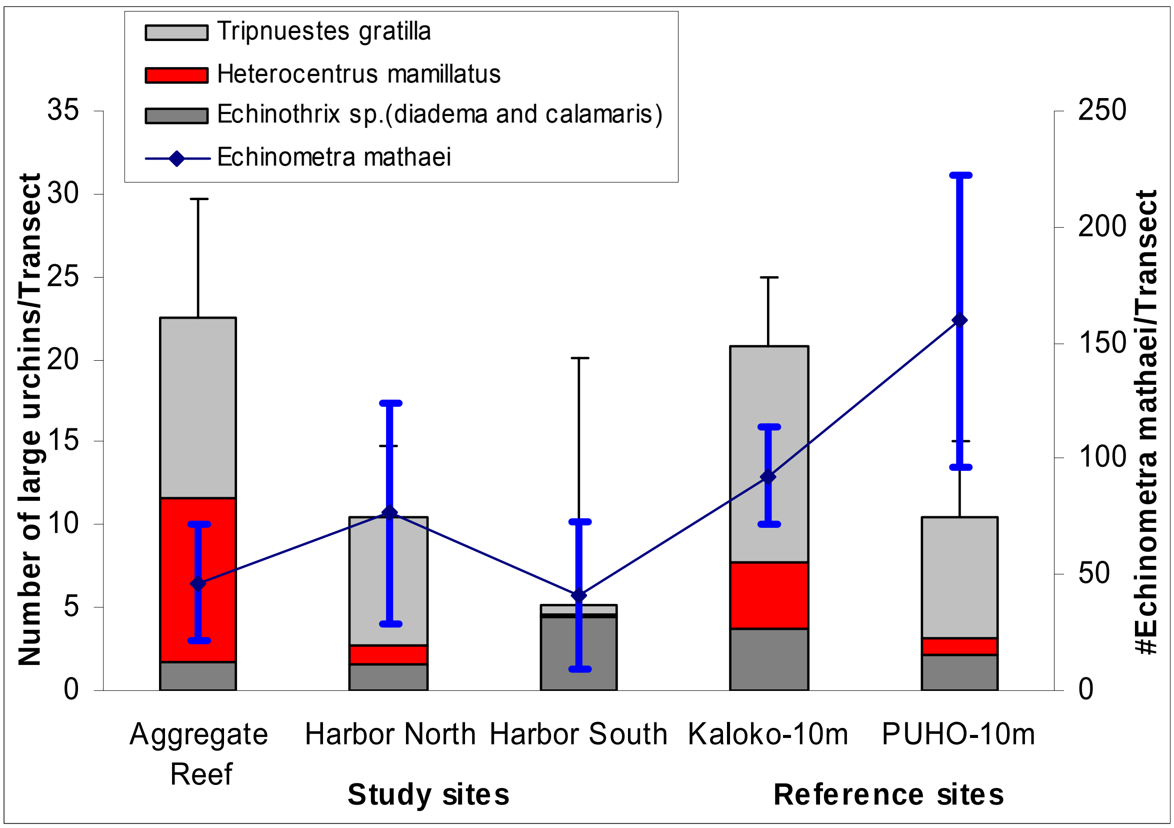

Figure 12. Average urchin abundance per 17.5-m^2 belt transect at each study site. Error bars represent standard error of the mean with the fat blue error bars the SE for *Echinometra mathaei*.

Coral Mortality Study

Among all sites, a total of 105 individual *Pocillopora meandrina* coral colonies were identified and measured for the mortality study (Table 7). There was little to no difference in the size classes among sites. None of the colonies had diseases but some had some bleached tips. All colonies were photographed and archived for future comparisons.

Table 7. Condition and measurements of individual colonies of *Pocillopora meandrina* at each study site. l=length; w = width; h=height.

Coral Colonies	Aggregate Reef	Harbor North	Harbor South	Kaloko	PUHO
Total	11	20	24	23	27
Alive	11	19	23	17	19
Half dead		1	1	1	2
Partially dead				5	6
Diseases	0	0	0	0	0
Minimum l*w*h (cm)	12 * 11 * 8.5	16 * 5 * 9	5 * 1.5 * 1	3 * 1 * 4	16 * 9 * 6
Maximum l*w*h (cm)	30 * 29 * 15	35 * 24 * 11	38 * 34 * 20	37 * 26 * 14	36 * 29 * 14

DISCUSSION

Benthic Cover

Compared with two other coastal national park units in Hawai‘i (Kalaupapa NHP on Moloka‘i and Pu‘ukoholā Heiau National Historical Site in Kohala, Hawai‘i Island) the coastal environments in Kaloko-Honokōhau NHP and offshore of Pu‘uhonua o Hōnaunau NHP have impressive coral communities interspersed among hard bottom habitats with very low coral cover and low spatial complexity (Beets et al. 2010, Cochran et al. 2007, Gibbs et al. 2007). Large fish species richness values were associated with the high-density coral communities (Beets et al. 2010). The benthic composition of the Harbor reef sites was very similar both in substrate cover and species composition to other well established reefs on the west coast of Hawai‘i (DAR unpublished data). The Honokōhau Bay area fronting the harbor has high coral cover in areas with colonized hard bottom, which attracts large numbers of dive tourists and fishers. All dive operators we spoke to use the Harbor reefs to some extent and there is a large fishing community. Across the state, Hawai‘i Island is second to O‘ahu in fish landings, with a total reported landing of 3.7 million lbs of fish in 2005 of which 1.2 million lbs were fished off the Kona Coast (DAR 2005). About 1% of the 25.1 million lbs of fish landed statewide in 2005 were inshore fish (DAR 2005).

Coral cover at the study sites in the harbor area was similar to that in the reference sites and coral cover found at other similar habitat reefs in West Hawai‘i. At DAR’s Honokōhau site, which lies within our Harbor North site, coral cover was 48.3% which is comparable to our mean (52.4%). Species composition was also similar. No diseases were observed apart from trematodiasis on massive *Porites* species. Observations of bleaching were infrequent indicating highly localized causes such as *Acanthaster plancii* predation rather regional conditions such as elevated water temperatures. The high octocoral cover observed at Harbor North and Kaloko sites was similar to that found in DAR's Honokōhau site (12.5%) and in the Park overall (10.1%) (Beets et al. 2010). Octocoral in Kaloko-Honokōhau waters is high compared to other areas along the Kona coast (Cotton 2004). Reasons for this high density and its ecological significance should be explored, possibly in cooperation with DAR. A possible link is salinity, nutrient, and/or contaminant concentration associated with groundwater. Spatial groundwater discharge data (Grossman et al. 2010) showed that octocoral and various green and brown algae were most dense in areas of high groundwater inputs.

Comparative results of benthic cover data at Kohanaiki sites within Kaloko-Honokohau NHP over three time periods within two years have shown that the sampling design is powerful in picking up changes (Marrack et al. 2014). Analysis of substrate-cover data of the Kohanaiki Benthic Survey, which used the same sampling design as used for the harbor benthic survey, demonstrated that detected changes < 5% between survey periods were statistically significant, although these detected changes were not considered biologically significant. Statistically significant changes less than 10% are within measurement and observer error and therefore, absolute change in coral cover ≥10 % was defined as biologically relevant if the change was statistically significant (Marrack et al. 2014).

Water quality

Nutrients are typically low in coral reef ecosystems and groundwater is an important source for supplying new nutrients. A substantial amount of groundwater discharges through the harbor, and this groundwater appears to be a source of new nutrients into the harbor and, after mixing, to the near-shore waters (Street et al. 2008). The existing harbor receives about 30 million gallons a day (mgd) of brackish groundwater, which is discharged at the back wall and causes the harbor waters to flush rapidly (~10 hrs). This high flush rate is crucial to maintain the Class A water quality inside the harbor. The brackish water discharge also leads to strong vertical stratification of water in the harbor, at the harbor mouth, and in adjacent marine waters (Moffat and Nickel 2007). Due to that stratification, nutrients and pollutants tend to stay in a brackish surface layer, which almost certainly limits their current impacts on benthic habitat in front of the harbor mouth. Results of water quality research of the existing harbor and proposed new marina (Moffat and Nickel 2007) showed that the present water quality can only be sustained if the new marina intercepts an additional 30 mgd of brackish water to the current interception in the existing harbor. Furthermore, the model used by the consultants to predict water quality changes assumed that the water withdrawal from the aquifer will not increase, the waste water treatment plant will be upgraded, and there will be no additional point or non-point sources into the new marina. These assumptions appear unrealistic.

A change in nutrient concentration in the groundwater could have serious impacts to the reef ecosystems adjacent to the harbor mouth. With the proposed development, groundwater discharge is likely to increase and, because the harbor is also a drainage area for its surroundings, the amount of nutrients, sediments, and pollution from run-off will likely increase as well. With nitrate levels already surpassing the limits set by the state (MRC 2000, Ziemann 2006, Department of Health 2008), an additional increase in nutrients from land-based activities has potential to become a serious problem for the health of the coral reefs in the harbor are. Controls on land-based polluted runoff and nutrient inputs will improve reef resiliency.

Herbivore Populations

Harbor development, including a proposed 300% increase in the number of boat slips, would likely lead to increased fishing pressures on local reefs. A recent meta-analysis of herbivore reduction and nutrient enhancement studies has indicated that a reduction of herbivores has more potential than eutrophication to drive a phase shift from coral-to-algal domination (Burkepile and Hay 2006). It is therefore important to understand how changes in consumers (herbivores) and resources (nutrient input) affect the benthic community to predict possible impacts from human activities. Reefs at other populated parts of the main Hawaiian Islands (particularly around Maui and O'ahu) with low stocks of herbivorous fishes have been profoundly affected by overgrowing blooms of invasive algae. To date, reefs on the Big Island have not suffered from invasive algal blooms, but they would become much more vulnerable, should herbivore stocks decline. Results of the macro-invertebrate survey show that urchins (herbivore) were quite abundant, with high numbers of *Echinometra mathaei* (>40 per transect). Long term urchin data (1999 – 2006) show an upward trend in urchin abundance with significant density increases for *Tripnuestes gratilla* and *Echinothrix* spp. in West Hawai'i (DAR unpublished data). For Honokōhau, *Tripnuestes gratilla* has most noticeably increased in numbers (Fig. 13). Whether this increase is due to an increase in nutrients or a decline in urchin predators is presently unknown.

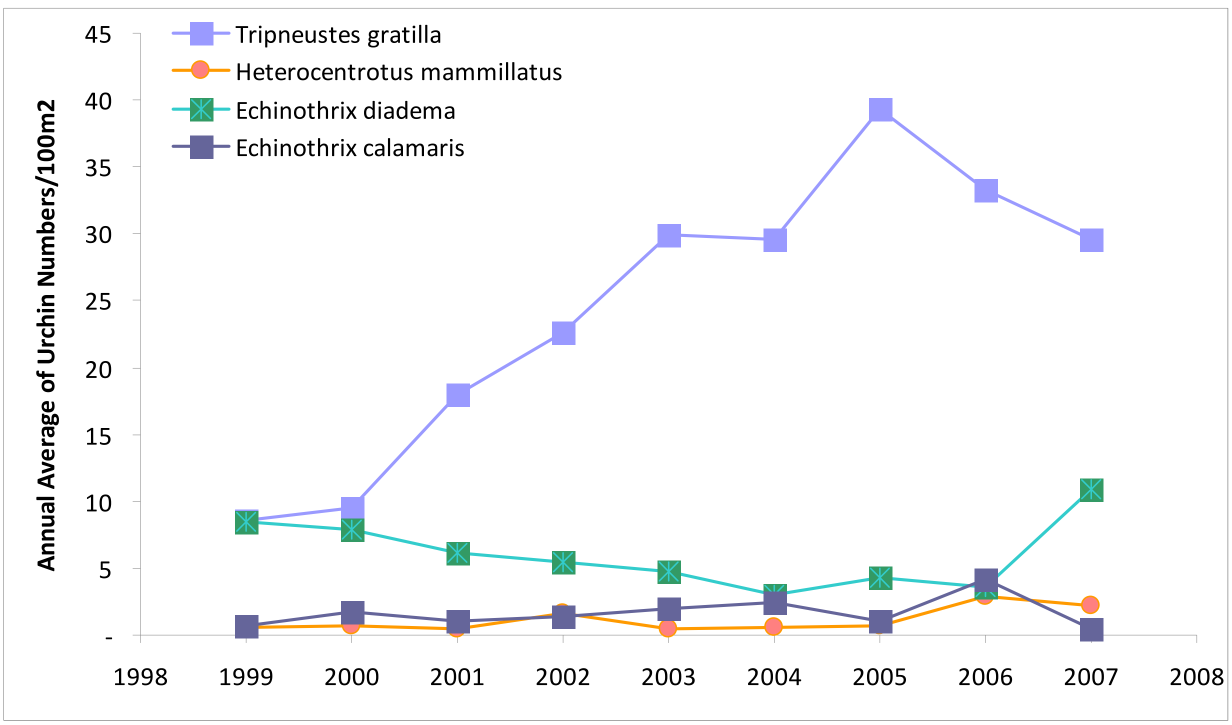

Figure 13. Long-term data of mean annual average of urchins at Honokōhau from 1999 to 2007. (DAR unpublished data, used with permission)

Macroalgae cover was very low (<1%) at all the study sites while the most abundant algae encountered was in a cropped state (turf). The near absence of macroalgae could be partially due to the high urchin density and partially because of still adequate herbivorous fish numbers. Fish surveys however, have indicated possible over-fishing in Honokōhau Bay with low numbers of apex predators and of large species (DAR unpublished data, Beets et al. 2010). Marine protected areas have been shown to be effective in conserving fish species within the protected area boundaries, and a recent study of Hawaii marine reserves showed that they had greater fish biomass, and higher abundance of apex predators and large species than comparable fished areas (Friedlander et al. 2007). Protection of fish stocks would very likely improve the reef's resilience to nutrient enrichment associated with land-based development.

Dive Tourism

High numbers of divers and snorkelers result in more broken and bleached corals, smaller coral colonies, and less overall coral cover (Hawkins and Roberts 1993, Tissot and Hallacker 2000). There is some evidence that this occurs at popular sites in Hawaiʻi. For example, in Kealakekua Bay (Hawaiʻi Island) more broken and bleached coral was found at high diver use areas than at a control site (Tissot and Hallacker 2000). Studies in Egypt found the size of coral colonies were impacted by divers with smaller colonies in the trampled dive sites, possibly because regularly broken corals need to invest energy in repairing tissue rather than in growth (Hawkins and Roberts 1993). Three of our five study sites are moderately popular dive sites, and the Aggregate Reef site is a very popular, heavily visited site used by both dive operators and shore divers. Coral breakage at heavily dived sites is mostly due to standing on coral, dangling gauges, placement of (photographic) equipment and poor buoyancy control and could possibly be improved by diver education. Future analyses should take into account the diver impact when comparing coral benthic cover over time between the sites.

Alien Algae

No alien species were found on transects in Kaloko-Honokōhau NHP and off Puʻuhonua o Hōnaunau NHP. However, the presence of *Acanthophora spicifera* has been documented on the west coast of Hawaiʻi at three sites including Kaloko-Honokōhau (Kaloko Fishpond) and Puʻuhonua o Hōnaunau (C. Squair unpubl. data 2006, Smith et al. 2002). Boats are known vectors for the distribution of marine (alien) species, therefore, special attention should be given in future surveys for alien species so that invasions can be identified as early as possible and control, i.e. local eradication, may still be feasible.

Summary

In general, reefs of Hawaiʻi face serious threats due to impacts from anthropogenic sources with numerous examples of degraded reefs in the vicinity of coastal development (Beets et al. 2010, Williams et al. 2007b). Although it is always difficult to compare reef conditions between different locations due to different oceanographic and water quality conditions, it is clear that land development contributes to degradation of coral reefs. A coastal development of the scale of the proposed Kona Kai Ola Harbor expansion would likely have significant and diverse impacts to the condition of the nearby reefs. Expected impacts include: (1) A change in the groundwater discharge in quality and quantity, which could lead to a deterioration in the health of corals (Fabricus 2005); (2) Increase in fishing pressure and a resulting decrease in the herbivore fish population, which could ultimately lead to a phase shift (Burkepile and Hay 2006, Williams and Polunin 2001); (3) Increase in dive tourism, which could contribute to physical destruction of coral species and lower coral cover (Hawkins and Roberts 1993); and (4) Increase in transoceanic and outer island boat traffic, which could lead to the invasion of alien algal species (Ruiz et al. 1997, Smith et al. 2002). Given the potential significance of anthropogenic impacts to reefs (e.g., Birkeland 1997, Porter et al. 2005, Fabricius 2005), adequate planning and management of water-development, land-based pollution controls, and fisheries resources are necessary to prevent direct and indirect cumulative impacts to the Park's natural and cultural resources.

MANAGEMENT RECOMMENDATIONS

- The methodology used for this study is capable of detecting statistically significant and biologically meaningful small changes in coral cover at survey sites (Marrack et al. 2014). A high priority should be placed on communicating acceptable limits to negative change in benthic coral community with all parties concerned (State, NPS, County, and land developers).
- To accompany the monitoring system, there should be clear identification of what is 'unacceptable' change. Specifically, if the level of change surpasses acceptable threshold limits, it should be clear what actions will be undertaken by whom to mitigate these changes to prevent further degradation.
- Fish numbers in Honokōhau Bay should be monitored closely to ensure that the already relatively low populations do not decline further. Collaboration between the DAR and the NPS I&M fish monitoring program is advised to obtain frequent updates of biomass numbers and population distribution. Also, the harbor urchin population should be compared with DAR's numbers of the west coast of Hawai'i Island to see if the upward density trend continues both locally and regionally. Additionally, it is wise to compare the NPS results of the benthic community composition with the results of the DAR's West Hawai'i's benthic monitoring program and in particular with their Honokōhau site, which lies within our Harbor North study site, and with the I&M benthic monitoring program. Comparing our results not only with the reference sites but also with results of the whole coastline and other parks will give us a better understanding of the causes of possible changes in the benthic community. Lastly, results of I&M water quality monitoring program can provide insights in any benthic habitat changes that might occur post-development.
- In collaboration with the DAR's Alien Invasive Species program, a monitoring survey should be set up for early detection and prevention of invasive alien species.

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APPENDIX I: Pilot study of sampling design.

A pilot study was conducted to determine the number of transects, number of frames per transect and the number of points per frame to use for the most accurate representation of percent coral cover with the least sample intensity. Firstly, we decided upon the number of transects to use that would represent the habitat with acceptable error and optimized sampling time.

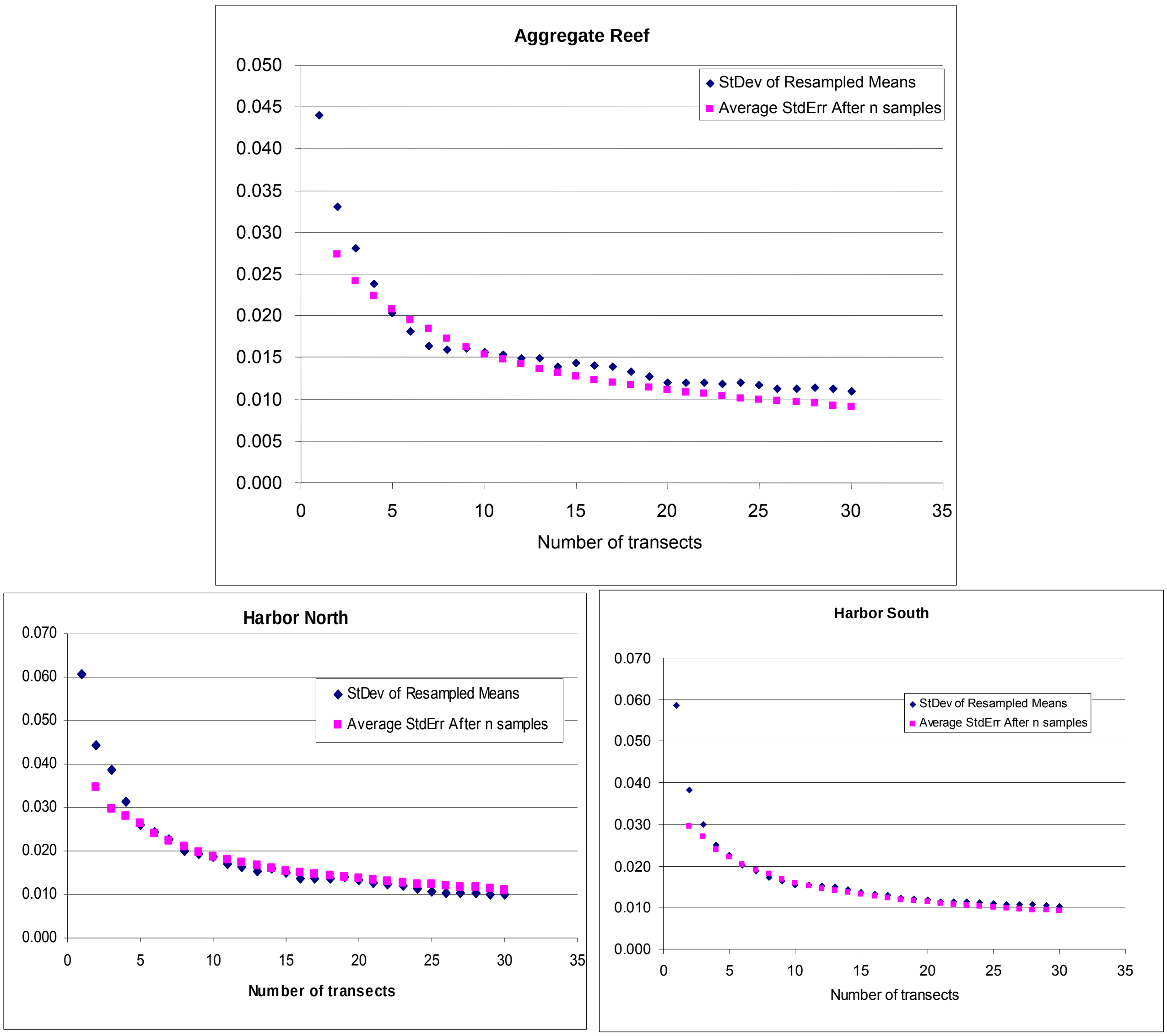

Figure A1. The average standard error for 1 to 30 transects at the three study sites. Calculations are based on 100 re-samples of 10 transects sampled in the 10-m zonation at Harbor study site.

The standard deviation as well as the standard error both come down significantly after about 10 transects at all three sites. After 10 transects one would need to add at least another 10 to obtain a 30% reduction in SE or SD. Therefore, 10 transects per study site will represent the average percent coral cover adequately with a reasonable sampling effort.

Secondly, we looked at the number of frames that should be analyzed to get reliable coral cover data and acceptable office time.

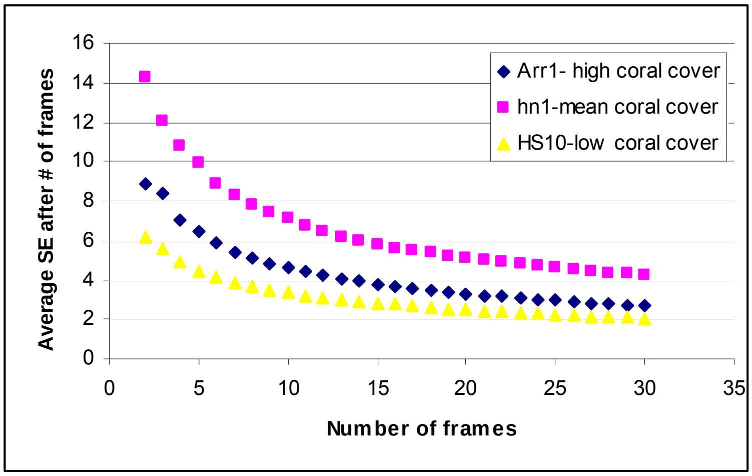

Figure A2. The average standard error for 1 to 30 frames for three transects with different mean coral cover. Calculations are based on 100 re-samples of 21 frames per transect sampled in the 10-m zonation at Harbor study site.

The slope of the SE curves all three sampled transects declines at 10 to 15 frames per transect. As the decrease in SE from 10 to 15 frames is maximum 1 SE unit (transect HN1) it is not worth the extra amount of work to analyze 5 more frames. Therefore we decided that 10 frames per transect would be sufficiently accurate.

Thirdly, we decided on the number of points per frame to use, representing that frame reliably.

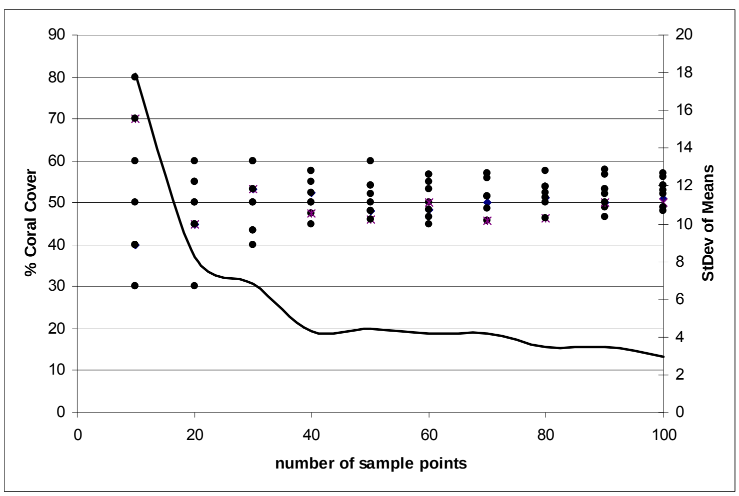

Figure A3. The analysis of number of points sampled per frame. Calculations are based on 10 repeated CPCe analysis of 1 frame with 100 point overlay. The solid line represents the standard deviation of the means of percent coral cover.

Forty sample points appears to be a good representation of the percent coral cover; an increase in sample points hardly lowers the actual percent coral cover until you use 75 or more points. At 40 sample points per frame, the actual mean percent coral cover ranges between 45% and 58% and seems therefore also a reasonable spread. Again, one would need to increase the sample points to almost 100 to obtain any further reduction in variation. Therefore, we decided to use 40 sample points per frame.

APPENDIX II: List of identified species and their categorization

C = Coral species; M INV = Mobile invertebrate: urchin, sea cucumber, crown-of-thorn starfish, other; INV = Sessile invertebrate: octocoral, zooanthid, sponge, tunicate, bryozoan, anemone, other; MA = Macro Alga: defined as fleshy with a canopy height $\geq$ 1 cm; SUB = Substrate with no colonization; TURF = Turf algae, defined as having a canopy height <1 cm; UNIDENT=Unidentified, this includes black hole, tape, wand, shadow, mobile invertebrate.

CPCe Code	Description	Category	Broad Category
NEC	Necrotic Coral	DISEASE	DISEASE
RDC	Recently Dead Coral	DEAD C	SUB
DMEA	Dead Pocillopora meandrina	DEAD C	SUB
TWS	Tape, wand, shadow	TWS	UNIDENT
FSCU	Cyphastrea ocellina	C	C
FSCU	Fungia scutaria	C	C
LBEW	Leptastrea bewickensis	C	C
LPUR	Leptastrea purpurea	C	C
LINC	Leptoseris incrustans	C	C
MCAP	Montipora capitata	C	C
MPAT	Montipora patula	C	C
MFLA	Montipora flabellata	C	C
PBRA	Porites Branching	C	C
PMAS	Porites Massive	C	C
PLOB	Porites lobata	C	C
PCOM	Porites compressa	C	C
PEVE	Porites evermanni	C	C
PRUS	Porites rus	C	C
PVAR	Pavona varians	C	C
PDUE	Pavona duerdeni	C	C
PEYE	Pocillopora eydou*i	C	C
PMEA	Pocillopora meandrina	C	C
PDAM	Pocillopora damicornis	C	C
UNCO	Unindentified coral	C	C
HOPU	Halimeda opuntia	MA	MA
NEOM	Neomeris sp	MA	MA
VENT	Ventricaria sp	MA	MA
CODI	Codium sp	MA	MA
CSER	Caulerpa serrulata	MA	MA
CRAC	Caulerpa racemosa	MA	MA
DVER	Dictiosphaeria versluysii	MA	MA
UNGR	Unindentified green	MA	MA
DICT	Dictyota sp	MA	MA
TURB	Turbinaria sp	MA	MA
LOBO	Lobophora sp	MA	MA
LOBU	Lobophora upright	MA	MA
SARG	Sargassum sp	MA	MA
PADI	Padina sp	MA	MA
STYP	Stypopodium sp	MA	MA
BRCR	Brown crustose	MA	MA
UBRN	Unindentifed brown	MA	MA
LIAG	Liagora sp	MA	MA

CPCe Code	Description	Category	Broad Category
GOOEY	Gelatinous red	MA	MA
GMAR	Gala*aura marginata	MA	MA
ASPA	Asparagopsis sp	MA	MA
JCAL	Jointed calcareous red	MA	MA
CRST	Crustose coralline algae	CCA	CCA
HALY	Halymenia sp	MA	MA
URED	Unindentified red	MA	MA
ASPI	Acanthophora spicifera	MA	MA
GSAL	Gracillaria salicornia	MA	MA
HMUS	Hypnea musciformis	MA	MA
KAPP	Kappaphycus sp	MA	MA
AVRA	Avrainvillea sp	MA	MA
CSER	Cladophora sericea	MA	MA
DCAV	Dictyosphaeria cavernosa	MA	MA
URCH	Urchin Sp.	M INV	UNIDENT
ACAN	Acanthaster Planci	M INV	UNIDENT
HOLO	Holothuriidae	M INV	UNIDENT
MINV	Other Mobile Inverts	M INV	UNIDENT
ZOAN	Zoanthid	INV	INV
TUNI	Tunicate	INV	INV
SPNG	Sponge	INV	INV
OCTO	Octocoral	INV	INV
BRYO	Bryozoan	INV	INV
ANEM	Anenome	INV	INV
OSIN	Other sessile inverts	INV	INV
REDC	Dead coral	DEAD C	SUB
SAND	Sand	SAND	SAND
RUBL	Rubble	SUB	SUB
BARR	Bare Rock	SUB	SUB
BHOL	Black Hole	NA	UNIDENT
BLGR	Blue green algae	BL GRN	BL GRN
TURF	Turf Algae	TURF	TURF
TAPE	Tape	TWS	UNIDENT
WAND	Wand	TWS	UNIDENT
Shadow	Shadow	TWS	UNIDENT
NOTES	***NOTES***	***NOTES***	***NOTES***
OD	*Other disease*	*DISEASE*	*DISEASE*
TREM	*Trematodiasis*	*DISEASE*	*DISEASE*
PBD	*Pink Band Disease*	*DISEASE*	*DISEASE*
BLTP	*Part bleaching on tips*	*BLEACH*	*BLEACH*
BL	*Full bleaching*	*BLEACH*	*BLEACH*

APPENDIX III: Detailed information on the percent benthic cover per transect

a. Percent cover of all encountered coral species per transect per site. Codes for coral species are given in Appendix II.

Aggregate Reef Site (KAHO)

Transect	Total	Points I.D.'d	PCOM	PLUT	PLOB	PMEA	Coral <0.5%	LBEW	MCAP	MPAT	PDAM	PDUE	PVAR
ar1	840	799	21.3%	1.5%	34.9 %	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ar2	840	805	26.6%	0.0%	27.7 %	0.0%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%
ar3	840	812	15.6%	0.1%	40.0 %	0.1%	0.2%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%
ar4	840	805	17.5%	3.4%	39.8 %	1.1%	0.4%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%
ar5	840	811	13.7%	3.7%	45.5 %	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
arr1	840	819	9.0%	19.2 %	38.8 %	1.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
arr2	840	820	7.3%	4.5%	47.8 %	1.2%	0.6%	0.0%	0.6%	0.0%	0.0%	0.0%	0.0%
arr3	760	720	14.9%	1.1%	39.0 %	2.2%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%
arr4	840	817	18.6%	0.0%	40.9 %	0.1%	0.2%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%
arr5	840	799	9.1%	0.0%	39.0 %	1.1%	0.4%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%
		Mean	15.4%	3.3%	39.3 %	0.8%	0.2%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%
		SD	6.0%	5.8%	5.5%	0.7%	0.2%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%

Harbor North Site (KAHO)

Transect	Total	Points I.D.'d	PCOM	PLUT	PLOB	PMEA	Coral <0.5%	LBEW	MCAP	MPAT	PDAM	PDUE	PVAR
hn1	840	833	9.1%	0.0%	36.5 %	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
hn10	840	835	17.0%	0.0%	35.3 %	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
hn2	840	826	19.6%	1.6%	26.3 %	1.0%	0.2%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%
hn3	840	828	16.3%	1.4%	38.3 %	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%
hn4	840	814	24.8%	0.0%	27.4 %	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
hn5	840	829	4.1%	0.0%	38.4 %	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
hn6	840	833	28.3%	0.0%	32.9 %	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
hn7	840	837	22.9%	0.0%	27.2 %	2.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
hn8	840	830	3.6%	0.5%	55.9 %	2.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
hn9	880	870	5.4%	0.0%	44.3 %	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Mean	15.1%	0.4%	36.2	0.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

			PCOM	PLUT	PLOB	PMEA	Coral <0.5%	LBEW	MCAP	MPAT	PDAM	PDUE	PVAR
					%								
		SD	9.1%	0.6%	9.0%	1.0%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%

Harbor South Site, Noio Point (KAHO)

Transect	Total	Points I.D.'d	PCOM	PLUT	PLOB	PMEA	Coral <0.5%	LBEW	MCAP	MPAT	PDAM	PDUE	PVAR
HS10	840	831	0.0%	0.0%	15.9%	0.1%	1.2%	0.0%	1.2%	0.0%	0.0%	0.0%	0.0%
HS11	840	834	0.0%	2.2%	12.0%	11.5%	3.4%	0.7%	1.1%	1.6%	0.0%	0.0%	0.0%
HS2	840	838	0.1%	0.0%	16.5%	17.4%	1.2%	0.0%	1.1%	0.0%	0.1%	0.0%	0.0%
HS3	840	840	0.0%	0.0%	12.1%	30.1%	0.6%	0.0%	0.4%	0.0%	0.0%	0.0%	0.2%

Harbor South Site, Noio Pt (KAHO), continuation

Transect	Total	Points I.D.'d	PCOM	PLUT	PLOB	PMEA	Coral <0.5%	LBEW	MCAP	MPAT	PDAM	PDUE	PVAR
HS4	840	834	0.1%	0.0%	10.1%	21.1%	1.4%	0.0%	1.4%	0.0%	0.0%	0.0%	0.0%
HS5	840	831	0.0%	0.7%	13.0%	12.3%	1.1%	0.2%	0.8%	0.0%	0.0%	0.0%	0.0%
HS6	800	791	0.1%	0.0%	17.2%	14.7%	2.4%	0.0%	2.1%	0.0%	0.0%	0.3%	0.0%
HS7	840	825	0.1%	4.2%	17.1%	17.1%	1.6%	0.0%	1.1%	0.5%	0.0%	0.0%	0.0%
HS8	840	838	0.0%	0.8%	11.0%	13.2%	1.0%	0.4%	0.6%	0.0%	0.0%	0.0%	0.0%
HS9	840	830	0.8%	0.5%	13.9%	11.7%	2.7%	0.0%	2.7%	0.0%	0.0%	0.0%	0.0%
		Mean	0.1%	0.8%	13.9%	14.9%	1.6%	0.1%	1.2%	0.2%	0.0%	0.0%	0.0%
		SD	0.3%	1.4%	2.6%	7.7%	0.9%	0.2%	0.7%	0.5%	0.0%	0.1%	0.1%

Kaloko Reference Site (KAHO)

Transect	Total	Points I.D.'d	PCOM	PLUT	PLOB	PMEA	Coral <0.5%	LBEW	MCAP	MPAT	PDAM	PDUE	PVAR
k15	440	424	12.5%	66.3%	7.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
k16	440	426	12.9%	4.9%	42.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
k17	440	419	6.4%	21.5%	13.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
k18	440	429	9.3%	37.1%	17.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
k19	480	475	7.8%	35.6%	31.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
k21	440	419	9.8%	9.3%	42.2%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
k24	440	434	16.6%	22.1%	23.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
k26	440	430	4.0%	6.7%	33.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

k22	440	405	28.1%	13.3%	23.5%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
k23	440	422	7.1%	59.2%	10.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Mean	11.5%	27.6%	24.5%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		SD	6.9%	21.6%	12.4%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

PUHO Reference Site (PUHO)

Transect	Total	Points I.D.'d	PCOM	PLUT	PLOB	PMEA	Coral <0.5%	LBEW	MCAP	MPAT	PDAM	PDUE	PVAR
P11	440	422	0.8%	0.5%	13.9%	11.7%	2.7%	0.0%	2.7%	0.0%	0.0%	0.0%	0.0%
P13	440	428	10.0%	0.0%	34.4%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
P16	440	425	7.5%	0.0%	30.1%	0.5%	2.6%	0.0%	2.1%	0.5%	0.0%	0.0%	0.0%
P17	440	428	14.8%	0.0%	17.4%	0.0%	0.2%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%
P18	440	427	16.1%	0.0%	30.1%	0.0%	0.2%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%
P19	440	435	0.2%	4.0%	27.2%	4.9%	0.7%	0.0%	0.7%	0.0%	0.0%	0.0%	0.0%
P21	440	436	0.0%	0.0%	17.9%	5.1%	1.4%	0.0%	1.4%	0.0%	0.0%	0.0%	0.0%
P23	440	424	4.4%	0.0%	26.1%	2.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
P6	440	429	9.4%	0.0%	42.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
P7	440	439	0.7%	0.0%	19.3%	9.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
P9	440	433	0.0%	0.2%	20.0%	8.4%	2.1%	0.0%	0.7%	1.4%	0.0%	0.0%	0.0%
		Mean	5.8%	0.4%	25.3%	3.9%	0.9%	0.0%	0.7%	0.2%	0.0%	0.0%	0.0%
		SD	6.1%	1.2%	8.5%	4.3%	1.1%	0.0%	0.9%	0.4%	0.0%	0.0%	0.0%

b. Percent algal cover per transect per site. Codes for algal species are given in Appendix II**.** Total MA = total Macro Algae, which is the sum of all macro algae species to the right of the column.

Aggregate Reef Site (KAHO)

Transect	Total	Points I.D.'d	BL GRN	CCA	Turf	Total MA	ASPA	DICT	DVER	GOOYE	LVAR	UNGR	UNRD
ar1	840	799	0.0%	12.9%	27.0%	0.25%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
ar2	840	805	0.0%	12.5%	32.8%	0.37%	0.00%	0.12%	0.00%	0.00%	0.00%	0.00%	0.12%
ar3	840	812	0.0%	13.4%	28.9%	0.00%	0.00%	0.00%	0.12%	0.00%	0.00%	0.25%	0.00%
ar4	840	805	0.0%	9.3%	28.6%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
ar5	840	811	0.0%	8.5%	28.5%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
arr1	840	819	0.0%	8.3%	23.0%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
arr2	840	820	0.0%	6.3%	25.9%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
arr3	760	720	0.0%	7.1%	30.8%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
arr4	840	817	0.0%	7.6%	32.1%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
arr5	840	799	0.0%	10.0%	36.0%	0.06%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		Mean	0.0%	9.6%	29.4%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		SD	0.0%	2.5%	3.7%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%

Harbor North Site (KAHO)

Transect	Total	Points I.D.'d	BL GRN	CCA	Turf	Total MA	ASPA	DICT	DVER	GOOYE	LVAR	UNGR	UNRD
hn1	840	833	0.0%	6.2%	25.5%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
hn10	840	835	0.4%	8.6%	30.9%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
hn2	840	826	0.0%	5.3%	37.5%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
hn3	840	828	0.0%	6.5%	31.9%	0.12%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
hn4	840	814	0.1%	5.8%	15.4%	0.00%	0.12%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
hn5	840	829	0.0%	5.5%	46.9%	0.84%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
hn6	840	833	0.1%	1.1%	15.8%	0.12%	0.84%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
hn7	840	837	0.4%	2.6%	30.6%	0.00%	0.12%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
hn8	840	830	0.0%	3.5%	25.4%	0.23%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
hn9	880	870	0.3%	4.6%	31.1%	0.13%	0.23%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		Mean	0.1%	5.0%	29.1	0.1%	0.13	0.00%	0.00	0.00%	0.00	0.00%	0.00%

					%		%		%		%		
		SD	0.2%	2.1%	9.4%	0.3%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Harbor South Site, Noio Point (KAHO)

Transect	Total	Points I.D.'d	BL GRN	CCA	Turf	Total MA	ASPA	DICT	DVER	GOOYE	LVAR	UNGR	UNRD
HS10	840	831	1.4%	5.8%	72.7%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
HS11	840	834	1.1%	3.4%	65.6%	0.12%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
HS2	840	838	3.1%	8.2%	52.0%	0.00%	0.00%	0.12%	0.00%	0.00%	0.00%	0.00%	0.00%
HS3	840	840	1.8%	6.5%	45.6%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
HS4	840	834	0.7%	3.4%	60.4%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
HS5	840	831	1.3%	6.4%	64.7%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
HS7	840	825	1.6%	1.1%	54.3%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Harbor South Site (KAHO), continuation

Transect	Total	Points I.D.'d	BL GRN	CCA	Turf	Total MA	ASPA	DICT	DVER	GOOYE	LVAR	UNGR	UNRD
HS8	840	838	0.5%	3.3%	68.9%	0.12%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
HS9	840	830	0.8%	3.0%	65.2%	0.02%	0.12%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		Mean	1.4%	4.7%	60.7%	0.0%	0.01%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%
		SD	0.8%	2.2%	8.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Kaloko Reference Site (KAHO)

Transect	Total	Points I.D.'d	BL GRN	CCA	Turf	Total MA	ASPA	DICT	DVER	GOOYE	LVAR	UNGR	UNRD
k15	440	424	0.0%	0.7%	12.3%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
k16	440	426	0.0%	0.9%	24.9%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
k17	440	419	0.0%	1.7%	48.0%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
k18	440	429	0.2%	2.6%	26.1%	0.21%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
k19	480	475	0.0%	4.4%	18.9%	0.00%	0.00%	0.00%	0.00%	0.21%	0.00%	0.00%	0.00%
k21	440	419	0.2%	2.6%	14.8%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
k24	440	434	0.0%	1.4%	31.3%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
k26	440	430	0.2%	6.5%	48.1%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
k22	440	405	0.0%	3.5%	14.3%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
k23	440	422	0.0%	3.1%	13.7%	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

		Mean	0.1%	2.7%	25.3%	0.0%	0.00%	0.00%	0.00%	0.02%	0.00%	0.00%	0.00%
		SD	0.1%	1.8%	13.5%	0.1%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%

PUHO Reference Site (PUHO)

Transect	Total	Points I.D.'d	BL GRN	CCA	Turf	Total MA	ASPA	DICT	DVER	GOOYE	LVAR	UNGR	UNRD
P11	440	422	0.8%	3.0%	65.2%	2.37%	0.12%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
P13	440	428	0.0%	15.4%	35.1%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.37%
P16	440	425	0.0%	8.4%	48.8%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
P17	440	428	0.0%	6.1%	59.3%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
P18	440	427	0.0%	14.3%	38.1%	0.23%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
P19	440	435	0.2%	8.4%	53.4%	0.00%	0.00%	0.00%	0.00%	0.23%	0.00%	0.00%	0.00%
P21	440	436	0.0%	6.4%	64.4%	2.06%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
P23	440	424	0.5%	21.6%	42.9%	0.24%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.06%
P6	440	429	0.0%	19.1%	28.8%	0.00%	0.00%	0.24%	0.00%	0.00%	0.00%	0.00%	0.00%
P7	440	439	0.0%	15.4%	54.8%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
P9	440	433	0.2%	11.6%	56.5%	0.46%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		Mean	0.2%	11.8%	49.7%	0.5%	0.01%	0.02%	0.00%	0.02%	0.00%	0.00%	0.40%
		SD	0.3%	5.8%	12.1%	0.9%	0.0%	0.1%	0.0%	0.1%	0.0%	0.0%	0.9%

c. Percent cover sessile invertebrates and available substrate for colonization per transect per site in 2006. INV = sessile invertebrates; OCTO = octocoral; BARR = bare rock; and RUBL = rubble**.**

Aggregate Reef Site (KAHO)

Transect	Total	Points Identified	INV:OCTO	SAND	BARR	RUBL
ar1	840	799	0.0%	1.8%	0.0%	0.1%
ar2	840	805	0.0%	0.0%	0.0%	0.0%
ar3	840	812	0.0%	1.1%	0.0%	0.0%
ar4	840	805	0.0%	0.0%	0.0%	0.0%
ar5	840	811	0.0%	0.1%	0.0%	0.0%
arr1	840	819	0.0%	0.5%	0.0%	0.0%
arr2	840	820	4.4%	2.0%	0.0%	0.0%
arr3	760	720	4.7%	0.0%	0.0%	0.0%
arr4	840	817	0.0%	0.5%	0.0%	0.0%
arr5	840	799	4.0%	0.0%	0.3%	0.0%
		Mean	1.3%	0.6%	0.0%	0.0%
		SD	2.1%	0.8%	0.1%	0.0%

Harbor North Site (KAHO)

Transect	Total	Points Identified	INV:OCTO	SAND	BARR	RUBL
hn1	840	833	21.7%	0.8%	0.1%	0.0%
hn10	840	835	6.9%	0.2%	0.1%	0.0%
hn2	840	826	7.6%	0.8%	0.0%	0.0%
hn3	840	828	3.9%	0.6%	0.0%	0.7%
hn4	840	814	26.4%	0.0%	0.0%	0.0%
hn5	840	829	1.4%	3.5%	0.0%	0.0%
hn6	840	833	20.8%	0.0%	0.0%	0.0%
hn7	840	837	13.3%	0.7%	0.0%	0.0%
hn8	840	830	7.1%	1.2%	0.0%	0.0%
hn9	880	870	13.7%	0.2%	0.1%	0.0%
		Mean	12.3%	0.8%	0.0%	0.1%
		SD	8.4%	1.0%	0.1%	0.2%

Harbor South Site, Noio Point (KAHO)

Transect	Total	Points Identified	INV:OCTO	SAND	BARR	RUBL
HS10	840	831	1.0%	1.4%	0.0%	0.4%
HS11	840	834	1.0%	0.0%	0.0%	0.0%
HS2	840	838	0.0%	1.2%	0.1%	0.0%
HS3	840	840	0.5%	2.7%	0.0%	0.0%
HS4	840	834	0.0%	2.6%	0.0%	0.0%
HS5	840	831	0.0%	0.1%	0.4%	0.0%
HS6	800	791	0.3%	0.0%	0.0%	0.0%

Harbor South Site, Noio Point (KAHO), continuation						
Transect	Total	Points Identified	INV:OCTO	SAND	BARR	RUBL
HS7	840	825	0.4%	2.5%	0.0%	0.0%
HS8	840	838	0.4%	0.2%	0.0%	0.7%
HS9	840	830	0.2%	1.0%	0.1%	0.0%
		Mean	0.4%	1.2%	0.1%	0.1%
		SD	0.4%	1.1%	0.1%	0.2%

KAHO Reference Site (KAHO)						
Transect	Total	Points Identified	INV:OCTO	SAND	BARR	RUBL
k15	440	424	0.5%	0.0%	0.0%	0.0%
k16	440	426	13.4%	0.7%	0.0%	0.0%
k17	440	419	3.3%	5.7%	0.0%	0.0%
k18	440	429	7.5%	0.0%	0.0%	0.0%
k19	480	475	1.9%	0.0%	0.0%	0.0%
k21	440	419	11.9%	8.8%	0.0%	0.0%
k24	440	434	0.9%	3.9%	0.0%	0.0%
k26	440	430	1.4%	0.0%	0.0%	0.0%
k22	440	405	16.5%	0.5%	0.0%	0.0%
k23	440	422	5.9%	0.0%	0.0%	0.0%
		Mean	6.3%	2.0%	0.0%	0.0%
		SD	5.8%	3.1%	0.0%	0.0%

PUHO Reference Site (PUHO)						
Transect	Total	Points Identified	INV:OCTO	SAND	BARR	RUBL
P11	440	422	0.2%	1.0%	0.1%	0.0%
P13	440	428	0.0%	2.4%	0.0%	0.0%
P16	440	425	0.0%	2.1%	0.0%	0.0%
P17	440	428	0.0%	2.1%	0.0%	0.0%
P18	440	427	0.5%	0.7%	0.0%	0.0%
P19	440	435	0.2%	0.5%	0.0%	0.0%
P21	440	436	0.0%	4.8%	0.0%	0.0%
P23	440	424	0.0%	0.0%	0.0%	0.0%
P6	440	429	0.0%	0.5%	0.0%	0.0%
P7	440	439	0.0%	0.0%	0.0%	0.0%
P9	440	433	0.0%	0.9%	0.0%	0.0%
		Mean	0.1%	1.4%	0.0%	0.0%
		SD	0.2%	1.4%	0.0%	0.0%

APPENDIX IV A: Kaloko-Honokōhau NHP, harbor preliminary algal species list

In the summer of 2006 Cheryl Squair of the University of Hawai‘i at Mānoa, conducted a qualitative and quantitative macroalgae survey at 10 and 20 m depth. Preliminary results of the random sampling locations in the vicinity of transect locations of the harbor benthic baseline study are compiled below (Fig. A4, algae sampling areas of interest are within the yellow circles).

Functional forms
Filamentous turf
Wiry Turf
Crustose Coralline Algae (Non-geniculate)
Brown crusts
Blue-green algae (Cyanophyta)

Chlorophyta
Dictyosphaeria cavernosa
Halimeda discoidea
Halimeda opuntia
Microdictyon sp.
Neomeris sp.

Rhodophyta
Asparagopsis taxiformis
Gibsmithia sp.
Laurencia sp.
Peyssonnelia sp.

Phaeophyta
Dictyota sp.
Lobophora variegata
Padina sp.
Stypopodium flabelliforme
Turbinaria ornate

Asparagopsis taxiformis (pink) grows at the basis of *Porites compressa* in the Aggregate Reef zone just outside the Honokōhau Small Boat Harbor

APPENDIX IV B: Puʻuhonoua o Hōnaunau preliminary algal species list

Inventory of algal species close to sampling locations of the PUHO reference site for harbor benthic baseline study, conducted by Cheryl Squair of the University of Hawaiʻi at Manoa in the summer of 2006. Presented macroalgal species are from 10 and 20-meters deep, random sampling locations (Fig. A4).

Functional Groups
Filamentous turf
Wiry Turf
Crustose Coralline Algae (Geniculate)
Crustose Coralline Algae (Non-geniculate)
Brown crusts
Blue-green algae (Cyanophyta)

Chlorophyta
Caulerpa sp.
Caulerpa racemosa
Caulerpa serrulata
Halimeda opuntia
Neomeris sp.
Rhipidosiphon javensis
Ventricaria ventricosa

Rhodophyta
Amansia sp.
Asparagopsis taxiformis
Galaxaura marginata
Galaxaura sp.
Gelids
Gibsmithia sp.
Liagora sp.
Laurencia sp.
Peyssonnelia sp.
Portieria hornmannii
Predaea sp.

Phaeophyta
Dictyopteris sp.
Dictyota sp.
Lobophora variegata
Padina sp.
Stypopodium flabelliforme
Turbinaria ornata

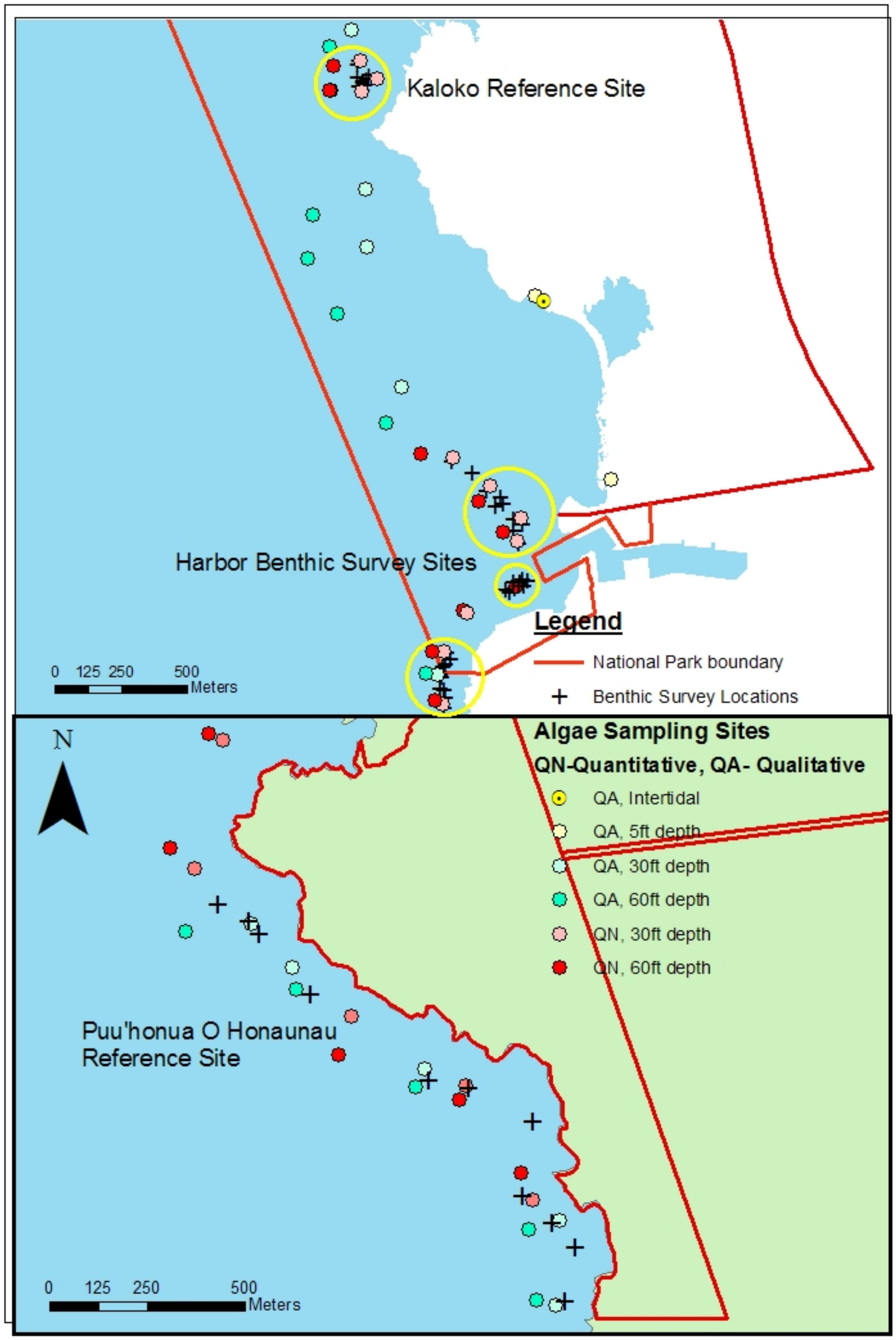

Figure A4. Sampling locations of macroalgae and benthic substrate at Kaloko-Honokōhau and Pu‘uhonua o Honaunau NHP in 2006-2007. Algal surveys conducted by Cheryl Squair, University of Hawai‘i-Mānoa. Preliminary list of encountered algal species from sampling locations within yellow circles for Kaloko-Honokōhau NHP and from all sampling locations for Pu‘uhonoua o Hōnaunau NHP given in text.