# Kaneohe Bay Mitigation Bank Monitoring Plan

Project Goal

The overall goal of this monitoring plan is to evaluate the effectiveness of the mitigation bank invasive algae control efforts (mechanical removal and urchin biocontrol) for restoration of coral reefs in Kaneohe Bay. More specifically, we will investigate whether coral cover can be increased by invasive algae management techniques and to what extent. In addition, we will monitor invasive algae density to evaluate the effectiveness of mechanical removal and biocontrol. Further, we will photo document changes in individual coral colonies over time on mitigation reefs. The scope of this plan includes reef slope and reef flat habitats (excluding sand patches) of designated treatment patch reefs in Kaneohe Bay.

Questions of Interest

All questions of interest below will be compared between the control and treatment reefs and before and after the treatment (algae removal).

1. Coral:
    a. Does percent cover differ?
    b. Does size frequency by species differ?
2. Invasive algae:
    a. Does *Eucheuma spp.* and *Kappaphycus spp*. percent cover and canopy height differ?
    b. Does *Gracilaria salicornia* percent cover and canopy height differ?
3. Crustose coralline algae (CCA):
    a. Does percent cover of CCA differ?
4. Rugosity:
    a. Does rugosity differ?

Site selection

Mitigation bank restoration sites were selected by ranking patch reefs based on co-occurrence of coral and invasive algae. All distinct patch reefs in the bay (53 reefs in total) were evaluated for coral and invasive algae cover as possible inclusion into the mitigation bank. Initial evaluation was done using satellite imagery and past survey data. Reefs composed primarily of sand, low coral cover, and no known invasive algae cover were designated as "low priority" for invasive algae management. All other Kaneohe Bay patch reefs (41 reefs) were surveyed as part of a snapshot ("snap") assessment to estimate coral and invasive algae cover. These survey results are summarized in the "Kaneohe Bay Snap-Assessment Report" (2014). Survey data was inputted into ArcGIS software to map and prioritize reefs based on the co-occurrence of coral and invasive algae cover. Based on the prioritization results, the patch reefs were ranked from 1 to 41 (high to low) management priority. The top four, high priority patch reefs (Reefs 10, 15, 16, 19) were selected for inclusion into the mitigation bank (Figure 1).

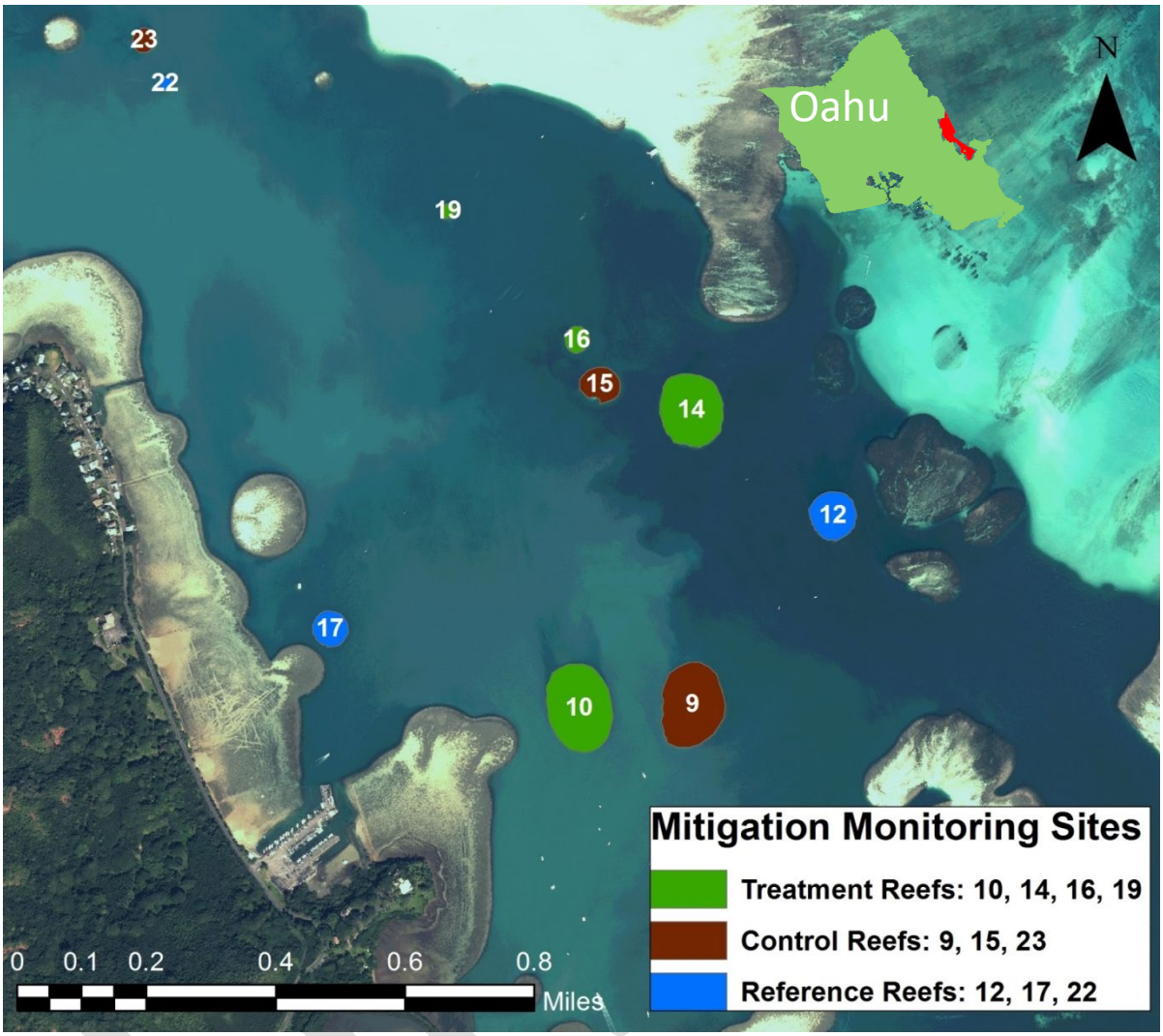


Figure 1. Kaneohe Bay, Oahu site map for mitigation bank treatment, control, and reference reefs to be included in the monitoring plan.

The survey data was also used to select control and reference reefs to include as monitoring sites for the mitigation bank. Three control reefs (Reefs 9, 15, 23) within a similar geographic proximity in the bay, reef area, habitat, coral and invasive algae cover were designated as control reefs. In contrast to the control site, the reference sites are unimpacted by invasive algae and will serve as a model system for setting post restoration goals in terms of coral and CCA cover. Three reference reefs (Reefs 12, 17, 22) with high coral cover but not impacted by invasive algae cover were designated as reference reefs.

Methods

***Sampling Design***

This sampling design is adapted from methods developed and tested by the Hawaii Division of Aquatic Resources (DAR), the Coral Reef Assessment and Monitoring Program (CRAMP), and The Nature

Conservancy of Hawaii. Field methods were tested and modified to maximize cost-effectiveness, statistical power and photo-documented results. This survey design contains three main components: fixed photoquadrat transects; permanent photo plots; and benthic habitat mapping.

***Fixed Transect Photoquadrats***

*Transects:* Fixed (10 m) transects will be established on treatment, control, and reference reefs (Figure 2). A stainless steel eye pin will be placed every 5 m along the transect tape. Transect locations will be based on a random stratified design. Each patch reef will be stratified by habitat type (reef slope and reef flat, and prominent wind direction. Large sand patches (>2 $m^2$) will be excluded from the survey area. The number of transects will be proportionate to the habitat area. Transect locations will be randomly selected within each habitat type using ArcGIS. Reef flat transects will run parallel to the reef slope. Reef slope transect locations will be randomly selected along a consistent slope contour, 30 cm below the average reef flat depth at mean lower low water (MLLW). The number of transect was based on a 0.80 power tests to detect a 15% increase in mean coral cover and an alpha of 0.1.

*Photos:* A camera raised 50 cm above the benthos, capturing a 50 x 40 cm image, will take photos every 0.5 m on both sides of the transect tape, totaling 40 photos per transect (Figure 2).

*Photo Analysis*: Photos will be uploaded into Coral Point Count with Excel extension (CPCe). Each photo will be analyzed with 20 stratified random points to estimate percent cover. The number of photoquads per transect and analysis points per photo were determined using power tests to optimize statistical power and work load. All biotic and abiotic benthos randomly selected in CPCe will be identified and recorded. Coral and macro algae will be identified to the lowest possible taxon.

*Invasive algae:* Percent cover of invasive algae and canopy height will be measured within each photoquadrat. One algae canopy height measurement will be taken to the nearest 1 cm. Surveyors will select the thickest areas of algae within the quadrat for the measurement.

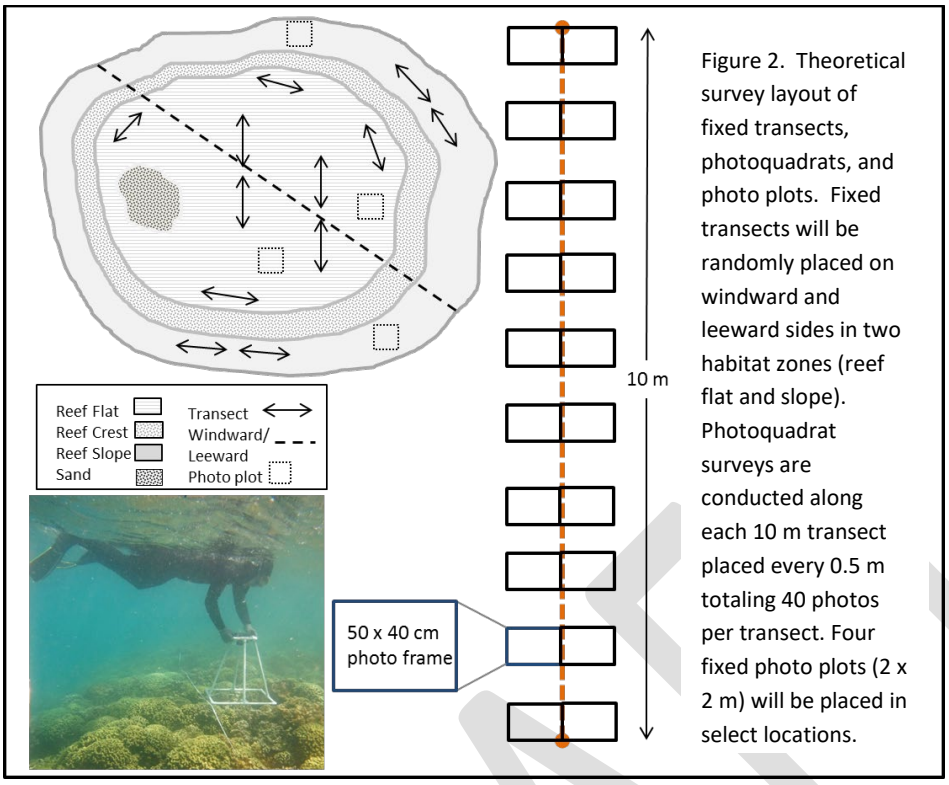


Figure 2. Theoretical survey layout of fixed transects, photoquadrats, and photo plots. Fixed transects will be randomly placed on windward and leeward sides in two habitat zones (reef flat and slope). Photoquadrat surveys are conducted along each 10 m transect placed every 0.5 m totaling 40 photos per transect. Four fixed photo plots (2 x 2 m) will be placed in select locations.

**Rugosity**

Rugosity will be measured along each 10 m transect. A brass chain partitioned into 1 m increments will be carefully placed, following the entire bottom contour along the 10 m horizontal transect tape. The length of chain divided by the 10 m horizontal tape will be used as an index of rugosity.

**Photo Plots**

*Photo documentation:* Fixed photo plots (2 x 2 m) will be placed in four locations (non-random) on the reef flat and reef slope. These plots will serve as demonstrative plots where changes specific to individual coral colonies will be photo documented. A series of 50 x 40 cm photos will be stitched together to capture the entire 2 x 2 m plot. A reference scale will be captured in each image to allow further digital analysis of coral colonies and partial mortality.

*Coral Sizing*: Each coral colony with its geometric center bounded by the quadrat (2 x 2 m) will be identified to the lowest possible taxon and binned according to eight coral colony size classes (Table 1). Each coral will be measured along the longest axis. Individual coral colonies will be defined as a single skeletal mass with living tissue (Nugues and Roberts 2003). Separate colonies will be distinguished based on a color, morphology, tissue and skeletal boundary separation (TNC 2013). If it is not possible to distinguish an individual coral colony, the presence will be noted, but no measurement will be recorded.

Table 1. Coral size classes.

| Size Classes | Size Classes |
|---|---|
| 0.1 to 5 cm | 20.1 to 40 cm |
| 5.1 to 10 cm | 40.1 to 80 cm |
| 10.1 to 20 cm | 80.1 to 160 cm |

**Benthic Habitat mapping**

Surveyors will conduct a survey using techniques described in the "Kaneohe Bay Snap-Assessment Report" (DAR 2014) with modifications to increase the sample density to 5 m and incorporate more habitat features. Surveyors, spaced approximately 5 m apart, will swim transects across the reef and place a 0.5 m measuring stick haphazardly every 5 m and take a GPS waypoint. Surveyors will survey the entire patch reef, recording percent cover of live coral, *Eucheuma/Kappaphycus, Gracilaria/Acanthophora,* sand, rubble, and hard bottom, based on the benthic composition below the measuring stick. Percent cover is categorized into five cover classes (0%, 1-10%, 11-50%, 51-75%, 76-100%). Reef habitat will be mapped in ArcGIS and percent cover of coral and algae will be estimated.

**Fish Surveys**

Visual fish census estimates will be conducted along belt transects (5 x 25 m). Belt transects will be located on two adjoining photo quadrat transects on reef flat and slope habitats. Surveyors will swim transects recording fish species and size class.

**Coral Outplanting**

All coral colonies outplanted to the reef will be measured (height and width) and photo documented.

**Sampling Frequency**

Treatment, control, and reference reefs will be sampled within the same two-week period. Sampling will be conducted in the summer (July) and winter (January) annually. In addition to semi-annual surveys, each set of reefs will be sampled before and after algae removal.

**Analysis**

A BACI (Before-After, Control-Impact) analysis (Stewart-Oaten et al. 1986) will be used to examine the Before (algae removal) and After (post-algae removal) condition of patch reefs, in addition to Control (reefs 9, 15, 23) and Impact (treatment reefs 10, 14, 16, 19) sites. Further, reference sites will be compared with the treatment sites and used to set post restoration goals. Coral recruitment and re-growth of partial mortality will be evaluated by species in terms of percent cover, number of colonies, and size frequency.

**Literature Cited**

Neilson, B., J. Blodgett, C. Gewecke, B. Stubbs, K. Tejchma. 2014. Kaneohe Bay, Oahu Snap-Assessment Report. Hawaii Division of Aquatic Resources Technical Report.

The Nature Conservancy of Hawaii. 2013. Kaneohe Supersucker Monitoring Protocol. The Nature Conservancy of Hawaii Technical Report.

Nugues, M.M., C.M. Roberts. 2003. Coral mortality and interaction with algae in relation to sedimentation. Coral Reefs 22 (4), 507-516.

Stewart-Oaten, A. W.W. Murdoch, K.R. Parker. 1986. Environmental impact assessment: pseudoreplication in time? Ecology 67:929-940.