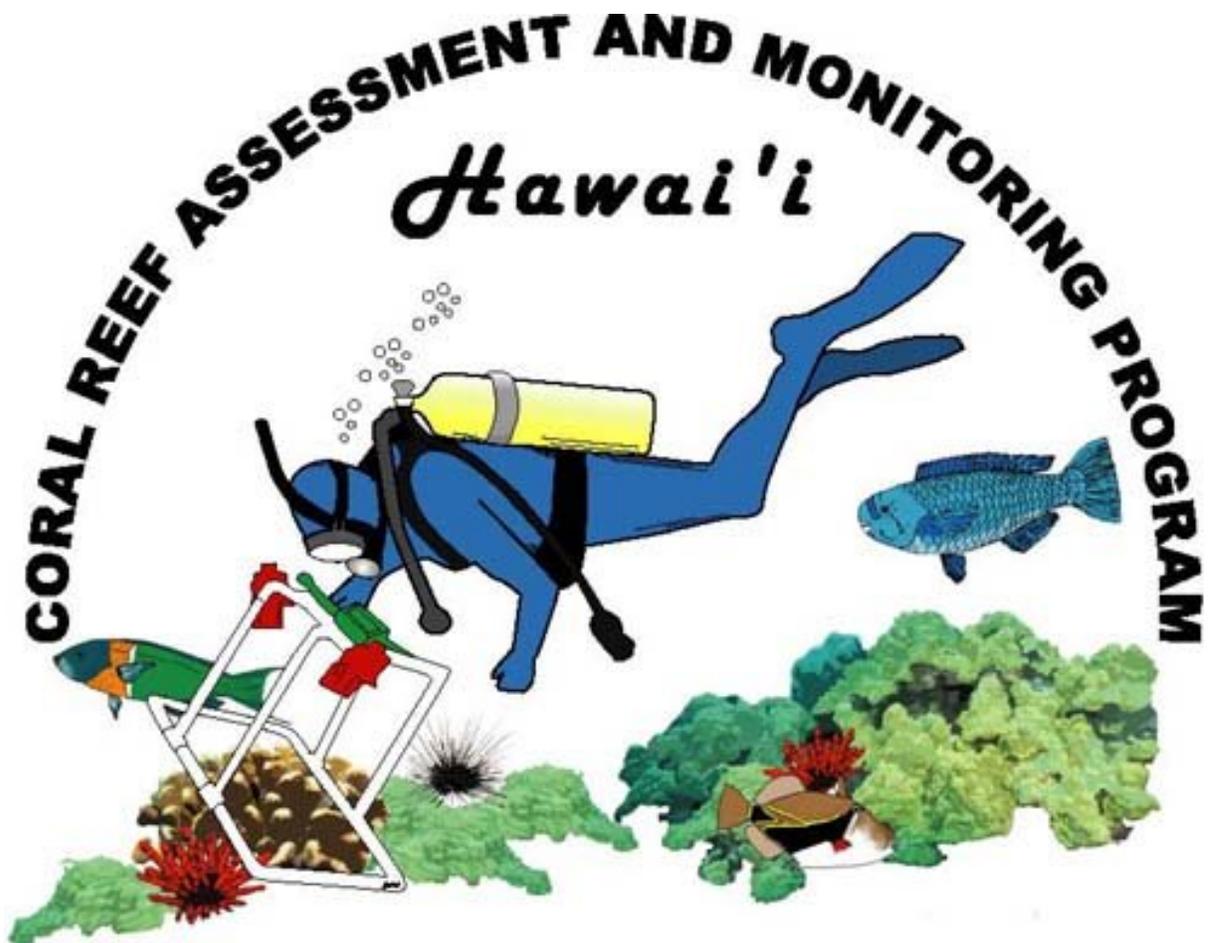


Hawai'i Coral Reef Assessment and Monitoring
Program
Quality Assurance Project Plan



1 August, 2008

Development of Coral Reef Biocriteria for Hawai'i

Principal Investigator: Paul Jokiel

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EPA Project Manager
CRAMP Monitoring Team

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CRAMP Monitoring Team: Dr. Paul Jokiel, Dr. Ku‘ulei Rodgers, Ann Farrell
Hawai‘i Department of Health: Linda Koch

1.0 PROJECT DESCRIPTION

1.1 Project Purpose and Problem Definition

The purpose of this project is to develop coral reef biological criteria for the State of Hawai‘i working with the Hawai‘i Department of Health , and the Hawai‘i Division of Aquatic Resources to bring current activities into line with the emerging U.S. EPA “Development of Assessment Tools for Coral Reef Biocriteria” program at the national level. This assessment of function of coral reefs will include reefs within the main Hawaiian Islands (MHI). Biocriteria will be used to develop a model using an Index of Biotic Integrity (IBI) to assess reef condition.

1.1.1 Project Goals

Project goals include:

- Refine and extend previous work on biocriteria: Working in close association with State and Federal resource managers with the intent of eventually reaching consensus on establishment of biocriteria standards for Hawai‘i will be a priority. This must be based on an iterative process with feedback from the agency personnel at various points along the way in biocriteria development.
- Addition of additional sensitive bioindicators: Coral recruitment, growth and mortality based on analysis of existing CRAMP photoquad data will be explored. These data are needed in order to define the relationship between water quality, watershed characteristics and condition of the living coral reef communities.
- Integration of Project with Regional Watershed Planning: Key watershed metrics have been an important part of the initial biocriteria and IBI analyses (Rodgers 2005) and will continue to be vital components of analyses undertaken in this project. Watershed area, human population on the watershed, watershed condition and watershed uses are all metrics that will be incorporated. We will work closely with Hawai‘i’s Local Action Strategy to Address Land-based Pollution Threats to Coral Reefs (CRLBP LAS). LAS has listed the development of a long-term monitoring program using pollution sensitive indicators as a priority area.
- Addressing Regional Priorities: Development of biocriteria is a priority for Hawai‘i which is not currently being addressed by State agencies due to lack of resources, although there is interest in moving ahead in this area. This project will provide leadership and give the State of Hawai‘i the opportunity to begin the process of developing biological criteria which is already moving ahead in other Region 9 Pacific island areas. The project will provide input to these areas through networking with the Commonwealth of the Northern Mariana Islands under Peter Houck, in Guam under Mike Gawel and in American Samoa under Edna Buchan and Mike Gawel. We also anticipate networking with Lesa Meng and others who are in the process of developing IBI metrics for the Caribbean.
- Addressing National Priorities by strengthening comprehensive state/tribal comprehensive wetland programs in all five major areas:
 - 1) Regulation; The development and implementation of biological criteria to the Hawai‘i State water quality standards will add an additional dimension that will strengthen regulation.

- 2) Monitoring and Assessment; Determination of which of the many possible metrics is most important in defining coral reef health will simplify and strengthen monitoring and assessment activities. Only the most relevant metrics need to be assessed or monitored.
- 3) Restoration; Defining the key metrics of a healthy coral reef system in a given habitat will enable agencies to set standards for restoration. Biological criteria can define the end point of a restored coral reef and allow standards to be set to govern such restoration.
- 4) Water Quality Standards; Preliminary work (Rodgers 2005) demonstrated that sites that scored the lowest using biological criteria were all on the “most impaired” site list that was established using water quality criteria. Therefore, biological criteria hold promise of supporting and strengthening the value of water quality standards.
- 5) Public – Private Partnerships; CRAMP has formed a number of effective partnerships in both the public and private sectors. In the private sector we are working closely with the Hanalei Watershed Hui and Limahuli Garden on issues regarding coral reefs.
- 6) Coordination with other water programs; This project will rely heavily on interaction with the State of Hawai‘i regulatory agencies that are responsible for setting biocriteria. Also, we will need to continually interact with programs developing and using biocriteria in American Samoa, CNMI, Guam and the Caribbean.

All of the work done under the proposed project will be carried out within the framework of the Hawai‘i Coral Reef Assessment and Monitoring Program (CRAMP), which has been monitoring Hawai‘i’s coral reefs throughout the state since 1998. Additional information gathered during this project will expand and strengthen the CRAMP efforts in the fields of monitoring and assessment.

1.1.2 Measurement of Success

Measures of Success of this Project:

- The primary standard for measuring success of this project will be the degree of progress towards the establishment of biocriteria for coral reefs as part of the State of Hawai‘i water quality program.
- The inclusion of project evaluation seminars will give us an interim mechanism for evaluation and will allow us to avoid possible pitfalls.
- Other tangible evidence of success will be the availability of the completed model, expanded data base, final report and journal articles. All of these will be widely available. The completed IBI and the complete data base will be available as a working IBI model in Microsoft Excel[®] available on CD or downloadable from the CRAMP web site (<http://cramp.wcc.hawaii.edu/>).

1.1.3 Anticipated Accomplishments

Relevant Applications:

- This project will promote the development and implementation of biocriteria in the State of Hawai‘i and thereby improve the ability of the regulatory agencies to protect the environment.
- The development and testing of a multivariate statistical model to predict conditions at sites not previously surveyed will be valuable in establishing management priorities, regional policy and evaluation of existing programs in the Hawaiian Islands. Application of a model would allow management to implement a preventative approach to environmental degradation.
- Baseline conditions for biological communities will be established. These data will provide a foundation for investigating spatial and temporal change and elucidate the need for protection of future designated marine protected areas and sanctuaries in Hawai‘i.

Quality assurance when generating data is an important part of CRAMP activities. To ensure the data generated and used by EPA, DOH and other state and federal agencies, and non-governmental organizations are of known quality and are scientifically valid, CRAMP will follow rigorous procedures in sampling, analyzing, and conducting quality control.

1.2 Project Area Description

A wide suite of factors have been evaluated (Table 1) at 184 transect locations (stations) at 52 sites throughout the MHI (Figure 1). These data will be used to fully develop biological criteria for the state. Station locations can be found in Table 2. Transect numbers for long-term monitoring Coral Reef Assessment and Monitoring (CRAMP) stations are by depth in meters (eg. 3=3m). Rapid Assessment Transects (RAT) stations are numbered in the order they were surveyed due to considerable overlap in depth. Often surveys at stations at the same site were conducted at identical depths.

CRAMP stations are located at long-term monitoring sites to track temporal changes. There are ten 10m benthic transects at each station and four 25m fish transects. RAT stations are an abbreviated version of the CRAMP transects designed to cover a larger spatial area. RAT's include one 10m benthic transect and one 25m fish transect. This assessment technique is robust enough to detect relationships among environmental factors and spatial distributions of reef organisms but not designed to detect changes over time. This RAT protocol was designed to produce quantitative spatial data, consistent and comparable to data recorded at the CRAMP permanent monitoring sites. At both CRAMP and RAT transects depth and topographic relief is recorded and sediments collected.

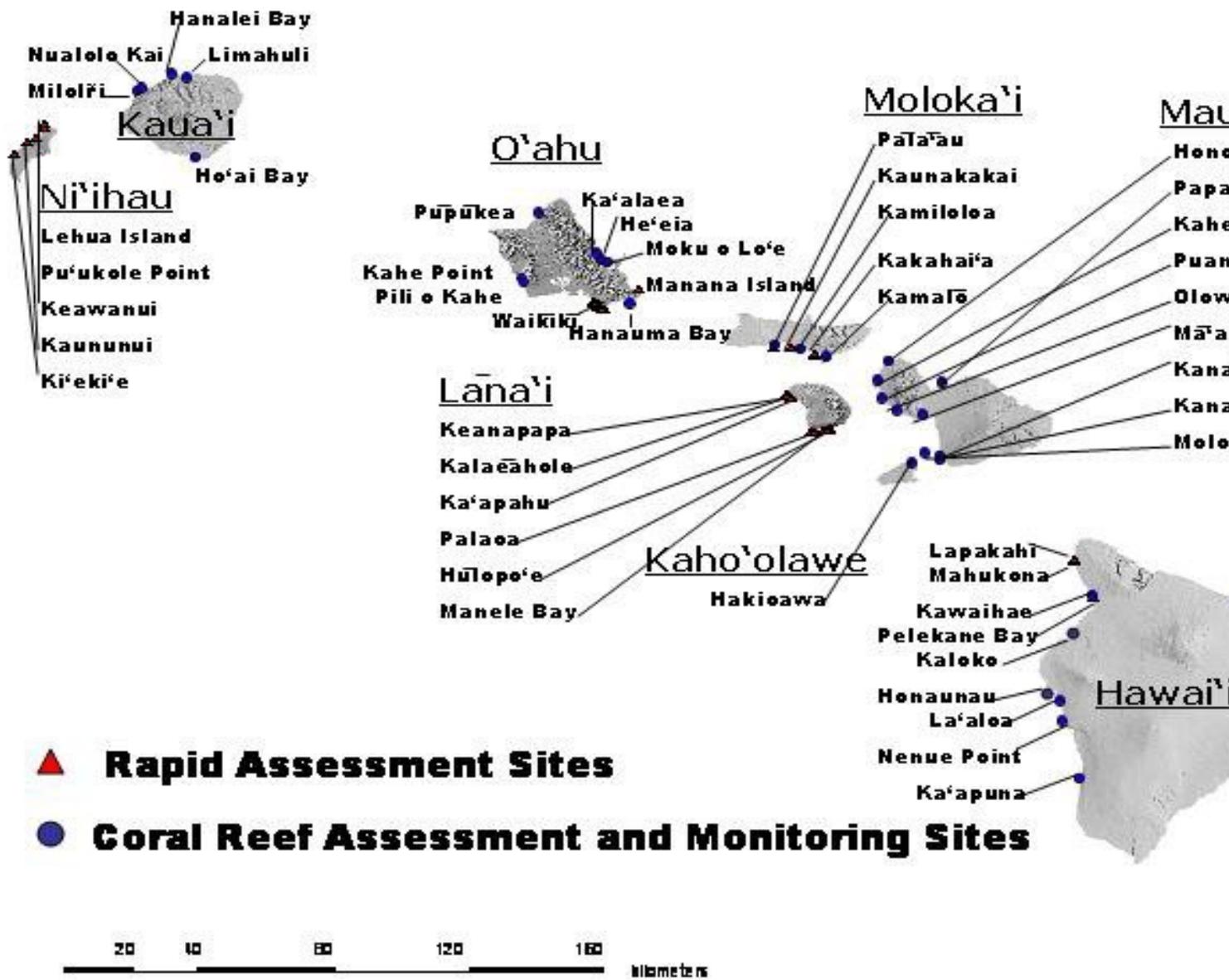


Figure 1 Map of the main Hawaiian Islands showing the reef sites involved in this study. A large body of information on the benthos, reef fish communities, physical environment and watershed characteristics have already been developed for each of these sites and will be used as the starting point of this project.

Table 2 Geographic locations in latitude/longitude for all stations used in development of biocriteria for coral reefs in Hawai'i.							
Site Name	transect	latitude	longitude	Site Name	transect	latitude	longitude
Waikiki	2 RAT	21.260742	-157.829437	Palaoa	4 RAT	20.732122	-156.960351
Waikiki	14 RAT	21.282131	-157.843301	Hulopoe	1 RAT	20.729997	-156.953228
Waikiki	19 RAT	21.250378	-157.799597	Hulopoe	2 RAT	20.733248	-156.949392
Waikiki	24 RAT	21.276219	-157.834991	Kaloko	1 RAT	19.664503	-156.032164
Waikiki	31 RAT	21.257872	-157.828505	Kaloko	2 RAT	19.687830	-156.036499
Waikiki	33 RAT	21.273512	-157.839311	Kaloko	3 RAT	19.686498	-156.035666
Waikiki	38 RAT	21.249226	-157.811671	Kaloko	4 RAT	19.692333	-156.045662
Waikiki	42 RAT	21.264530	-157.827258	Kaloko	5 RAT	19.681667	-156.035002
Waikiki	4 RAT	21.272565	-157.831637	Kaloko	6 RAT	19.675504	-156.034668
Waikiki	22 RAT	21.274340	-157.832288	Kaloko	7 RAT	19.690164	-156.039001
Waikiki	27 RAT	21.252464	-157.809747	Kaloko	8 RAT	19.670663	-156.030163
Keanapapa	1 RAT	20.888888	-157.062505	Kaloko	9 RAT	19.674167	-156.033501
Keanapapa	2 RAT	20.888851	-157.062429	Kaloko	10 RAT	19.671501	-156.031168
Keanapapa	3 RAT	20.889028	-157.062100	Kaloko	11 RAT	19.670000	-156.028832
Keanapapa	4 RAT	20.888703	-157.062133	Kaloko	12 RAT	19.689021	-156.038117
Keanapapa	5 RAT	20.889080	-157.061859	Kaloko	13 RAT	19.675261	-156.035244
Keanapapa	6 RAT	20.889051	-157.061744	Kaloko	14 RAT	19.678666	-156.035353
Kalaeahole	1 RAT	20.877416	-157.053629	Kaloko	15 RAT	19.673375	-156.031991
Kalaeahole	2 RAT	20.877344	-157.053611	Kaloko	16 RAT	19.679358	-156.034053
Kalaeahole	3 RAT	20.878020	-157.053535	Kaloko	17 RAT	19.668387	-156.027890
Kalaeahole	4 RAT	20.877912	-157.053546	Honaunau	1 RAT	19.414062	-155.908066
Kaapahu	1 RAT	20.865816	-157.041440	Honaunau	2 RAT	19.419895	-155.915548
Kaapahu	2 RAT	20.865846	-157.041757	Honaunau	3 RAT	19.423420	-155.913692
Kaapahu	3 RAT	20.865815	-157.041392	Kaapuna	4 CRAMP	19.269974	-155.893775
Kaapahu	4 RAT	20.865794	-157.041152	Kaapuna	10 CRAMP	19.269972	-155.894145
Kaapahu	5 RAT	20.866662	-157.041996	Kawaihae	3 CRAMP	20.028791	-155.832499
Kaapahu	6 RAT	20.866827	-157.042176	Kawaihae	10 CRAMP	20.027849	-155.834351
Kaapahu	7 RAT	20.866652	-157.041938	Laaloa	3 CRAMP	19.589162	-155.972121
Kaapahu	8 RAT	20.866722	-157.041688	Laaloa	10 CRAMP	19.589131	-155.972950
Kakahaia	1 RAT	21.047906	-156.944458	Laupahoehoe	3 CRAMP	19.990941	-155.239161
Kakahaia	2 RAT	21.049198	-156.940775	Laupahoehoe	10 CRAMP	19.991240	-155.238810
Kakahaia	3 RAT	21.047839	-156.944873	Lelewi	3 CRAMP	19.733860	-155.017922
Kakahaia	4 RAT	21.050302	-156.943935	Lelewi	10 CRAMP	19.734397	-155.018147
Kakahaia	5 RAT	21.053699	-156.945581	Nenue	5 CRAMP	19.512218	-155.957877
Kakahaia	6 RAT	21.055468	-156.947722	Nenue	10 CRAMP	19.511802	-155.958399
Kakahaia	7 RAT	21.051165	-156.948127	Hanalei Bay	3 CRAMP	22.210926	-159.512125
Kakahaia	8 RAT	21.049635	-156.938085	Hanalei Bay	8 CRAMP	22.210837	-159.511756
Kakahaia	9 RAT	21.057119	-156.950585	Hoai	3 CRAMP	21.879283	-159.474567
Kamiloloa	1 RAT	21.062764	-156.996008	Hoai	10 CRAMP	21.878057	-159.473450
Kamiloloa	2 RAT	21.064334	-156.992812	Limahuli	1 CRAMP	22.224689	-159.575817
Kamiloloa	3 RAT	21.062859	-156.997171	Limahuli	10 CRAMP	22.226813	-159.575487
Kamiloloa	4 RAT	21.065501	-156.996039	Milolii	3 CRAMP	22.152398	-159.719401
Kamiloloa	5 RAT	21.068869	-156.997514	Milolii	10 CRAMP	22.153714	-159.719873
Kamiloloa	6 RAT	21.070631	-156.999838	Nualolo Kai	3 CRAMP	22.160740	-159.701870
Kamiloloa	7 RAT	21.065740	-156.991023	Nualolo Kai	10 CRAMP	22.163274	-159.702823
Kamiloloa	8 RAT	21.067600	-156.992470	Hakioawa	3 CRAMP	20.592518	-156.551066

Table 2. continued

Kamiloloa	9 RAT	21.067992	-157.000509	Hakioawa	10 CRAMP	20.592821	-156.550831
Kaunakakai	1 RAT	21.080257	-157.037643	Honolua N	3 CRAMP	21.015357	-156.639113
Palaau	1 RAT	21.082583	-157.108785	Honolua S	3 CRAMP	21.013829	-156.639608
Puhi Bay	1 RAT	19.732365	-155.047309	Kanahena B	1 CRAMP	20.617407	-156.437392
Puhi Bay	2 RAT	19.735523	-155.049412	Kanahena B	3 CRAMP	20.616897	-156.438321
Lapakahi	1 RAT	20.173866	-155.901921	Kahekili	3 CRAMP	20.936373	-156.693296
Lapakahi	2 RAT	20.174299	-155.900871	Kahekili	7 CRAMP	20.936657	-156.693638
Lapakahi	3 RAT	20.174799	-155.901607	Kanahena Pt	3 CRAMP	20.601428	-156.436959
Lapakahi	4 RAT	20.174226	-155.901322	Kanahena Pt	10 CRAMP	20.601154	-156.437999
Lapakahi	5 RAT	20.173270	-155.901379	Maalaea	3 CRAMP	20.789634	-156.510116
Lapakahi	6 RAT	20.173135	-155.901917	Maalaea	6 CRAMP	20.788873	-156.509927
Lapakahi	7 RAT	20.174309	-155.900421	Molokini Is	8 CRAMP	20.631476	-156.496576
Mahukona	1 RAT	20.184012	-155.901405	Molokini Is	13 CRAMP	20.632331	-156.496379
Mahukona	2 RAT	20.183472	-155.902554	Olowalu	3 CRAMP	20.808594	-156.611522
Mahukona	3 RAT	20.184021	-155.901415	Olowalu	7 CRAMP	20.805806	-156.612315
Mahukona	4 RAT	20.183914	-155.902029	Papaula Pt	4 CRAMP	20.921780	-156.426196
Mahukona	5 RAT	20.183249	-155.901659	Papaula Pt	10 CRAMP	20.924371	-156.426181
Mahukona	6 RAT	20.183995	-155.900995	Puamana	3 CRAMP	20.856101	-156.667192
Pelekane	1 RAT	20.027041	-155.825534	Puamana	13 CRAMP	20.855306	-156.668491
Pelekane	2 RAT	20.027308	-155.825328	Kamiloloa	3 CRAMP	21.037470	-156.897571
Pelekane	3 RAT	20.026557	-155.824722	Kamiloloa	10 CRAMP	21.069651	-157.000227
Pelekane	4 RAT	20.027271	-155.825749	Kamalo	3 CRAMP	21.068169	-157.000920
Pelekane	5 RAT	20.026677	-155.823822	Kamalo	10 CRAMP	21.041603	-156.897282
Pelekane	6 RAT	20.027063	-155.826221	Palaau	3 CRAMP	21.089200	-157.107672
Manana	1 RAT	21.326636	-157.662389	Palaau	10 CRAMP	21.087050	-157.108498
Manana	2 RAT	21.326355	-157.658863	Hanauma Bay	3 CRAMP	21.268430	-157.695355
Manana	3 RAT	21.326907	-157.658983	Hanauma Bay	10 CRAMP	21.267801	-157.693520
Manana	4 RAT	21.326695	-157.659640	Heeia	2 CRAMP	21.447812	-157.809703
Manana	5 RAT	21.327237	-157.659664	Heeia	8 CRAMP	21.447757	-157.809597
Manana	6 RAT	21.327049	-157.660910	Kaalaea	2 CRAMP	21.476647	-157.831483
Kiekie	1 RAT	21.893313	-160.218032	Kaalaea	8 CRAMP	21.476664	-157.831242
Kiekie	2 RAT	21.893400	-160.225737	Pili o Kahe	3 CRAMP	21.372266	-158.141917
Kaununui	1 RAT	21.940690	-160.163332	Kahe Point	3 CRAMP	21.356407	-158.132404
Kaununui	2 RAT	21.940718	-160.163333	Moku o loe	2 CRAMP	21.436210	-157.786698
Keawanui	1 RAT	21.961147	-160.130196	Moku o loe	8 CRAMP	21.436110	-157.786650
Keawanui	2 RAT	21.960990	-160.129400	Pupukea	4 CRAMP	21.646270	-158.065079
Puukole Pt	1 RAT	22.003990	-160.097231	Pupukea	8 CRAMP	21.646872	-158.066147
Puukole Pt	2 RAT	22.004947	-160.097316	Maunalua Bay	1	21.269756	-157.730597
Lehua Is	1 RAT	22.014505	-160.099976	Maunalua Bay	2	21.270407	-157.721214
Lehua Is	2 RAT	22.014165	-160.099470	Maunalua Bay	3	21.265023	-157.715257
Palaoa	1 RAT	20.738703	-156.883881	Maunalua Bay	4	21.272765	-157.731892
Palaoa	2 RAT	20.741368	-156.885399	Maunalua Bay	5	21.271314	-157.734854
Palaoa	3 RAT	20.730906	-156.956787	Maunalua Bay	6	21.272660	-157.726467
Ala Wai	3 RAT	21.68680	-157.507750	Maunalua Bay	7	21.271210	-157.720995
Ala Wai	10 CRAMP	21.167860	-157.50825	Mahinahina	3 CRAMP	20.574360	-156.412520
Ahihi Kinau	1 CRAMP	20.57434131	-156.371986	Mahinahina	10 CRAMP	20.574610	-156.413360

1.3 Responsible Agency and Participating Organizations

The Coral Reef Assessment and Monitoring Program (CRAMP) will take the lead conducting this project. CRAMP is part of the University of Hawai‘i’s Hawai‘i Institute of Marine Biology. We will work closely with Hawai‘i’s Local Action Strategy to Address Land-based Pollution Threats to Coral Reefs (CRLBP LAS). LAS has listed the development of a long-term monitoring program using pollution sensitive indicators as a priority area.

Development of biocriteria is a priority for Hawai‘i which is not currently being addressed by State agencies due to lack of resources, although there is interest in moving ahead in this area. This project will provide leadership and give the State of Hawai‘i the opportunity to begin the process of developing biological criteria which is already moving ahead in other Region 9 Pacific island areas. The proposed work in Hawai‘i will provide input to these areas through networking with the Commonwealth of the Northern Marianas under Peter Houck, in Guam under Mike Gawel and in American Samoa under Edna Buchan and Mike Gawel. We also anticipate networking with Lesa Meng and others who are in the process of developing IBI metrics for the Caribbean.

We are currently working with EPA regional manager Wendy Wiltse to develop biocriteria for Hawai‘i. She has arranged meetings, presentations and workshops with state agencies including the Hawai‘i Department of Health, the Division of Aquatic Resources, and the National Oceanographic and Atmospheric Administration. Dr. Wiltse and the CRAMP team are currently in the process of working with the Hawai‘i Department of Health (DOH) Water Quality Monitoring and Assessment Program. DOH has initiated an Integrated Water Quality Reporting workgroup to bring together diverse expertise and experience necessary to upgrade their water quality evaluation toolbox. Their objective is to establish meaningful, yet simple methods to determine designated use attainment with limited data to develop methods to accurately monitor the quality of Hawai‘i’s reefs. Currently, no method exists other than our biocriteria data and we are working with Dr. Wiltse and others to integrate this into their program. She has also arranged collaboration with Leska Fore to further develop biocriteria. Leska Fore is a statistician and biologist working as a statistical consultant for EPA and specializing in issues related to biological monitoring.

1.4 Project Organization Roles and Responsibilities

Overall administrative and program development for the development of biocriteria lies with the Principal Investigator. The PI is responsible for daily activities and has the overall responsibility for assuring quality data are generated and used by CRAMP. Dr. Paul Jokiel will serve as our project quality assurance manager. The Assistant Researcher is responsible for coordinating and overseeing all activities of the CRAMP Monitoring Team while conducting this project. This responsibility will be under the jurisdiction of Dr. Ku‘ulei Rodgers. This includes survey and sample design, data collection, supervision of analytical procedures, validation of data, and preparation of data reports. CRAMP divers will be conducting surveys and collecting data. CRAMP consists of the following individuals (and their roles). See section 5.0 for a detailed description of data collection techniques.

Principal Investigator – Paul Jokiel

QA Officer
Project Leader

Assistant Researcher – Ku‘ulei Rodgers

Benthic Data Collection
Co-Project Leader

Benthic and Fish Data Collection

CRAMP Team Members – Ann Farrell, Fred Farrell, Kanako Uchino

Benthic, Fish, Coral, rugosity, and sediment data collection
Assist with underwater equipment

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1.5 Permits for Collection of Environmental Measures

The majority of CRAMP sites are in open access areas (Figure 1). Permits for marine protected areas (MPA) have been approved for site installations, data collection and surveys conducted at CRAMP sites within the state of Hawai‘i. These include the following.

1) Special Activity Permit # PRO-2008-52 State of Hawai‘i Department of Land and Natural Resources Division of Aquatic Resources Issued to: Dr. Ku‘ulei Rodgers West Hawai‘i Regional FMA 1) State of Hawai‘i, Department of Land and Natural Resources, Division of Aquatic Resources (DAR) Permits for marine protected areas. Marine Protected Areas included in the permits include Honolua-Mokuleia, Molokini, Pūpūkea, and Puako. All Fisheries Management Areas on the West Coast of Hawai‘i were added as a rider to the Honolua-Mokuleia permit PRO-1999-65 and have been renewed annually. These permits are departmental permits and are reissued upon request up to a month prior to expiration. The permits allow placement of stainless steel pins on the inner and outer reef at all sites to identify changes in fish density and coral cover. Placement of settlement plates and sediment traps are permitted activities included in the

Honolua-Mokuleia permit application. These permits have been renewed annually since 1998 by Richard Sixberry of DAR. A Conservation District Use Permit (CDUP) was not required for the activity requested. Copies of the appropriate permits are in the possession of the CRAMP team when activity is occurring in these protected areas. The Department of Conservation and Recreation Enforcement (DOCARE) is informed prior to work at these sites. No activity is conducted until approval and receipt of final permits.

2) State of Hawai‘i, Department of Land and Natural Resources, Natural Area Reserve System Commission.

A special use permit issued by the Department of Land and Natural Resources for the site ‘Āhihi-Kīna‘u on the island of Maui, was approved by the Natural Area Reserve System commission (NARS). Prior to field entry NARS and DOCARE staff are notified in advance. This permit is renewed on an annual basis to accommodate long-term monitoring.

3) State of Hawai‘i, Department of Land and Natural Resources Collecting Permit (covers all sites except MLCD and NARS)

CRAMP scientific collecting activity is covered under a permit issued to the Hawai‘i Institute of Marine Biology by the Board of Land and Natural Resources. This permit allows collection of certain organisms including all corals, under Section 187-A-6, Hawai‘i Revised Statutes and other applicable laws. This permit allows collection from all state waters excluding marine protected areas. Results of all collecting activities performed under authority of this permit are reported annually to the Division of Aquatic Resources within a month after expiration, as required. Report of collecting includes the following information: Date of collection, location, common or scientific name, quantity collected and the disposition of specimens.

4) State of Hawai‘i, Department of Land and Natural Resources, Land Division Site Plan Approval for Monitoring Hawai‘i’s Reefs SPA ST 00-20.

This permit was granted for activities and placement of pins at all CRAMP sites under Section 13-5-22, 11-200-8 and 11-200(8)5 of the Hawai‘i Administrative Rules which allows basic data collection, research, education and resource evaluation. This permit has no expiration date and will be valid until revoked.

5) State of Hawai‘i, Department of Land and Natural Resources, Kaho‘olawe Island Reserve Commission (www.state.hi.us/kirc/main/home.htm) ecological changes (<http://www.state.hi.us/kirc/ocean/monitoring.html>). The KOMP recognizes the need for approaches that complement existing monitoring programs within the state. Goals of KOMP relevant to our common objectives include use of quantitative approaches to monitoring, assuring data integrity and accuracy of data, and making the best use of limited funding resources. CRAMP will continue this partnership in compliance with existing and future regulations and ensure responsible scientific research that is in accordance with KIRC policies and with the KOMP.

1.6 History, Previous Studies, Regulatory Involvement

CRAMP long-term monitoring sites were established in 1998 in response to management needs for temporal monitoring data. Additional rapid assessments were added to encompass as wide a spatial range as possible and to assess spatial variability. Sites on all eight main Hawaiian Islands are included in the sampling design: Hawai‘i, Maui, Kaho‘olawe, Lāna‘i, Moloka‘i, O‘ahu, Kaua‘i and Ni‘ihau (Figure 1). A diverse

spectrum of environmental conditions was selected to provide accurate representation of the main islands in the State of Hawai'i. The following criteria were used in the site selection process:

- A range along a gradient of anthropogenic impact from heavily impacted sites to sites with limited human activity;
- Sites with specific impacts including fishing, sedimentation, eutrophication and introduced species ;
- Naturally occurring conditions as close to original as possible;
- Sites that encompass the entire scope of wave exposure and direction;
- Sites that provide a wide range in human population;
- A range of legal protection including sites with various levels of marine protection and open access;
- Wide spatial gradients to encompass longitudinal differences;
- Accessibility.

Permanent monitoring sites are relocated using navigational GPS. Rapid Assessment transects are randomly selected by generating 99 random points onto habitat maps using GPS Pathfinder Office 2.8. To assure adequate coverage of the different habitats and full representation of each site, a stratified design is employed. Points are stratified within depth ranges (<5 m, 5 to 10 m, and >10 m) and habitat types (coral, sand and macroalgae). One-third of the 99 points (33) are used in each of the 3 depth ranges. Within each depth range 1/3rd of the points (11) are generated within each habitat type. Not all habitat types are present at every site. If habitat types are not present, points are divided among the remaining habitat types. Navigational GPS is used in the field to determine the exact position of each point, marking the beginning of a transect. Where habitat maps are not available, a visual assessment of habitat type is conducted and depth is determined using either a depth gauge or fathometer. A random number of fin kicks is used to designate the beginning of each transect.

1.7 Project Schedule

This project two year project is broken down into quarterly tasks (Table 3).

Quarter	Research Activity	State/Federal Agency Feedback on Biocriteria Development Community Outreach	Product
1	Develop EPA Quality Assurance Project Plan Review CRAMP Biocriteria	Initial Presentation on Development of Biocriteria Agencies for Input.	Qtr. Rpt. 1 July 2008
2	Re-analyze data and models	Revise approach as indicated from initial input	Qtr. Rpt. 2 Aug. 2008
3	Testing and Additional Field Studies	Meet with DAR biologists individually from each of the major islands.	Qtr. Rpt. 3 Sept. 2008
4	Complete initial Proposed CRAMP Biocriteria	Present revised model to agencies. Present at Hawai'i Conservation Alliance Conference	Qtr. Rpt. 4 Quality Assurance Plan Dec. 2008
5	Analysis of data, refine biocriteria and model	Sea Grant Reef Talk Kamuela, Hawai'i	Qtr. Rpt. 5 Mar. 2009
6	Field test biocriteria and model	Presentation to Molokai Community Association and Hanalei, Kaua'i community	Qtr. Rpt. 6 June 2009
7	Prepare draft final report on biocriteria –	Solicit additional input from agencies. Hanauma Bay Lecture Series, O'ahu	Qtr. Rpt. 7 Draft Final Report Sept. 2009
8	Revise and prepare Final Report	Sea Grant Reef Talk Kona, Hawai'i Final Presentation to Agencies	Qtr. Rpt. 8 Final Report Oct. 2009

2.0 PROJECT DATA QUALITY OBJECTIVES (DQO)

2.1 Data Quality Objectives and

2.2 Data Quality Indicators for Field Activities

Field sampling QC consists of recording and checking survey sheets. The following accuracy checks are conducted on site. Field QC is intended to support a number of data quality goals:

- Fish datasheets are reviewed immediately following the survey by the recorder and one other survey team member to check for misspelling, unusual data, and legibility.
- All field data is entered into a computer spreadsheet at the end of each field day.

The model QC consists of evaluating values and checking accuracy:

- If the ecological index provides a low overall station value (< 2.0) representing impaired conditions then a more detailed assessment will be conducted to confirm the severity of the degraded station. This will include a qualitative visual assessment of the benthic and fish populations.
- If any single metric provides a value outside the normal range of values (± 3.0) for comparable stations then a thorough data review will be instigated. Checks of original field datasheets, computer spreadsheets and calculations, and model input will be performed.
- Any outliers or anomalies will be investigated to determine if they are factual. If no inaccuracies are found then the outlier or anomaly will be retained and noted in the statistical analyses.

It is the goal of CRAMP and cooperating agencies to ensure that the reported results from this project are reliable. This goal can be accomplished only by strictly adhering to established procedures in data collection techniques. Prior to CRAMP monitoring surveys, one entire year (1998) was spent on QA/QC to assure the best methodology was applied to answer the questions asked. Where applicable, each measurement parameter used in the development of biocriteria (see Table 1) was assessed for statistical power to ensure the accuracy and precision of the data met our needs.

2.3 Data Review and 2.4 Data Management

The CRAMP ecologists check all data sheets from each survey within 24 hours of its collection. Data checked includes:

- misspellings
- unusual observations
- legibility
- date/time
- blank sections (eg. observer initials)
- site/station name
- species acronyms
- meteorological/oceanographic observations

The observer of any suspect data is questioned to verify the accuracy of the data. The final decision to accept or reject data resides with the CRAMP ecologists, who enter data into an ACCESS database. This database is backed up and stored in several locations.

- Hawai'i Institute of Marine Biology Coral Reef Ecology Lab, Moku o Lo'e, O'ahu, Hawai'i
- National Parks Service Kalaupapa, Moloka'i, Hawai'i Marine Program Office
- Division of Aquatic Resources Regional Office, Maui, Hawai'i

All photographic images used in data analyses, PhotoGrid files (csv, pgc), Photoquad images, excel files are archived annually at the National Oceanographic Data Center (NODC) located on the University of Hawai'i campus under the direction of Mr. Patrick Caldwell. The data format is updated as new formats become available (eg. floppy disc to CDs to DVDs). These data and images are also stored at the Hawai'i Institute of

Marine Biology Coral Reef Ecology Lab, Moku o Lo'e, O'ahu, Hawai'i in two separate buildings to assure perpetuity. Sediment remains after ashing are housed in air tight bottles, labeled, cataloged and placed in secure containers at the Hawai'i Institute of Marine Biology's Coral Reef Ecology Lab.

Data management is an important part of any long term monitoring program. Collected data are worthless if they can't be analyzed and used to make sound management decisions. The five CRAMP ACCESS databases are designed to reflect the objectives of the marine monitoring program (Figure 4).

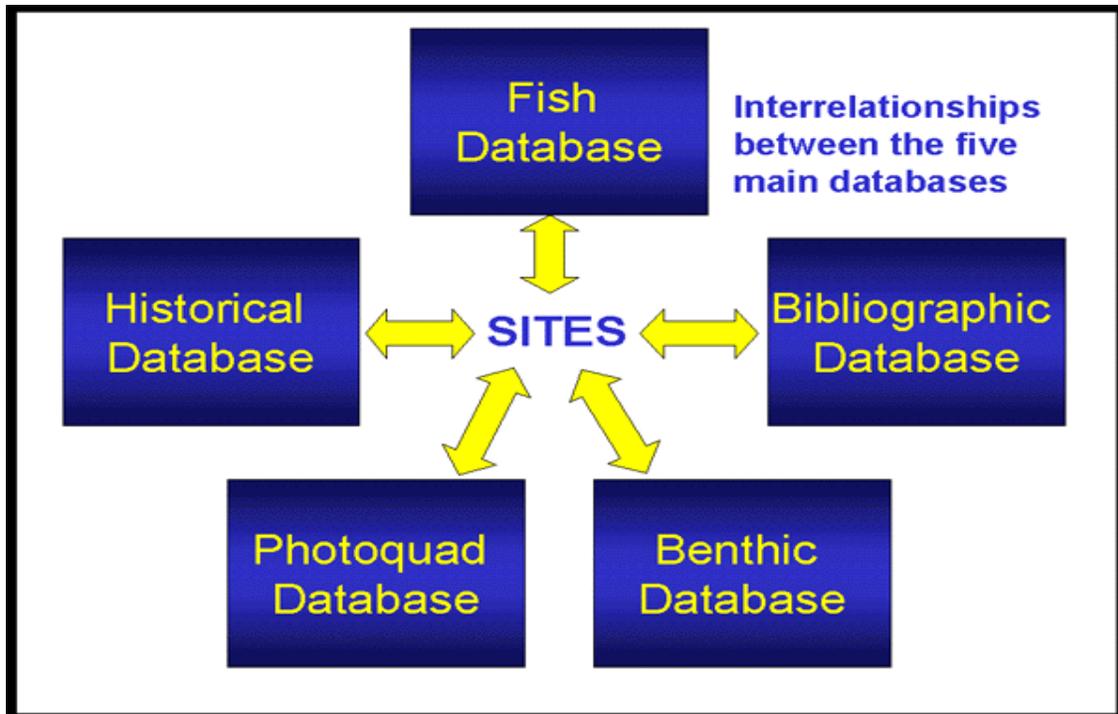


Figure 4. The five databases maintained for this project

Detailed records are kept in both hardcopy and digital formats. Records include:

- information on number and names of participants for each survey
- Site name, location, and dates surveyed
- Diving profiles for each dive team
- Tasks completed

CRAMP files all original data sheets and provides copies to the other agencies upon request. The original data sheets are kept on file for a minimum of ten years. The final decision to accept or reject data resides with the lead biologist. Data is entered into CRAMP ACCESS long-term database. These data are backed up in locations on the islands of O'ahu, Maui, and Moloka'i. All electronic media used for photographic and video type surveys is filed indefinitely at the Hawai'i Institute of Marine Biology. It is also archived for perpetuity at the National Ocean Data Center (NODC). Data is transferred to other media as technology advances. The CRAMP website at

www.cramp.wcc.hawaii.edu has been created and maintained to disseminate results. Request for data are open to any federal, state, non-profit, or educational agency or group. To insure the integrity and accountability of the data a single data manager (Dr. Eric Brown) maintains and updates the original databases.

2.5 Assessment Oversight

The only samples collected and shipped away from collection sites are sediment samples. Samples are processed at the HIMB, Coral Reef Ecology lab. Processing includes grain-sizing and composition determination. Replicate samples are taken from each of two subsamples collected from every transect. No chemical or hazardous processing is conducted. The capability of this laboratory is assessed by the UH Environmental Health and Safety Office (EHSO) which ensures safe campus environments through the development and administration of health and safety programs critical to the university experience. The EHSO Lab Safety Program oversees emergency safety showers, eyewash equipment, and lab ventilation. Any employee exposure to chemical and physical hazards in campus laboratories are identified, evaluated, and controlled. Chemical and lab safety training is required. Labs are certified annually by the EHSO. The HIMB lab has the capability and capacity to provide analytical services for the sediment processing. Standard Operating Procedures are used in sediment processing.

2.6 Acquired and/or Secondary Data or Non-direct Measurements

Data acquired from existing sources have been reviewed by the primary agency disseminating the data. Metadata is supplied for all GIS layers. Data quality assessment to determine their adequacy for use in this project is conducted by the Principal Investigator, Dr. Paul Jokiel and GIS expert, Erin Naughton. The data are reviewed to verify the original source, identify similar uses, and evaluate literature. Secondary data acquired from sources other than CRAMP surveys to aid in identification of indicators include:

- Wave data

Quantification of all wave variables are generated using significant wave height and mean wave direction from Naval Oceanographic WAM models (www.navo.navy.mil). Hawai'i forecasts are generated from data collected by instruments on buoys surrounding the Hawaiian Islands. Wave factors used in data analysis include mean, minimum and maximum annual and seasonal wave heights and mean annual wave direction.

- State of Hawai'i GIS basemap layers for Watershed, Streams and Precipitation

Terrestrial variables used in statistical analyses include total watershed area, mean annual precipitation, and perennial stream lengths. All geographic information system layers were obtained from the State of Hawai'i GIS database (www.state.hi.us/dbedt/gis). The geographic extent of the watershed layer encompasses the eight MHI while rainfall contours cover the six largest Hawaiian Islands. Watershed unit boundaries were originally generated in Arc/Info and GRID using USGS Digital Elevation Model data

(1995). The State Department of Land and Natural Resources served as the original source of median annual precipitation data.

- Political boundaries and administrative layers include census tracts and blocks.

Population data were originally five county layers downloaded from www.geographynetwork.com and merged into a single layer. The geographic extent of the latest 2000 census tracts and blocks covers the entire main Hawaiian Islands (MHI).

- Physical features and basemap layers included; coastline, hillshade, islets and perennial streams.

The Commission on Water Resource Management, Hawai'i Stream Assessment Project provided the original perennial stream data (1993).

The data projection for all layers is Universal Transverse Mercator (UTM), Zone 4 (meters), Old Hawaiian Datum. Projection conversions were applied to geographic coordinates for georeference compatibility using the ArcView extension, Hawai'i Datums and Projections and the software program, Corpscon. Distances were calculated utilizing the Spatial Analyst version 1.1 extension for ArcView GIS version 3.1.

3.0 FIELD STUDY DESIGN/MEASUREMENT PROTOCOLS

Transects (184 at 52 sites) were selected for use in this project. Site names and location can be found in Fig. 1 and Table 2. Survey data from 2001-2002 was selected for use in this project due to the completeness of the data set. A diverse spectrum of environmental conditions were selected to provide accurate representation of the main islands in the State of Hawai'i. The following criteria were used in the site selection process:

- A range along a gradient of anthropogenic impact from heavily impacted sites to sites with limited human activity;
- Sites with specific impacts including fishing, sedimentation, eutrophication and introduced species ;
- Naturally occurring conditions as close to original as possible;
- Sites that encompass the entire scope of wave exposure and direction;
- Sites that provide a wide range in human population;
- A range of legal protection including sites with various levels of marine protection and open access;
- Wide spatial gradients to encompass longitudinal differences;
- Accessibility.

For each transect the following data is collected:

- 20 photographic images are taken on each 10m transect. Each image covers an area measuring 50x69 cm.
- Fish number, species, and length are recorded along each 25x5 meter transect.
- Two 2 kg sediment samples are taken along each 10m transect where sediment is first found.

- A rugosity measurement is taken along the center of the transect line. Rugosity chain is marked with flagging tape at 1m intervals. Any segment less than 1m is measured against the transect line.

Accuracy Assessment of Benthic Transects

This research program employs proven cost-effective techniques and methods most commonly employed throughout the world by scientists and resource managers to assess impact of natural and anthropogenic change on coral reefs. This approach was selected because resource managers continually report that the amount of money available is too small to allow use of untested, complex and unproven techniques based on molecular, physiological or advanced analytical chemistry. Local managers require biological criteria that can be measured with the skills and budgets currently available to them.

CRAMP was established in 1998 to monitor and detect change in coral cover on Hawaiian reefs. Three steps were used to evaluate appropriate techniques for the program (See Brown et al. 2003)

- First, methods and results from five previous or ongoing monitoring programs in Hawai‘i using different sampling procedures were investigated for precision and statistical power.
- Second, input was solicited from long-term coral reef monitoring programs in Florida, the Caribbean, and the Great Barrier Reef.
- Third, field trials were conducted to examine the following parameters in various sampling designs; Repeatability and appropriate length of the transects, number of transects/samples, number of frames/subsamples, cover estimation techniques, observer variation, and time and monetary constraints.

Historical methods generally had low statistical power to detect change due to low precision and small sample size. Power varied from 0 on transects with quadrats to 0.95 for fixed photoquadrats. Sampling designs with low statistical power had long transects (50m) in heterogeneous habitats with moderate coral cover (20-60%).

Existing programs outside of Hawai‘i highlighted the following;

- 1.) Video transects were recommended as a cost-effective method to analyze the substrate,
- 2.) Digital video was preferred over analog due to higher image resolution and better data retention,
- 3.) Fixed transects were endorsed over random transects,
- 4.) Statistical power as a tool to evaluate the appropriateness of the selected sampling design was seldom used.

Field trials indicated that repeatability of conventional transects or quadrats had high variation unless efforts were made to reposition the sampling units with greater precision. Statistical Power to detect change in coral cover decreased dramatically when coral cover

was greater than 20%. Longer transects (e.g. 25m and 50m) fared well in homogeneous substrates but shorter transects (e.g. 10m) were more appropriate in heterogeneous habitats. Variability between observers analyzing the same data was low in comparison to other sources of error.

Visual estimation techniques were cost effective but did not permit data archiving, collected the smallest amount of data per unit of field time and consequently had lower power. Digital video had the highest initial monetary investment but yielded the largest quantity of data per unit of field effort. Video results indicated that 10m transects could detect a 10% change in coral cover with high statistical power ($P > 0.80$) using 50 points per frame, 20-30 frames per transect and 8-10 transects/depth. Fixed photoquadrats with high precision were also recommended to address questions on recruitment, growth and mortality. Standardized techniques for CRAMP were structured so that resource managers could generate sound decisions based on data collected with a statistically defensible sampling design.

Database storage and initial analysis was conducted in Access 97 and Excel 97. Two separate analyses were conducted; determination of precision of field techniques sampled over a short temporal scale (Sale 1997) and power estimation of previous and current studies. Percent data were subjected to an arcsin-square root transformation prior to testing. Power estimation was calculated for repeated measures ANOVA and nested 2 way ANOVA designs using methods described in Cohen (1988), Green and Smith (1997) and Zar (1999). Paired t-tests were used in the precision comparisons instead of a repeated measures ANOVA due to the unequal sample sizes between different transect lengths.

Repeat photoquadrats and point-intercept quadrat data showed high variability and consequently low precision. Longer transects had higher mean percent difference between quadrats (e.g. 25m at Kāne'ōhe – $15.9\% \pm 9.8$) than shorter transects at the same location (e.g. 10m at Kāne'ōhe – $10.0\% \pm 14.6$). Variability between mean differences for both transect lengths (10m – $7.5\% \pm 7.6$ and 25m – $8.9\% \pm 6.7$) was reduced by placing temporary pins every 2m along the transect. The pins reduced transect movement during the survey and allowed more accurate repositioning of the line during subsequent surveys. At Molokini Island, Maui, transect length of 50m had the lowest precision with the highest mean percent difference ($23.7\% \pm 18.1$) among quadrats.

Photoquadrats produced statistically higher estimates of coral cover than planar point intercept for the same quadrats sampled (10m transect, $t = -2.7$, $df = 9$, $p = .025$; 25m transect, $t = -2.3$, $df = 16$, $p = .032$). The mean percent difference between comparable quadrats, however, was quite similar between methods (Table 4). The variability between quadrats for the 10m transect (10.6% - PPI vs 10.0% photoquadrat) was more comparable than the mean percent differences for the 25m transect (10.9% - PPI vs 15.9%

photoquadrat). Neither method, however, yielded satisfactory precision. Variability between observers analyzing the same data was low for both transect lengths.

The variability in methods prompted CRAMP to place permanent pins every 10m, select transect lengths of 10m, use 20 frames per transect, and generate 50 random points on each frame. This greatly increased precision and accuracy allowing the long-term monitoring transects can detect a 10% change in total coral cover.

Table 4: Precision of repeated measures. PPI= Planar-point intercept, TL = transect length, SD = standard deviation, %CC = percent coral cover

Method	Site	Date1	Date2	TL	N	Mean % difference	SD	%CC
PPI	Kāneʻohe	12/2/98	12/4/98	10m	17	10.6	11.8	47.6
		12/2/98	12/4/98	25m	31	10.9	9.7	33.5
Photoquad	Kāneʻohe	12/2/98	12/4/98	10m	20	10.0	14.6	55.1
		12/2/98	12/4/98	25m	72	15.9	9.8	39.9
	Kāneʻohe	12/17/98	12/18/98	10m†	20	7.5	7.6	41.7
		12/17/98	12/18/98	25m†	50	8.9	6.7	40.5
	Kāneʻohe	12/17/98	12/18/98	10m*	10	Same Obs.	7.5	7.6
		12/17/98	12/18/98	10m*	10	Diff. Obs.	10.4	10.0
	Kāneʻohe	12/17/98	12/18/98	25m*	25	Same Obs.	8.9	6.7
		12/17/98	12/18/98	25m*	25	Diff. Obs.	8.3	5.5
	Molokini	10/10/98	10/11/98	50m	32	23.7	18.1	35.2

† Pins placed every 1m to reduce transect movement

* Same transects used but different observers on photo analysis

Precision of digital video transects

Analysis of standard deviation in 10 point increments indicated that optimum number of points per frame appeared to be around 50 (Figure 2).

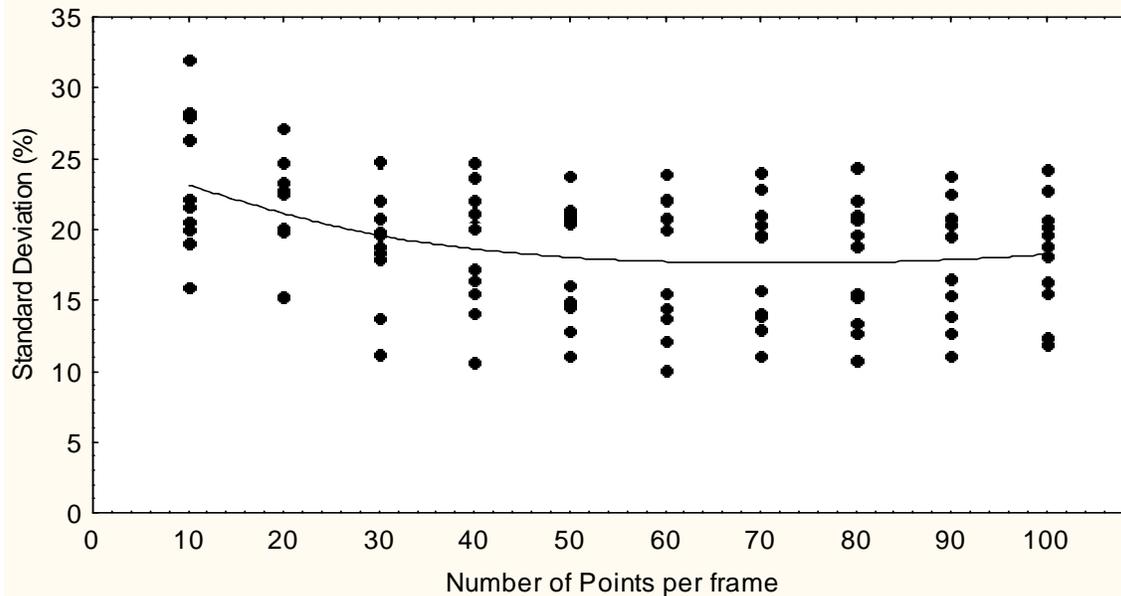


Figure 2. Relationship between standard deviation of mean coral cover versus number of points sampled per frame for transects surveyed in Hanauma Bay.

This was illustrated by the weighted least squares curve leveling off at about 50 points per frame. Precision was higher with more points but so was effort. Another approach to determining optimal number of points per frame was to examine the interaction term in a 2-way ANOVA for transects sampled at 2 times in close proximity. Theoretically, coral cover estimates should be reasonably similar between the surveys and any trends in coral cover should also be similar. Ten points per frame showed a different trend in coral cover over time compared to 50 and 100 points sampled per frame ($F_{2,20} = 8.29$, $p < .0024$). To examine how accurately the point method characterized true substrate cover we mapped out the coral cover using visual estimation with a grid placed on the screen (Dethier, et al. 1993). A similarity matrix was constructed and different observers had very similar estimates (~95%) using the visual technique. These values also corresponded well to the estimates from 50 and 100 points per frame (> 85% similarity). In contrast, 10 points per frame had less than 80% similarity with the other estimation techniques. Though the sample size was small (N=10 frames), the overall impression was that 50 and 100 points per frame provided a reasonable estimate of what was truly on the substrate from a 2D perspective.

Power analysis for digital video and digital stills

Power curves were constructed for the number of points per frame and number of frames per transect using methods described by Zar (1999). The target sample size (number of transects) was set to detect a 10% change (effect size) in coral cover across 2 time periods. Number of frames was more important in increasing power than number of points though the difference was not substantial (Figure 3).

Statistical power provides a measure of confidence or probability that a false null hypothesis will be correctly rejected (Zar 1999). If there is a change CRAMP would be able to detect it. The null hypothesis is that there is no change in benthic abundances at

CRAMP sites over time. Power analysis was carried out to assess which methods provide enough power to detect this change. Power calculations yield a probability (β) of encountering a type II error (incorrect acceptance of a false null hypothesis) based upon the number of and variance among replicate transects (Zar 1999). Power is directly related to precision which increases with replication.

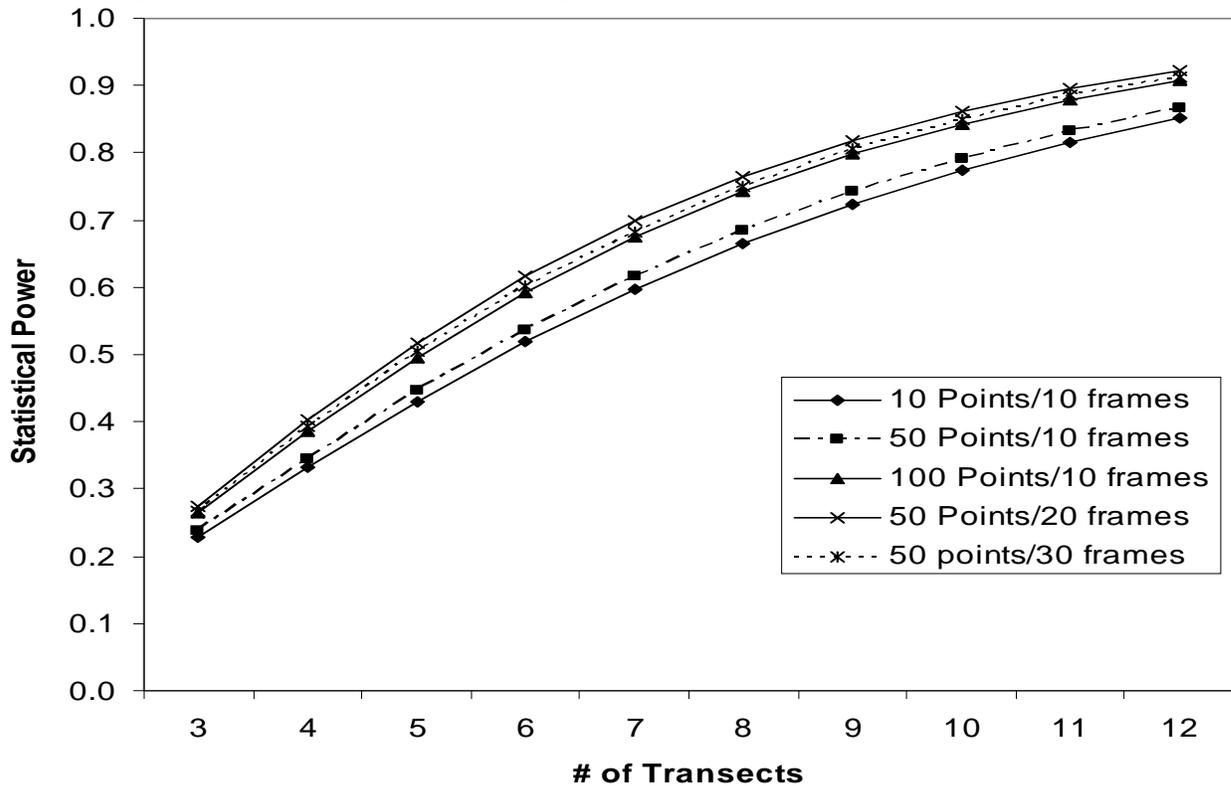


Figure 3 Power analysis for number of transects with different numbers of points/frame and different number of frames/transect (Zar, 1999).

For example, the power for 50 points using 20 frames is higher than 100 points using 10 frames even though the total number of points examined is the same. This is primarily due to the fact that more frames sample a larger portion of the habitat, which incorporates more of the heterogeneity of the substrate. A sample size of 10 transects per site appeared to be adequate for characterizing the coral cover using a power value of 0.8 set as a convention by Cohen (1988).

Accuracy assessment of visual fish census methods

Observer variability was compared each time before a new observer conducted fish transects. This calibration minimized observer variability. Two divers swim parallel 25 by 5-m transects in similar habitat separated by 10 m until there is no significant difference as determined by a student's t-test. For example, the first trial conducted on the foreereef at Hoai Bay, Kaua'i, in December 1999 showed there were no significant differences in number of fish species ($t=0.206$, $P=0.839$), number of individuals ($t=1.800$, $P=0.086$), or biomass ($t=0.133$, $P=0.895$) observed between the two divers. All subsequent visual census fish data were collected using only observers calibrated in this manner.

Prior to observer calibrations, biomass estimates derived from underwater estimates of fish lengths during the study were also carefully calibrated. This improves the accuracy associated with fish length measurements. The methodology selected compares observer length estimates with those of plastic-laminated or wooden painted fish models. Fish models ranging in size from 5–30 cm are comprised of several different species with varying shapes. Fish are attached to a weighted line using snap swivels. Each diver swims along the transect line estimating the total length of each fish model. Divers then return along the transect line and measure actual length of models. Fish are changed and trials continued until diver estimates are within one cm of actual lengths.

Spatial and temporal variability of fishes can be extremely high due to mobility and large home ranges. Many fish species are cryptic, rare or transient. There are also diurnal/nocturnal and seasonal sources of variability. Fish surveys are susceptible to highly variable data collection. Complex interactions and numerous causal relationships add to this variability. Causes of variability have been attributed to chance distribution of individuals, local disturbances, animal movement, statistical and methodological limitations, error and environmental heterogeneity. This variability can significantly reduce statistical power (Brown et al. 2003). To quantify absolute values for fish populations an extremely large sample size is required especially for heterogeneous habitats thus, only relative values were used to determine differences between CRAMP sites.

When working with such an extensive, diverse database involving numerous parameters, multivariate techniques are commonly used to group similar sets of samples. This type of analysis is highly efficient in summarizing data for intrinsic analysis of ecological communities (Gauch 1982). Multivariate analysis can reveal the distribution of species along environmental gradients, highlight patterns in the data through spatial comparisons and habitat characterization, clarify habitat relationships and reveal trends and patterns with minimal expression of the noise typical in community data. With ordination techniques, similar entities are placed close to each other while dissimilar species or samples are located far apart in ordination space. In community analysis involving large data sets that have several community gradients and high variability, as in the case of this research, detrended correspondence analysis (DCA) and non-metric multidimensional scaling (MDS) have been shown to be highly effective (Gauch 1982; Clarke and Warwick 2001). These robust methods of multivariate analysis are relatively free from distortion and give equal emphasis to all data. These quantitative techniques are useful in identifying differences in community types and environmental gradients.

3.1 Physical Characteristics

3.1.1 Sediment

Sediment Grain-size Procedure

Standard brass sieves were used to determine size fractions: 2.8 mm, 500 μm , 250 μm , and 63 μm (USA Standard Testing Sieve: A.S.T.M.E.-11 specifications). A brass catch pan was used to collect the silt/clay fraction. Five size fractions were determined: granule (>2.8 mm), coarse and very coarse sand (500 μm -2.8 mm), medium sand (250-

500 μm), fine and very fine sand (63-250 μm), and silt/clay (<63 μm) in accordance with the Wentworth scale (Folk 1974). Each size fraction was collected in pre-weighed Whatman 114 wet strength filters, air dried and weighed to determine the proportion of each size fraction. Extremely large pieces were removed prior to sorting to reduce variability and eliminate overweighting of some samples by a single piece of material. Only the four smallest size fractions were used in the analyses.

Sediment Composition Procedure

Approximately 2 Kg of sediment are collected with a disposable scoop along each transect at each site and secured in Nasco™ Whirlpak 18 oz (532 ml) sample bags. Samples are air dried for two weeks (Parker 1983; McManus 1988; Craft et al. 1991). To determine the inorganic-organic carbon fraction, 20 g of bulk sediment is finely ground using a mortar and pestle. Subsamples are taken from each replicate to determine variability. Samples are then oven dried for 10 h at 100 °C to remove moisture, placed in a desiccator and massed. To remove the organic fraction, 10 g were burned in a muffle furnace for 12 h at 500 °C (LOI₅₀₀), placed in a desiccator and massed (Parker 1983; Craft et al. 1991). For removal of carbonate material, samples are placed in a muffle furnace for 2 h at 1000 °C (LOI₁₀₀₀), cooled in a desiccator and massed (Craft et al. 1991). The percent organic material and the carbonate fraction are calculated from these data.

3.1.2 Rugosity

Rugosity measurements to determine topographical relief and spatial complexity were conducted along each transect. A 15 m chain marked at 1 m intervals with 1.3 cm links was draped along the length of the transect (10 m) following the contours of the benthos. An index of rugosity was calculated using the ratio of the reef contour distance as measured by chain length, to the linear, horizontal distance (McCormick 1994).

3.1.3 Depth

Depth was determined at each transect with an electronic depth sounder at the surface. To provide a range of depths along the entire transect a digital dive computer (Suunto) was used on the benthos.

3.2 Biological Characteristics

3.2.1 Habitat Assessment

To assess the characteristics of benthic populations, high resolution digital images are taken along a 10 m transect using an Olympus 5050 zoom digital camera with an Olympus PT050 underwater housing. The camera is mounted to an aluminum monopod frame, 1.7 m from the substrate to provide a 50x69 cm image. A 6 cm bar provides a measurement scale. The software program PhotoGrid (Bird 2001) is used to quantify percent cover, richness and diversity of corals, algal functional groups and substrate cover. Images are downloaded and the 20 non-overlapping images from each 10 m transect are imported into PhotoGrid where 50 randomly selected points are projected onto each image. These data are saved in a comma separated values (CSV) file, proofread in Excel and imported into Microsoft Access XP, a relational database. Access data is queried and exported to statistical programs for analyses.

3.2.2 Statistical Analyses

Past analyses were conducted as follows. Any further statistical analyses required will be performed in the same manner.

Transformations

In order to determine whether transformations were appropriate, prior to analyses, residual distribution, partial regression plots and coefficient of variation were examined. Data transformations were conducted to satisfy the assumptions of normality, linearity, and homogeneity of variance required for some of the formal statistical tests performed. To determine the best transformation, histograms and normality plots were generated. Normality was assessed using the Ryan-Joiner test, which is similar to Shapiro-Wilk. Direction and strength of skewness were determined since strong skew can cause leverage problems. Partial regression plots were generated to determine leverage. Since large data sets such as the one this research generated are quite robust against normality violations due to the central limit theorem, data were left in its original form whenever possible. Independent variables that were calculated as percentages and species data containing numerous zero values were transformed.

The transformations used to meet the assumptions of normality and homogeneity of variances included:

- Arcsine square-root, in which variables in percentages were changed to proportions in order to normalize data and obtain a continuous variable. Distributions of proportion data are skewed because they are between 0 and 1 and thus have no tails. Arcsine transformation was used to stretch out the tails on both ends for a more bell-shaped, normal distribution. These are useful in extreme proportions <0.2 or >0.8 . Data in degrees was changed to radians.
- Log transformation, in which variables with high positive skewness were log transformed.
- Log (X+1) transformation, in which variables that are counts were $\log(x+1)$ transformed to reduce skewness. Variables that contained zero values were also $\log(x+1)$ transformed because the log of zero is undefined.
- Square root (X+1/2), in which coral species abundances were square root (X+1/2) transformed since the community ecology matrix is sparse, containing few non-zero values.
- No transformation applied, in which data with a coefficient of variation below 100% were retained in their original form.

Univariate and Multivariate Statistics

Statistics were computed with Minitab 13.0. Explanatory variables were selected from among 23 environmental predictors. To avoid multicollinearity, variables that were highly correlated ($>90\%$) were dropped from the analysis without loss of information (Clarke and Gorley 2001).

Coral species richness data may not be suitable for use as a response variable since it is strongly dependent on sampling effort and observer variability, making it difficult to

compare across sites. Richness values were determined from coral cover data. Some species of corals may be missed in data collection.

Diversity was not used as a response variable since coral diversity is low in Hawai'i and may not be an appropriate indicator of environmental conditions in this region. Hawaiian communities are often dominated by a few primary species where diversity does not decline with decreasing latitude as in other regions (Grigg 1983). Due to geographic isolation, corals in Hawai'i are depauperate relative to the Indo-West Pacific. Only 16 genera containing 42 species have been documented from the Hawaiian Islands. Difficult field identification and detection of cryptic or deep species and low digital resolution may also reduce the predictive ability of diversity.

To determine which environmental variables best explain coral cover and species richness, a general linear multiple regression model was used. Stations without coral were removed prior to analysis. Of the 184 stations at the 52 sites, 12 had no coral cover. Coral cover and species richness were regressed against the following environmental variables: rugosity, depth, sediment composition and grain-sizes, wave parameters, human population parameters, precipitation, distance from a perennial stream, and watershed area. A Best Subsets routine was utilized in Minitab 13.0, applying Mallows C_p and R^2 as the criteria in model selection. A lack of fit test was conducted to verify the model selection. Coral diversity was not used as a response variable since coral diversity is relatively low in Hawai'i and digital quality may restrict detection of small or cryptic species.

Ordination methods were used to highlight patterns in the data through spatial comparisons and habitat characterization. Ordination techniques can clarify habitat relationships and reveal trends and patterns with minimal expression of the noise typical of community data (Gauch 1982). Sample and species relationships are represented in a low-dimensional space with ordination techniques. Similar entities are placed close to each other while dissimilar species or samples are located far apart in ordination space allowing a visual representation of sample similarity.

Multivariate statistical analyses were conducted using Primer 5.0 and Multivariate Statistical Program version 3.0 (MVSP). These include the following statistical tools and techniques:

- Correspondence analysis (CA) was performed on data from the six most abundant coral species in Hawai'i: *Porites lobata*, *P. compressa*, *Montipora capitata*, *M. patula*, *M. flabellata* and *Pocillopora meandrina*.
- A site similarity matrix was generated to evaluate coral species distributions.
- A BIOENV procedure was used to link biological data to environmental data so that patterns in coral communities could be identified.
- SIMPER was used to determine the contribution of each species to the dissimilarity between sites.

3.2.3 Fish Data

Fish populations are quantified using standard visual belt transects (Brock 1954). SCUBA divers swim along one 25 m x 5 m transect (125 m²) at each station recording species, quantity and total fish length. All fishes are identified to the lowest taxon possible.

Total length is estimated to the nearest cm in the field and converted to biomass estimates (tons/hectare) using length-weight fitting parameters. In order to estimate fish biomass from underwater length observations, most fitting parameters were obtained from the Hawai'i Cooperative Fishery Research Unit (HCFRU). Additionally, locally unavailable fitting parameters were obtained from Fishbase (www.fishbase.org) whose length-weight relationship is derived from over 1,000 references. Congeners of similar shape within certain genera were used in those rare cases lacking information.

Conversions between recorded total length (TL) and other length types (e.g. fork length FL) contained in databases involved the use of linear regressions and ratios from Fishbase linking length types. A predictive linear regression of logM vs. logL was used in most cases to estimate the fitting parameters of the length-weight relationship. Visual length estimates were converted to weight using the formula $M = a \cdot L^b$ where M=mass in grams, L=standard length in mm and a and b are fitting parameters.

Any anomalous values are detected by calculating a rough estimate for a given body type. The general trend for a 10 cm fish of the common fusiform shape should be approximately 10 g. Gross deviations were replaced with values from the alternate source.

Trophic levels for fish species are determined using published Fishbase data. The trophic categories included: piscivores, herbivores, detritivores, mobile and sessile invertebrate feeders, and zooplanktivores.

Statistical Analyses

CRAMP transects are standardized to meet statistical compatibility requirements with RAT transects by randomly selecting one of the four 25 m transects at each station.

CRAMP and RAT transect differences are explained in Section 1.2 on page 7 of this plan. Minitab 13.0 was used to perform all univariate, formal statistical tests.

Spreadsheet and relational database software were used to determine population characteristics including; dominant and rare species, biomass and abundance rankings, feeding guilds and endemism status.

Multivariate statistical analyses included the same procedures used in the analysis of benthic data with the exception of a non-metric, multi-dimensional scaling technique, used to identify groups of similar sites. Environmental variables were overlaid on the

ordination to identify the factors and their directions that are most important in structuring of fish communities.

4.0 FIELD PREPARATION AND DOCUMENTATION

4.1 Field Preparation

Prior to field surveys, permitting is required to establish permanent markers at all sites. Additional permitting is required for collection of sediment and to obtain access to marine protected areas. The Coral Reef Assessment and Monitoring Program (CRAMP) has installed pins at survey sites around the state and continues to conduct monitoring and assessment work under permits issued from agencies responsible for managing near shore reefs. CRAMP activity has been conducted under the following permits (see section 1.4 for details):

- 1) State of Hawai‘i , Department of Land and Natural Resources, Division of Aquatic Resources (DAR) Permits for marine protected areas.
- 2) State of Hawai‘i , Department of Land and Natural Resources, Natural Area Reserve System Commission.
- 3) State of Hawai‘i , Department of Land and Natural Resources Collecting Permit (covers all sites except MLCD and NARS)
- 4) State of Hawai‘i , Department of Land and Natural Resources, Land Division Site Plan Approval for Monitoring Hawai‘i’s Reefs SPA ST 00-20.
- 5) State of Hawai‘i , Department of Land and Natural Resources, Kaho‘olawe Island Reserve Commission (www.state.hi.us/kirc/main/home.htm)

Background Information

Background information for sites are gathered from peer reviewed journals, environmental impact statements, governmental reports, and other published sources. Collection of all relevant literature is obtained through the University library system, State archives, government documents, and journals.

Maps, aerial photography and GIS layers are obtained from the State of Hawai‘i hawaii.gov/dbedt/gis/download.htm. The Office of Planning GIS Program leads a multi-agency effort to establish, promote, and coordinate the use of geographic information systems (GIS) technology among Hawai‘i State Government agencies. The State Office of Planning is responsible for the planning and coordination of activities that are critical to the State’s enterprise GIS. The primary goal of the Statewide GIS Program is to improve overall efficiency and effectiveness in government decision-making.

The Benthic habitat maps CRAMP uses to help determine site selection is part of the NOAA’s CCMA's Biogeography Branch. NOAA completed an investigation in 2007 to consistently and comprehensively map the distribution of coral reefs and other benthic habitats throughout the main Hawaiian Islands. The product includes the development of a web site and DVD which provides access to digital geographic information system (GIS) data, maps, and imagery depicting the location and distribution of shallow-water seafloor habitats the main Hawaiian Islands. Completion of this project represents a major milestone towards completion of the U.S. Coral Reef Task Force's

recommendation to develop shallow-water coral reef ecosystem maps for all U.S. waters. This is the fifth set of major coral reef ecosystem maps produced with support from NOAA/National Ocean Service's (NOS) Coral Reef Conservation Program.

The digital habitat maps can be downloaded from the main Hawaiian Islands website. In addition to digital/georeferenced benthic maps and metadata, digital/georeferenced mosaics of satellite imagery, ground validation data, accuracy assessment data, ground control data, an ArcGis Habitat Digitizer Extension, printable maps, and a methods manual are also available. Thirty-two distinct benthic habitat types (i.e., 4 major and 14 detailed geomorphological structure classes; 8 major and 3 detailed biological cover types) within 13 zones were digitally mapped in GIS (geographic information system) using heads-up visual interpretation of orthorectified satellite imagery. Assessment of these maps indicates that a high degree of thematic and spatial accuracy was achieved. Excellent accuracy, detailed documentation of methodology, and inclusion of a wide range of potential users during all phases of map production has resulted in a suite of products designed to accommodate a broad spectrum of interest groups, and at the same time, complete the project over a 24 month time period. Benthic features were mapped that covered an area of 1,310 km². In all, 387 km² of unconsolidated sediment, 288 km² of emergent vegetation, and 915 km² of coral reef and colonized hardbottom were mapped. Detailed attention was placed on thematic accuracy (correctly classified habitats) and the geospatial accuracy of map polygons (correct spatial coordinates). Although very small features such as individual coralheads of one meter in size are visible in the airborne imagery, only continuous habitats greater than one acre in size were individually delineated to ensure that maps were completed within a reasonable time frame. The overall thematic accuracy was 98% for the major structure, 90% for the detailed structure, 92% for the major biological cover, and 93.6% for the detailed biological cover classifications. The location of the habitat polygons is generally within three meters of their correct coordinates on the Earth. The georeferenced imagery enables managers and scientists to have the ability to delineate smaller features and modify the classification scheme for their specific project requirements.

(http://ccma.nos.noaa.gov/ecosystems/coralreef/main8hi_mapping.html)

Field surveys require survey gear and safety equipment. The following comprehensive list of equipment, materials, and supplies are not inclusive of each field trip. Resources vary depending on the work involved.

- Dive gear

buoyancy compensator, regulator, weight belt with weights, masks, snorkels, fins, dive boots, wetsuits, compressed air tanks, dive computers

- Survey equipment

quadrats, photoquad, monopod, camera and housing, desiccant, transect lines, clipboard, underwater paper, numbered transect clips, maps, data sheets, SS rods, sledge hammers, flagging tape, pencils, sample bags, disposable sediment scoops, 1 gallon bucket for homogenization of sediments

- Field supplies

permits, permanent markers, logbook, GPS, pelican floats, secchi disk, extra batteries

- Safety equipment

alternative air source, O₂ kit, standard first aid kit, dive flags, cell phone, dive plan with emergency contacts, personal floatation devices, flotation ring

Equipment maintenance and calibration is conducted prior to each field survey. Batteries for cameras and GPS units are charged and checked prior to each dive.

All dive gear including dive computers are inspected annually by a licensed inspector in compliance with the UH Dive Safety Office.

Records must be kept for each item from its original acquisition until three years after the date equipment is withdrawn from University service. Each equipment modification, repair, test, calibration, or maintenance service shall be logged including the date and nature of work performed, serial or identification number of item, and the name of the person performing the work.

SCUBA tanks are maintained according to the following University regulations:

SCUBA cylinders must be designed, constructed and maintained in accordance with the applicable provisions of the Unfired Pressure Vessel Safety Orders.

SCUBA cylinders must be hydrostatically tested in accordance with federal Department of Transportation standards.

SCUBA cylinders must have an internal visual inspection at intervals not to exceed 12 months.

SCUBA cylinder valves must be functionally tested at intervals not to exceed 12 months.

SCUBA cylinders and valves which are subjected to usage higher than 15 dives per month or filling by multiple users, must be inspected at a more frequent interval.

The following regulations for the use of Dive Computers (DC's) shall be followed by Scientific Divers while diving under University auspices.

Training Requirements:

The diver must complete a training session on Dive Computer (DC) use, of scope deemed appropriate by the DCB. The training must include the operational guidelines defined below and must include a DCB-approved written examination to demonstrate knowledge mastery of DC use.

The diver must demonstrate proficiency of DC use in a dive checkout with the DSO or his designated agent. The proficiency review must include:

Proper interpretation of the DC indicator system;

Adherence to the DC-prescribed rates of ascent and descent;

Demonstration of proper DC use protocols, as outlined below.

Equipment Requirements:

The DCB reserves the right to designate makes and models of DC's which are acceptable for use during University dives.

A diver must only use those models of DC for which the diver has demonstrated proficiency, as described above.

DC's must be tested for depth accuracy at 6 month intervals

Operational Requirements are also required. See

<http://www.hawaii.edu/ehso/diving/manual97.doc> for these and other details concerning the dive safety requirements.

All auxiliary equipment must be of a type approved by the DSO and/or the DCB. First Aid Supplies and Emergency Equipment regulations are as follows:
A first-aid kit adequate for the diving operation must be available at the dive location. When used in a hyperbaric chamber or bell, the first-aid kit shall be suitable for use under hyperbaric conditions.
An emergency oxygen supply adequate for the diving operation must be available at the dive location.

Procedures for field health and safety considerations are firmly in place at both the University of Hawai'i and the Hawai'i Institute of Marine Biology. Requirements include training in CPR, DAN oxygen, first aid, and scientific diving certification. In addition vessel safety inspections and a \$1 million insurance policy is required for all chartered vessels. All vessels are required to carry personal flotation devices, rescue tube or ring, flares, and first aid kit.

4.2 Field Notes

4.2.1 Field Logbooks

All field notes, dive times, triangulation relocation maps, GPS coordinates, and field information on oceanographic and meteorologic conditions are written clearly and accurately enough to recreate field activities following the surveys. Documentation has consecutively numbered pages. All entries are clearly legible, organized, and contain only factual, objective language. All field notes are written in a waterproof field tablet (write in the rain™). They are digitally entered into spreadsheets and/or databases immediately upon return from each field trip.

Field notes also include:

- Team members full names and their responsibilities
- Time of arrival/entry on site and time of site departure
- Other personnel on site
- Deviations or variances from sampling plans, site safety plans, and QAPP procedures
- Changes in personnel and responsibilities with reasons for the changes
- Calibration readings for any equipment used and equipment model

4.2.2 Field Data Sheets and Forms

The following data sheets are used in field surveys:

- 1) Fish numerical abundance and length data sheet
- 2) Field notes
- 3) Sediment Collection information data sheet
- 4) Photograph data sheet

1) Fish numerical abundance and length data sheet

Time	Location	Transect	Date	Observer
Fis com/A ch Ceph argu Lutj kash				
Cirr fasc Cirr pinn Para arcu Para fost				
Mull flav Mull vani Paru bifa				
Para cycl Paru mult Kyph sp				
Chae mult Chae ornat Chae quad				
Chae trif Chae unim Forc flav				
Plac impa Plec john Steg fasc				
Abud abdo Chro oval Chro hanu Chro vand				
Cori venu Hali orna Labr phth Macr geof				
Gomp vari Stet balt Thal ball Thal dupe				
Chlo pers Scar psit Scar rubr Chlo sord				
Cirr vand Acan bloc Acan leuc Acan nigrof				
Acan oliv Acan trio Cten stri				
Naso litu Zebr flav Meli nige				
Meli vidu Rhin rect Suff burs				
Cant dume Cant amb Cant jact				

4.2.3 Field Photographs

Photographs will be taken at the observation locations, sampling locations and at other areas of interest on site or in the sampling area. They will serve to verify information entered in the field logbook. For each photograph taken, the following information will be written in the logbook:

- Time, date, location
- Description of the area photographed
- Name of person taking the photograph
- Number of photographs taken

4.3 Documentation of Sample Collections

The following information is recorded during the collection of each sediment sample:

- Sample location and description
- GPS reading or other specific locational data as an aid for future sampling
- Sampler's name
- Date and time of sample collection
- Type of sample (sand, mud etc.)
- Type of sampling equipment used
- Field observations and details related to analysis or integrity of samples (e.g., weather/ocean conditions etc.)
- Lot numbers of the sample bag, sample identification numbers
- Destination information

4.4 Labeling of Sample Collections

Each sediment bag is assigned a unique sample number. Labels are written prior to collection with permanent markers and checked in the field to verify correct placement of sample into labeled bags. Labels contain the following information: sample location, date of collection, and type of sample.

Information concerning digital photographs are entered into the field books and reentered into computers upon return. All photos are assigned a unique number using the following code: eg. This photo was taken in 2008 on O'ahu in Waikīkī at 8 meters depth on the 2nd transect and is the 15th image in the series. (08OaWai08m02015)

08= 2008

Oa=first two letters indicate the island location

Wai=the next three letters designate first three letters of the site name

08m=depth

02=transect number

015=fifteenth image along the transect

4.5 Field Variances

As conditions in the field may vary, it may become necessary to implement minor modifications to sampling as presented in this plan. When appropriate and feasible, the EPA Project Officer will be notified before implementing the changes. Minor or temporary modifications will be documented in field logbooks or field data sheets and in the final report as appropriate. Significant or major changes to the approved plan may require prior approval by the EPA Project Officer and will be documented in the final report.

5.0 QUALITY CONTROL FOR SAMPLES COLLECTED FOR OFF-SITE ANALYSIS

Quality control sediment samples collected for off-site analyses are intended to help evaluate conditions resulting from field activities and are intended to accomplish two primary goals, assessment of field contamination and assessment of sampling variability. To assess the precision and accuracy of the sampling and analysis activities and to gauge if the sample is representative of the area surveyed, subsamples are collected in the field. Replicate samples are then used to determine the variability in sediment composition and grain-sizes (see Section 3.1.1).

5.1 Data Quality Indicators for Off-Site Analyses

The accuracy of measurements is limited by sampling techniques, storage conditions, equipment, and, the capability of the operator. To achieve the best possible results special care is taken to address the level of uncertainty associated with each measurement.

- Accuracy is determined by comparison of a first sample with a second sample collected on the same transect. A replicate sample is a separate sample taken close to the first sample. Each replicate sample is processed and analyzed in an identical manner. Replicates are taken to determine representation of the entire transect.
- Precision is addressed by sediment subsamples. Standard deviations are used as an indicator of agreement. A subsample is a portion of the sample taken as part of the sample. Subsamples are averaged to address within sample variability. Acceptable levels for organics is 0.5% of the sample, for higher carbonate composition, acceptable levels are within 10% of the total sample, and for terrigenous material 5% of the total. This was determined by assessing within transect variability.
- Completeness obtained is >90% of the expected 100% for valid, usable data. Occasional spills are recorded. Mistakes are minimized by weighing and checking all data in triplicate.
- Comparability is assured by requiring all standard procedures are strictly adhered to. All data entry is entered into identical spreadsheets using identical units and formulas.

- Detection limits: grain size sieving efficiency and accuracy increases with smaller sample sizes thus we use a 50 g thoroughly homogenized wet aliquot from each sample. The finer size grains also determine efficiency (Royse, 1970).
- Detection limits for sediment composition all samples are weighted using a Mettler Toledo Model: #AB 104 Certification Type: COC. We weigh sediments to 1000th of a gram. Quality Control Services calibrates this balance annually and has detected very minimal drift. Changes in weight due to humidity are minimized by storage in desiccators between weighings.
- The Isotemp Muffle Furnace 550 Series Model 58 performance characteristics include: Operating range: 50⁰C to 1125⁰C, Avg Temperature Stability: ±1⁰C, Set Point Repeatability: ±1⁰C, Set Point Accuracy: ±10⁰C, Rise Time: 25 min., Recovery Time: 10 min., and Cool Down Time: 25 min.

5.2 Assessment of Field Variability (Field Duplicate or Co-located Samples)

Sediment samples are homogenized with a trowel in a dedicated one-gallon container. Samples are subsequently mixed thoroughly prior to lab procedures.

5.3 Laboratory Quality Control Samples

Laboratory quality control (QC) samples are analyzed as part of our standard laboratory practice. The laboratory monitors the precision and accuracy of the results of its analytical procedures through analysis of these QC samples. Laboratory QC samples consist of duplicate samples for organic analyses and for inorganic carbonate analyses. Variability for both replicates and subsamples are expected to be low.

A routinely collected sediment sample contains sufficient volume for both routine sample analysis and additional laboratory QC analyses. Therefore, a separate sediment sample for laboratory QC purposes will not be collected.

6.0 FIELD SAMPLE COLLECTION PROTOCOLS FOR OFF-SITE ANALYSES

Sediments are processed to determine grain-size and organic and carbonate composition (as determined by loss on ignition (LOI)). Standard sample collection methods are used for collection of sediment samples for off-site analysis. A Fisherbrand™ Disposable Sterile Scoop (237 ml) capacity is used to collect approximately 1 kg of sediment from the benthic surface layer and placed into a plastic, disposable Nasco™ Whirlpak collection bag (532 ml).

6.1 Field Equipment

Equipment used in the field to collect sediment samples are limited to the following:

- disposable scoop
- Nasco™ whirlpak collection bags
- one-gallon pail

6.2 Sample Collection by Matrix

6.2.1 Sediment Sampling

Sediments are sampled with a scoop from the benthic surface layer. Ocean depth at sites vary from 1m to 20m. Samples are analyzed for grain-size, organic, and carbonate composition as detailed in section 3.1.1. Samples are placed in a sample-dedicated 1-gallon disposable pail and homogenized with a disposable scoop. Material in the pail is transferred with a scoop from the pail to the sieve. No volatile organic compounds are analyzed.

6.3 Equipment Cleaning and Decontamination Procedures

The only field equipment used to collect sediments for grain-sizing and composition analyses is a disposable scoop in accordance with SOP's (refer to section 3.1.1).

Sediment is scooped into disposable Nasco™ whirlpak collection bags intended for one-time use only. All used bags are packaged for appropriate waste disposal.

Laboratory equipment used to process sediments include mortar and pestles, crucibles and sieves. Decontamination for mortar and pestles and sieves include:

- Non-phosphate detergent and tap water wash, using a brush
- Tap-water rinse
- Deionized water rinse (three times) using a pretreatment scale eliminator, ultrapure filter, and Barnstead meter measuring ppm NaCl.

Decontamination for crucibles include:

- 100°C burn in muffle furnace
- scraping with wire brush

7.0 LABORATORY ANALYSES AND SELECTION

7.1 Summary of Laboratory Analyses

Sediment analysis type	# of locations	# of samples	# of subsamples	# of replicates
Grain-size	184	2	2	2
LOI (loss on ignition)	184	2	2	2

As enumerated in Table 5 sediment samples have been taken at 184 stations at 54 sites and will be taken at an additional 100 stations. Sediment samples are taken from each station. Duplicate samples are taken at each station. Each sample is then subsampled and two replicates are taken from each of the two subsamples.

7.2 Selecting a Laboratory

All sediment processing and analyses are completed by our University of Hawai'i, Hawai'i Institute of Marine Biology, Coral Reef Ecology Laboratory. The staff used to collect sediments also process sediments and analyze results. The capability of this

laboratory is assessed by the UH Environmental Health and Safety Office (EHSO) as detailed in section 2.5. Laboratory training is also required and provided by the EHSO. This laboratory has both the capability and capacity to provide analytical services for the project. The laboratory is equipped with all materials, supplies, and equipment necessary to process sediment samples. This includes:

- filtration system for deionized water
- sieves, wash bottles, filters
- balances
- drying oven
- muffle furnace
- crucibles, desiccators

Standard Operating Procedures for methods performed are explained in section 3.1.1.

8.0 SAMPLE SHIPMENT TO OFF-SITE LABORATORY

8.1 Sample Chain-Of-Custody Forms and Custody Seals

Until sediment samples are shipped, the custody of the samples are the responsibility of CRAMP under the direction of Dr. Ku‘ulei Rodgers. Dr. Rodgers is the designee that signs the chain-of-custody form and notes, sample numbers, duplicate numbers, date, time, and location of samples. Chain-of-custody forms are kept in the CRAMP logbook transported on each survey. No custody seal is placed on samples. Proper handling and labeling protects the integrity of samples.

8.2 Packaging and Shipment

All sample bags are placed in a strong-outside shipping cooler. The following outlines the packaging procedures that are followed.

- The bottom of the cooler is lined with bubble wrap to prevent breakage during shipment.
- Samples are labeled with indelible ink directly on sampling bags.
- Samples from each site are sealed in heavy duty plastic zip-lock bags with sample numbers written on the outside of the plastic bags with indelible ink.
- Any empty space in the cooler is filled with bubble wrap to prevent movement and breakage during shipment.
- Each cooler is securely taped shut with vinyl, fabric-reinforced, multi-purpose pressure sensitive tape with a soft and tacky pressure sensitive adhesive (duct tape).

Records are maintained by CRAMP’s sample custodian (Dr. Ku‘ulei Rodgers). Records include the following information:

- Sampling organization (Coral Reef Assessment and Monitoring Program)
- Carrier, method of shipment
- Shipment date and arrival date received by laboratory
- Irregularities or anticipated problems associated with the samples
- Name and location of station and site
- Number of samples

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