Long-Term Monitoring of Coral Reefs of the Main Hawaiian Islands

Standard Operating Procedure 1:

Surveys of Benthic Reef Communities Using Digital Still Photos

---

ID Williams, SP Cotton, Wj Walsh, KA Stamoulis

State of Hawaii Division of Aquatic Resources
Kona, Hawai'i
January 2006

Contents

INTRODUCTION....4

USING DIGITAL STILL PHOTOS TO SURVEY REEF BENTHOS....4

EQUIPMENT....5

In the field....5

In the laboratory....5

FIELD SAMPLING....6

Fixed-Transect Surveys (previously WHAP)....6

Benthic Characterization....6

IMAGE ANALYSIS - FIXED TRANSECT SURVEYS....7

CPCe Settings....7

CPCe Benthic Categories....8

- Hard Corals....8
- Other Invertebrates....9
- Macroalgae....9
- Cropped/Other Algae....10
- Abiotic....11
- Unidentifiable or Obscured Points....11
- Quantifying Substrate Types....11

IMAGE ANALYSIS – BENTHIC CHARACTERIZATION....12

CPCe Settings....13

CPCe Benthic Categories....13

- Hard Corals....13
- Non Living-Coral Categories....14

ACKNOWLEDGEMENTS....14

REFERENCES....15

APPENDIX A. GENERAL NOTES ON SAMPLING DESIGN....16

APPENDIX B. EXAMPLE CPCE CODE FILE FOR FIXED-TRANSECT SURVEYS....17

List of Figures and Tables

Figures

Figure 1. Benthic Characterization Transect Layout 7

Tables

Table 1. Fixed Transect Coral Codes 8

Table 2. Fixed Transect survey 'Other Invertebrate' Codes 9

Table 3. Fixed transect Survey Macroalgal Codes 10

Table 4. Benthic Category Codes Including Substrate Types 12

Table 5. 'Benthic Characterization' Coral Codes 13

Table 6. Benthic Characterization Non-coral Codes 14

Introduction

This standard operating procedure details the method used by the State of Hawaii's Division of Aquatic Resources (DAR) to survey coral reef benthos using underwater digital still photography. It is intended to be a comprehensive guide for anyone in or out of the department who wishes to follow the same approach.

Digital still surveys of reef benthos are suitable for gathering detailed and precise information about small to medium areas of reef including on cover of corals identified to species, macroalgae to genera, and other benthic categories identified to functional or broad taxonomic groups (e.g. "octocoral", "rubble", "turf").

This is version 0.2 of this SOP.

Using Digital Still Photos to Survey Reef Benthos

The DAR MHI monitoring program utilizes two types of digital still surveys to sample benthos:

- **Fixed-Transect Surveys** (previously 'WHAP'; 25m long permanently-located transects), which are appropriate for detecting small to moderate changes in benthic cover at permanent sites; and
- **'Benthic Characterization'**, a larger spatial scale method aimed at generating broad information about benthos within approx 200m * 30m areas, sufficient to 'characterize' a medium-scale area and to detect gross change in benthic communities. To date, this method has only been employed in West Hawaii medium-scale sampling units where 'resource-fish' surveys are also conducted. It is not a compulsory component of DAR's MHI monitoring scheme.

Additionally, in order to maintain continuity at existing long-term benthic monitoring sites, DAR staff, particularly on Maui, will continue to utilize the 'CRAMP' methodology (http://cramp.wcc.hawaii.edu/) at some MHI monitoring sites.

Methodological information is divided into two broad categories: (1) field sampling; and (2) image analysis. Additionally, we include information on minimum equipment requirement.

Equipment

In the field

For fixed-transect surveys, core equipment requirements are:

- Some means of identifying transect start and end points, which effectively necessitates use of a GPS, together with some means of marking reef locations, such as pelican floats. As the aim is generally to repeat survey fixed transects, semi-permanent tie-off points, such as eye-bolts attached to reef substratum, generally need to be established.
- Transect line(s) marked in a way that makes it is possible to identify transect start and end points. Photographs are to be taken at regular intervals (e.g. 1m apart), so transect lines need to be marked appropriately.
- High quality digital camera and underwater housing. We currently use Olympus 5060 and 7070 digital cameras with high capacity memory chips (256MB or above). Whatever camera is employed, it is very advantageous to use one with a 'white balance' feature, which is a means of adjusting the camera for the loss of red light at the specific survey depth and light conditions, and therefore means that 'natural' color images can be taken without the use of artificial lighting.
- A plexiglass spacer-rod/foot attached to the camera housing is used to maintain the camera at a fixed height (0.75m) from the benthos.
- An underwater compass

For 'benthic characterization', additional requirements are:

- Transect line sufficient to mark out a single 100m long 'spine' marked at 10m intervals (e.g. 4 * 25m transect tapes marked at 5m intervals are used in West Hawaii). Additionally, multiple (3 used in West Hawaii surveys) 10m-long transect tapes marked at 2m intervals.
- A wide-angle lens
- Some means of maintaining a fixed height above the benthos, such as a plumb bob attached to a 1.5m long string.

In the laboratory

Images can be analyzed on any modern desktop computer, but if possible it is worth using a large monitor, and to have a computer with a large hard disk capacity. Surveys generate large numbers of large image files which need to be archived. Therefore the computer used should also have a CD or DVD writer.

There must be some means of transferring images from digital camera flash memory to the computer on which they will be analyzed: either a USB cable which can be attached between the camera and the computer, or, preferably, a flash card reader which can be plugged into to the computer.

A variety of image analysis software tools are suitable. We have used PhotoGrid (www.photogrid.netfirms.com/), but CPCe ('coral point-count with Excel extensions' www.nova.edu/ocean/cpce/) appears to be a slightly more sophisticated and robust equivalent.

Field Sampling

Fixed-Transect Surveys (previously WHAP)

Overview and Objectives: Benthos on short (25-m-long) fixed transects is surveyed using a high quality digital still camera. Images are taken at 1m intervals from a standard height of 0.75 m above benthos. Aim is to generate data sufficient to detect small to moderate % change in key benthic components (e.g. coral cover).

Detail:
Requires a minimum of 2 divers: one to lay out transect lines; the other to take images. On entering the water, divers should lay out all fixed transect lines (e.g. 4 fixed-transects per site in West Hawaii). Assuming the 'white-balance' feature is being used, the diver with the camera should set that separately at the start of each survey.

Images are taken at 1m intervals along each transect line starting at the zero point of each transect, and ending at the 25m mark (therefore 26 images per transect). Use of a 75cm spacer-pole ensures that images are taken from a standard height. Care should also be taken to ensure that shots are taken straight down (i.e. camera not held at an angle).

Data will be analyzed by transect and therefore some means of identifying sub-transects at each site is important, for example a slate with the transect label written on it, can be dropped into the first frame of each transect.

Benthic Characterization

Overview and Objectives: Benthos over medium-large area (approx 200m by 30m) surveyed by means of photo surveys of 20 10m-long 'rib' transects located at 10m intervals on alternating sides of a central 'spine' transect. A wide-angle lens is used and images are taken from 1.5m above benthos, so each image covers a much larger area than fixed-transect images. Aim is to generate data of sufficient quality to 'characterize' an area and to be able to detect gross change. A series of 'panoramic' shots – one at the start of each rib transect - provide a means of quantifying reef structure on a visually estimated scale. Benthic characterization data complements the medium-scale 'resource fish' surveys.

Detail: Benthic characterization sites (~200 m long) are surveyed by two separate dives or dive teams, each of which covers one side of the survey area. Survey dives consist of 3 divers: 2 to lay transects, one to take photographs. The survey team enters the water

together and attach one end of the spine transect to the centre point of the survey area (generally a fixed pin). Divers then swim outward from the starting point following the depth contour and remaining where possible within a contiguous stretch of habitat. In total 100m of spine transect are laid out (could be a single 100m transect line or, for example, 4 separate end-to-end 25m transects). When the entire 100m 'spine' transect has been laid out, divers begin laying out 10m 'rib' transects, beginning at the 100m mark at the end of the spine and subsequently at 10m intervals working back towards the starting point. 10m rib transects are laid perpendicular to the spine transect, each rib starting on the spine. Rib transects are laid on alternate sides of the spine, e.g. first on the left side, next on the right side (Figure 1). The two transect divers are together responsible for retrieving rib spines as they are completed, for laying out new rib transects ahead of the diver taking the images and for reeling in the main spine transect as the dive team work back towards the starting point.

As soon as the first rib transect is laid out, the camera operator begins taking images. At the start of each rib transect, a single panoramic shot is taken which encompasses the entire area of the rib transect, and which will subsequently be used (a) as an archive 'reef-shot' image form the site; and (b) as the basis of visual assessing reef structure on a 5-point scale (more detail later in the document). On each transect, 5 images are then taken: at the 2m, 4m, 6m, 8m, and 10m marks on the rib transect. Each image taken from 1.5m above substratum, with height standardized by use of a plumb bob attached to a line. The camera operator should strive to maintain the camera horizontal above the main plane of the benthos within the frame.

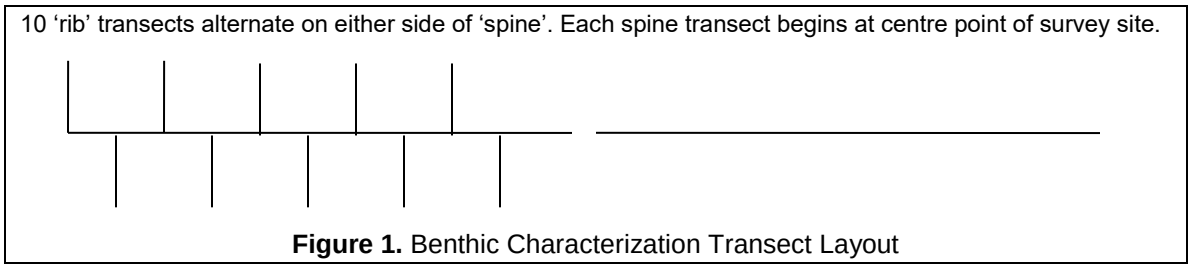

Figure 1. Benthic Characterization Transect Layout

Image Analysis - Fixed Transect Surveys

Coral Point Count with Excel extensions (www.nova.edu/ocean/cpce/) is recommended for image analysis. Whatever image analysis tool is used, data is pooled by transect.

CPCe Settings

Default configuration is 4 transects per site, 26 frames per transect, and 20 stratified random points per frame (4 rows, 5 columns).

Data points should be marked with circles and cross-hairs, and benthos at the exact centre of the cross-hair should be identified each time. If the cross-hair falls exactly on

the boundary between two distinct benthic categories, the category which is most abundant within the circle should be selected.

An accompanying with specimen images of benthic categories is currently in development.

CPCe Benthic Categories

Benthos is recorded in 4 biotic categories: 'hard corals', 'other invertebrates'; 'macroalgae'; and 'cropped/other algae', and one non-living category: 'abiotic'.

Within each of those categories, multiple sub-categories of benthos are identified and recorded with specific codes. A companion CD of benthic images corresponding to specific benthic codes is in preparation at the time of writing (Jan 2006). An example fixed-transect CPCe benthic code file is given in Appendix B.

Hard Corals

Corals are identified to species level (Table 1), and where that is not possible, coral is simply recorded as 'Unidentified coral'.

Table 1. Fixed Transect Coral Codes

Taxa/Group	Code
***Porites compressa*[1]**	PCOM
***Porites lobata*[1]**	PLOB
Porites evermanni	PEVE
Porites rus	PRUS
Fungia scutaria	FSCU
Leptoseris incrustans	LINC
Leptastrea purpurea	LPUR
Montipora capitata	MCAP
Montipora flabellata	MFLA
Montipora patula	MPAT
Pavona duerdeni	PDUE
Pavona varians	PVAR
Pocillopora eydouxi	PEYE
Pocillopora meandrina	PMEA
Pocillopora damicornis	PDAM
Unindentified coral	UNCO

Note (1): Recent research indicates that it is not always possible to distinguish *Porites compressa* and *Porites lobata* by growth form alone. *Porites lobata* appears to grow in branching forms at times, and it is also possible that *P. compressa* and *P. lobata* hybridize. To maintain consistency with previous data, and accept limits of what is possible from image analysis, branching forms of *P. compressa/lobata* are to be recorded as *P. compressa*, and lobed forms as *P. lobata*.

Coral condition codes, which are used to indicate 'unhealthy', 'diseased' or recently dead coral' are saved in the 'notes' column of the CPCe data entry screen. Current condition codes are:

Bleached (BLCH)	Pale to white tissue
Necrotic (NECR)	
Tumor (TUMO)	Abnormal growth form
Recently Dead (RECD)	Recent partial or total colony mortality. Skeletal features still visible
Other Disease (OD)	Unidentified disease

Other Invertebrates

Table 2. Fixed Transect survey 'Other Invertebrate' Codes

Taxa Group	Code	Notes
Mobile Invert	MINV	Urchins, Sea stars, any other mobile invertebrate
Bryozoan	BRYO	
Anenome	ANEM	
Octocoral	OCTO	
Zoanthid	ZOAN	
Tunicate	TUNI	
Sponge	SPNG	
Other Sessile Invertebrate	OSIN	Any other sessile invertebrate

Macroalgae

Macroalgae are identified as having distinguishable structures such as fronds, stalks and holdfasts.

Macroalgal codes can be set to one of two levels, depending on the expertise of the person doing the analysis (Table 3). At the simplest level of analysis (Level 1), invasive algal species are identified to species level, all other macroalgae are identified as 'large macroalgae', which have (or, more accurately as identification is done from photographs, appear to have) canopy heights or fond extensions of >2cm; 'low macroalgae" which have distinguishable structural features but which are smaller than 2cm; and crustose macroalgae. For Level 3, large macroalgae are sub-divided to genera. Levels are hierarchical; therefore detailed lower level data can be pooled up to higher levels.

Table 3. Fixed transect Survey Macroalgal Codes

Taxa/Group	Code	Notes
Level 1		
Large macroalgae	MACR	
Low macroalgae	LMAC	Identifiable structural features, but canopy height or frond extension < 2cm
Crustose macroalgae	CMAC	Crustose macroalgae (not crustose corallines algaes)
Invasive species		
Acanthophora spicifera	ASPI	
Dictyosphaeria cavernosa	DCAV	
Gracillaria salicornia	GSAL	
Hypnea musciformis	HMUS	
***Kappaphycus* sp.**	KAPP	
Level 3 (above plus..)		
***Avrainvillea* sp.**	AVRA	
***Asparagopsis* sp.**	ASPA	
***Codium* sp.**	CODI	
***Caulerpa* sp.**	CAUL	
***Cladophora* sp.**	CLAD	
Dictyosphaeria versluysii	DVER	
***Dictyota* sp.**	DICT	
***Galaxaura* sp.**	GMAR	
***Halimeda* sp.**	HALI	
***Halymenia* sp.**	HALY	
***Liagora* sp.**	LIAG	
***Lobophora* sp.**	LOBO	
***Neomeris* sp.**	NEOM	
***Padina* sp.**	PADI	
***Sargassum* sp.**	SARG	
***Stypopodium* sp.**	STYP	
***Turbinaria* sp.**	TURB	
***Ventricaria* sp.**	VENT	
Gelatinous red	GOOEY	Genera-level ID difficult for these groups
Jointed calcareous red	JCAL	

Cropped/Other Algae

All algae other than macroalgae are included here, specifically:

- **Turf/Bare** TU/B Turf algae encrusts the substratum and has no discernible structural features. This category also includes substrate which is apparently bare, but which is presumably colonized by microalgae. NB turf/bare substratum generally falls in a continuum between completely bare (e.g. very recent grazing scar) and moderately thick turf. Especially with photographs, it is difficult to create a clear distinction

between those categories, hence they are pooled here.

- **Crustose Coralline** CRST Encrusting coralline algae
- **Blue-Green Algae** BLGR Cyanobacteria

Abiotic

Abiotic categories include 'sand' and holes which are sufficiently deep that benthos at that point can not be identified from the photographic image.

- **Sand (SAND)** Ranging from fine silt to calcareous sediment.
- **Black Hole (BHOL)** Benthos under point falls on hole in the reef and is therefore unidentifiable. Generally point will be in shadow.
- ***Porites compress* Hole (PCHO)** Similar to 'Black Hole' (i.e. hole in reef, and benthos not identifiable), but in this case, the 'hole' is within a *Porites compressa* bed – gaps of that kind between fingers of *Porites* are common, and are likely important habitat features for many fish species. To be identified as PCHO only when the hole is within 2cm of a distinct *P. compressa* finger.

Unidentifiable or Obscured Points

Points can sometimes not be identified from photographs because either benthos is obscured by survey tape or the spacer pole, or because image quality is too poor. 'Unidentified' benthic categories are:

- **Tape (TAPE)** Point falls under transect line or tape
- **Wand (WAND)** Point falls under camera spacer pole
- **Shadow (shadow)** This category is required by the CPCe program, but should not be used, as DAR categories 'Black Hole' or '*Porites compressa* hole'.
- **Unidentified (UNID)** Inadequate image quality means that benthos can not be identified.

Quantifying Substrate Types

Optional additional benthic codes, currently used in image analysis as part of West Hawaii benthic monitoring, contain information not only on the living veneer, but also on the underlying substrate type. Qualifying benthic categories in that way clearly adds a level of complexity to image analysis, but is considered desirable as the underlying

substrate types are basic habitat types which likely influence suitability of the reef area for particular groups of fishes (e.g. some species of fishes are heavily dependent on *Porites* finger-coral beds, others on rubble, for others, a distinction between aggregate coral and bare rock is also likely important). Using these qualifying codes allows post-processing of data to generate reasonable estimates of % cover of those different sub-habitat types in addition to the veneer information available from the unqualified codes.

Substrate-types identified are:

- Rubble — Fist-size or smaller unconsolidated dead coral fragments
- *Porites* finger habitat — Base of, or dead, fingers of branching Porites (typically *P. compressa*)
- Aggregate coral — Dead coral substrate
- Other — All other substrates with organisms growing on them (e.g. rock)

The mechanism for saving this information is for benthic code to include information on both the veneer (e.g. 'turf', 'octocoral') and the underlying substrate type ('Rubble', '*Porites* finger', 'Aggregate coral', 'Other'). To date, these qualifying codes have only been used for veneer categories, when both: (1) those categories are at least sometimes abundant (and so much additional information is gained by quantifying substrate type); and (2) it is relatively easy to identify underlying substrate type, i.e. for 'Turf/bare', 'Crustose coralline', "Blue-green algae" "Octocoral" (Table 4).

Table 4. Benthic Category Codes Including Substrate Types

Benthic Category	**No info / 'other' substrate**	**Rubble**	***Porites* finger**	**Aggregate Coral**
Turf/Bare	TU/B	TB/R	TU/DC	TU/DL
Crustose Coralline Algae	CRST	CR/R	CR/DC	CR/DL
Octocoral	OCTO	OC/RU	OC/DC	OC/DL
Blue-green algae	BLGR	BG/R	BG/DC	BG/DL

Image Analysis – Benthic Characterization

As above, CPCe is recommended for image analysis. Data is always pooled by side of the survey area (in West Hawaii that is generally 'north' or 'south'), i.e. the 10 'rib' transects on one side of the survey area central point, which are physically surveyed in one dive.

CPCe Settings

Default configuration is 20 transects per site, 5 frames per transect, and 20 stratified random points per frame (4 rows, 5 columns).

As above, data points should be marked with circles and cross-hairs, and benthos at the exact centre of the cross-hair should be identified each time. If the cross-hair falls exactly on the boundary between two distinct benthic categories, the category which is most abundant within the circle should be selected.

CPCe Benthic Categories

The aim of the benthic characterization surveys is to generate broad data about the nature and condition of the habitat in the area surveyed, and to generate sufficient quantitative information to be able to detect gross changes in benthos. Therefore, benthic categories are greatly simplified from those used for fixed-transect surveys, which has the additional advantage of reducing the difficulty and effort required for image analysis. Target categories for benthic characterization are: living coral (to functional form, Table 5); macroalgae; or habitat type (i.e. *Porites* finger habitat, Aggregate coral, Rubble, Rock, Sand. Table 6).

Hard Corals

Corals are identified to functional group (Table 5), and where that is not possible, coral is simply recorded as 'Unidentified coral'.

Table 5. 'Benthic Characterization' Coral Codes

Taxa/Group	Code	Notes
Porites lobe	PMAS	Massive/mounded Porites, e.g. *P. lobata, P. lutea*
Porites finger/branching	PFIN	e.g. *Porites compressa, Porites duerdeni,* columnar form of *P. rus*
Branching	BRAN	*Pocillopora damicornis, P. eydouxi, P. meandrina*
Encrusting	ENCR	Colonies adhere and encrust the substrate and have little vertical growth, e.g. most *Montipora*
Plate-Like	PLAT	Horizontal plates with small basal attachment e.g. laminar forms of *Porites rus & Montipora capitata*
Lobate	LOBE	Mounded non-*Porites*, e.g. *Pavona duerdeni*
Other coral	C/OT	All others, includes fungids
Unindentified coral	UNCO	Living coral, but image quality too poor to identify in above categories

Non Living-Coral Categories

Table 6. Benthic Characterization Non-coral Codes

Taxa Group	Code	Notes
Large macroalgae	MACR	AS ABOVE, Identifiable structural features, canopy height or frond extension < 2cm
Veneer other than living coral or macroalgae (i.e. veneer is low macroalgae, turf, crustose coralline algae, apparently bare, or any sessile invertebrate other than coral)		
Rubble	RUBB	Fist-size or smaller unconsolidated dead coral fragments
Porites finger habitat	POFH	Substrate is dead branching *Porites*, or holes between *Porites* fingers.
Other coral habitat	AGCH	Substrate is dead coral other than *Porites* finger coral, or is a hole adjacent to live or dead coral.
Sand	SAND	
Other habitat	OTHH	Substrate is not dead coral or hole, rubble, or sand (e.g. substrate is granite rock).
unidentified/obscured points		
Tape	TAPE	Point falls under transect line or tape
Wand	WAND	Point falls under camera spacer pole
Shadow	SHADOW	This category is required by the CPCe program, but should not be used, as DAR categories 'Black Hole' or '*Porites compressa* hole'.
Mobile Invert	MINV	Urchins, Sea stars, any other mobile invertebrate obscures benthos
Unidentified	UNID	Inadequate image quality means that benthos can not be identified.

Acknowledgements

Document outline taken from AIMS standard operating procedures.

References

Ryan DAJ, Heyward A (2003) Improving the precision of longitudinal ecological surveys using precisely defined observational units. Environmetrics 14:283-293

Appendix A. General Notes on Sampling Design

Sampling designs are essentially hierarchical: (1) multiple replicate transects need to be conducted per area surveyed; (2) multiple digital images taken per transect; and (3) multiple data points analyzed per digital image. Transect dimensions can be readily varied – length depending on the length of line layed out, and the effective width sampled being dependent on the height from which photographs are taken. At each level a decision has to be made about the amount of replication and whether sampling is random or systematic (e.g. are transects randomly located, or laid out in some consistent pattern? Are digital images taken at random points along transect line or at fixed intervals, such as once every meter? Are analysis points per frame randomly scattered around the frame, or in some fixed pattern, or some combination of the two such as stratified-random?).

The optimum sampling regime varies from situation to situation, depending on a number of factors including the size of reef area to be sampled and the aims of the survey, including the desired statistical and taxonomic precision. However, general principles of sampling which should be considered include:

- Maximizing the number of images surveyed and the spread of those images throughout the survey area will tend to improve the quality of data generated (the data will better represent the actual benthic cover and variability of the whole area being surveyed). In other words, to the extent that it is logistically feasible, it is better to aim to maximize the number of sampling units (transect per area, and images per transect) and reduce the number of data points per image. However, from purely practical perspective, the best strategy is the exact opposite - to use as few transects and few images as possible, and to heavily sub-sample those images. There is no simple answer to balancing those two considerations.

- Images and transects must be non-overlapping (so portions of benthos are not double counted)

- To the extent possible, survey within a single habitat. That will tend to reduce the variability of resulting survey data (and therefore reduce the amount of sampling necessary) and generate data that are more easily interpretable.

- In general, randomly locating transects each time is the best way to get an overall estimate of benthic cover within an area, but permanently located transects are much better at detecting change. Given the substantial amount of effort involved in carrying out benthic still surveys, and the inherent patchiness of reef benthos at likely scales of interest, it will generally be hard, to impossible, to detect small to moderate change over time on surveyed reefs without using permanently-fixed transects (Ryan & Heyward 2003).

- To the extent possible, survey regime should be standardized among comparative times or sites. Reducing variability in methods will greatly increase confidence that any differences among surveys are due to real differences in benthos rather than differences being an artifact of differing survey approaches.

Appendix B. Example CPCe Code File for Fixed-Transect Surveys

```
7
"C", "Coral"
"OI", "Other Invert"
"A", "Abiotic"
"CA", "Cropped/Other Algae"
"MA", "Macroalgae"
"U", "Unidentified"
"TWS", "Tape, wand, shadow"
"PCOM", "Porites compressa","C"
"PLOB", "Porites lobata","C"
"FSCU", "Fungia scutaria","C"
"LINC", "Leptoseris incrustans","C"
"LPUR", "Leptastrea purpurea","C"
"MCAP", "Montipora capitata","C"
"MFLA", "Montipora flabellata","C"
"MPAT", "Montipora patula","C"
"PDUE", "Pavona duerdeni","C"
"PVAR", "Pavona varians","C"
"PEVE", "Porites evermanni","C"
"PRUS", "Porites rus","C"
"PEYE", "Pocillopora eydouxi","C"
"PMEA", "Pocillopora meandrina","C"
"PDAM", "Pocillopora damicornis","C"
"UNCO", "Unindentified coral","C"
"MACR", "Large macroalgae","MA"
"LMAC", "Low macroalgae","MA"
“CMAC”, “Crustose macroalgae”,“MA”
"UBRN", "Unindentifed brown","MA"
"URED", "Unindentified red","MA"
"UGRE", "Unindentified green","MA"
"ASPI", "Acanthophora spicifera","MA"
"DCAV", "Dictyosphaeria cavernosa","MA"
"GSAL", "Gracillaria salicornia","MA"
"HMUS", "Hypnea musciformis","MA"
"KAPP", "Kappaphycus sp","MA"
"GOOEY", "Gelatinous red","MA"
"JCAL", "Jointed calcareous red","MA"
"AVRA", "Avrainvillea sp","MA"
"ASPA", "Asparagopsis sp","MA"
"CODI", "Codium sp","MA"
"CAUL", "Caulerpa sp.","MA"
"CLAD", "Cladophora sp","MA"
"DVER", "Dictyosphaeria versluysii","MA"
"DICT", "Dictyota sp","MA"
"GALA", "Galaxaura sp.","MA"
"HALI", "Halimeda sp.","MA"
```

"HALY", "Halymenia sp","MA"
"LIAG", "Liagora sp","MA"
"LOBO", "Lobophora sp","MA"
"NEOM", "Neomeris sp","MA"
"PADI", "Padina sp","MA"
"SARG", "Sargassum sp","MA"
"STYP", "Stypopodium sp","MA"
"TURB", "Turbinaria sp","MA"
"VENT", "Ventricaria sp","MA"
"MINV", "Mobile Invert","OI"
"OSIN", "Other sessile inverts","OI"
"BRYO", "Bryozoan","OI"
"ANEM", "Anenome","OI"
"ZOAN", "Zoanthid","OI"
"TUNI", "Tunicate","OI"
"SPNG", "Sponge","OI"
"OCTO", "Octocoral","OI"
"OC/R", "Octocoral on rubble","OI"
"OC/DL", "Octocoral on dead coral","OI"
"OC/DC", "Octocoral on dead compressa","OI"
"TU/B", "Turf/Bare","CA"
"TB/R", "Turf/Bare on rubble","CA"
"TB/DL", "Turf/Bare on dead coral","CA"
"TB/DC", "Turf/Bare on dead compress","CA"
"CRST", "Crustose","CA"
"CR/R", "Crustose on rubble","CA"
"CR/DL", "Crustose on dead coral","CA"
"CR/DC", "Crustose on dead compressa","CA"
"BLGR", "Blue green","CA"
"BG/R", "Blue green on rubble","CA"
"BG/DL", "Blue green on dead coral","CA"
"BG/DC", "Blue greed on dead compressa","CA"
"BHOL", "Black Hole","A"
"PCHO", "Porites compressa hole","A"
"SAND", "Sand","A"
"UNID", "Unidentified", "U"
"TAPE", "Tape","TWS"
"WAND", "Wand","TWS"
"Shadow", "Shadow","TWS"
NOTES,NOTES,NOTES
"BLCH", "Bleached","NA"
"NECR", "Necrotic","NA"
"TUMO", "Tumour","NA"
"RECD", "Recently Dead", "NA"
"OD", "Other disease","NA"