PACIFIC ISLANDS FISHERIES SCIENCE CENTER

Analysis of Benthic Survey Images via CoralNet: A Summary of Standard Operating Procedures and Guidelines

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January 2017

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CONTENTS

I. INTRODUCTION

This document is intended as a reference and provides guidelines for training and the analysis of images on CoralNet from surveys conducted by the Coral Reef Ecosystem Program (CREP), Ecosystem Sciences Division of the NOAA Pacific Islands Fisheries Science Center (PIFSC). The user documentation outlined in this report applies to the analysis of photoquadrat images collected by CREP and its partners in the coral reef ecosystems of about 40 primary islands, atolls, and shallows banks in the Hawaiian Archipelago (including the Papahānaumokuākea Marine National Monument), the Mariana Archipelago (Guam and the Commonwealth of the Northern Mariana Islands, including the Marianas Trench Marine National Monument), the Territory of American Samoa, and the Pacific Remote Islands Marine National Monument (Wake, Johnston, Palmyra, and Kingman Atolls and Howland, Baker, and Jarvis Islands).

II. BACKGROUND

Estimates of benthic community composition and structure are fundamental components of coral reef monitoring programs. Typically, percent cover is measured to characterize the benthic habitat, and there are several available approaches to deriving this metric, each with differing levels of accuracy, effort, and efficiency (Ohlhorst et al., 1988; Jokiel et al., 2015). The Coral Reef Ecosystem Program's Pacific Reef Assessment and Monitoring Program (Pacific RAMP) has implemented three different protocols to derive estimates of benthic percent cover at different spatial scales: 1) visual Towed-diver Surveys (TDS) that cover approximately 15,000–25,000 m^2 per survey (Kenyon et al., 2006) have been conducted to provide broad-scale assessments of benthic composition around each island since the inception of Pacific RAMP in 2000; 2) the Line-Point-Intercept (LPI) method (Hill and Wilkinson, 2004) was conducted at long-term, Rapid Ecological Assessment (REA) surveys sites to provide fine-scale information on benthic community composition of coral, algae, and invertebrates from 2005 to 2012; and 3) analysis of digital benthic imagery collected to photo-document the benthic habitat as part of TDS, or as part of fish and coral demographic surveys conducted at long-term fixed or stratified-random REA sites (Brainard et al., 2012).

In 2010, interdisciplinary members of the CREP benthic ecology and monitoring team, the CREP fish ecology and monitoring team, the CREP benthic habitat mapping team, as well as partners from Scripps Institution of Oceanography and Moorea Coral Reef Long-term Ecological Research, organized an image analysis workshop to better integrate and

unify all concurrent image analysis efforts. The main objective of the workshop was to develop a replicable, consistent, and statistically robust image analysis protocol that included a classification scheme that unified all disparate CREP image analysis efforts. At this workshop, it was also decided that Coral Point Count with Excel extensions (CPCe) (Kohler and Gill, 2006) would be named the main image analysis tool. From this point until 2012, benthic cover estimates derived from the analysis of images collected during both TDS and REA surveys were determined at the functional or morphological group level (e.g. encrusting coral, upright macroalgae, sand). This level of identification is referred to as Tier 2 and can be collapsed into more general categories as Tier 1 (e.g., coral, macroalgae, sediment).

In 2013, CREP replaced LPI surveys with photoquadrat surveys and began to derive REA site-specific percent cover and benthic composition estimates solely from the photoquadrat images (Coral Reef Ecosystem Division, PIFSC, NOAA Fisheries, 2015). With the availability of high-resolution images and the implementation of more rigorous observer training, CREP began to classify benthic composition from REA images at a finer level of taxonomic resolution that included several algal and coral genera (Tier 3). Tier 3 was later modified to Tier 3b, which includes additional coral taxa and morphological designations, and combines some rare algal groups. It should be noted, however, that TDS images are still currently analyzed at the Tier 2 level as a result of reduced image quality.

In Q1-2015, CREP began to transition to the web-based annotation tool, CoralNet (Beijbom et al., 2016), which features semi- to fully-automated annotation capabilities. The transition involved translating CPCe benthic categories into CoralNet labelsets, producing (a) a classification guide for the 95 image analysis benthic categories used by CREP; (b) a mapping guide that shows how categories from different tiers are related; and (c) six Standard Operating Procedures (SOPs) as follows: 1) setting up an account on CoralNet, 2) CoralNet pre-analysis calibration exercise, 3) CoraNet image analysis user guide for REA photos, 4) CoralNet image analysis user guide for TDS photos, 5) setting up a CoralNet Source page, and 6) uploading images to CoralNet. These SOPs are integrated into a single product in this document, followed by the associated guides as appendices. By Q3-2015, CREP fully implemented the use of CoralNet to annotate the photoquadrat images collected during Pacific RAMP cruise to American Samoa and the Pacific Remote Island Marine National Monument.

III. METHODS – BENTHIC IMAGE ANALYSIS STANDARD OPERATING PROCEDURES

III.A. CoralNet User Guide

When working with numerous analysts and a large photoset, a Benthic Image Analysis (BIA) coordinator will be responsible for pre-production processing, tracking the

progress of the analysis, and communicating the assignments and additional instructions to the analysts. Specifically, the BIA coordinator will ensure that prior to analyses, all photographs have undergone appropriate post-collection processing: photographs have been renamed appropriately, tagged, and cataloged in the appropriate folder within the V:\OPTICAL directory structure developed by the Data Management Team. The BIA coordinator will also be responsible for uploading all the photoquadrat images to CoralNet along with the metadata file (with analyst site or image assignments included) prepared by the Data Manager. The BIA coordinator will also be responsible for updating and reporting the tracking log to the analysts.

III.A.1. Set Up Your CoralNet Account

a) Launch CoralNet on your preferred web browser: http://coralnet.ucsd.edu
b) For first time users, request a new user account by clicking on the Sign Up link
   Fill in the following fields:
   First Name
   Last Name
   Email - *use your preferred email account*
   Username - *for ease in tracking, use the suggested formats: "firstnamelastname" (e.g. janesmith); "firstname_lastname" (jane_smith); "firstand/middlenameinitialslastname" (e.g.jksmith)*
   Affiliation - *e.g. NOAA PIFSC ESD Coral Reef Ecosystem Program*
   Reason for requesting an account - *e.g. Analyze CREP's optical data (primarily photoquadrat images) via CoralNet*
   Project description - *e.g. One of the aims of the Pacific Reef Assessment and Monitoring Program (Pacific RAMP) is to collect data on coral population and reef community structure. While coral demography, partial mortality, and conditions are surveyed and assessed by the Coral Reef Ecosystem Program (CREP) via belt transects, benthic community structure and percent cover are derived from photoquadrat images. For more info, please go to https://www.pifsc.noaa.gov/cred/*
   How did you hear about us: Oscar Beijbom
c) Click on the "Agree to data policy" check box
d) On the blank field, type the text that you see on the reCAPTCHA™ image
e) Click on "Submit"
f) You will receive a confirmation email from "noreply@coralnet.ucsd.edu" that will contain a link to activate your account and a temporary password. You may also receive a welcome email from Oscar Beijbom with links to the CoralNet instructional videos on Vimeo. Review this video series to gain an overview and understanding of how CoralNet functions before attempting to use the program
g) Once your account is activated, change your user password and sign in
h) If working with a BIA coordinator(s), immediately inform them of your CoralNet username so you can be added as a user to the source page where all of the analysis will take place

III.A.2. Analyst Inter-Calibration Process

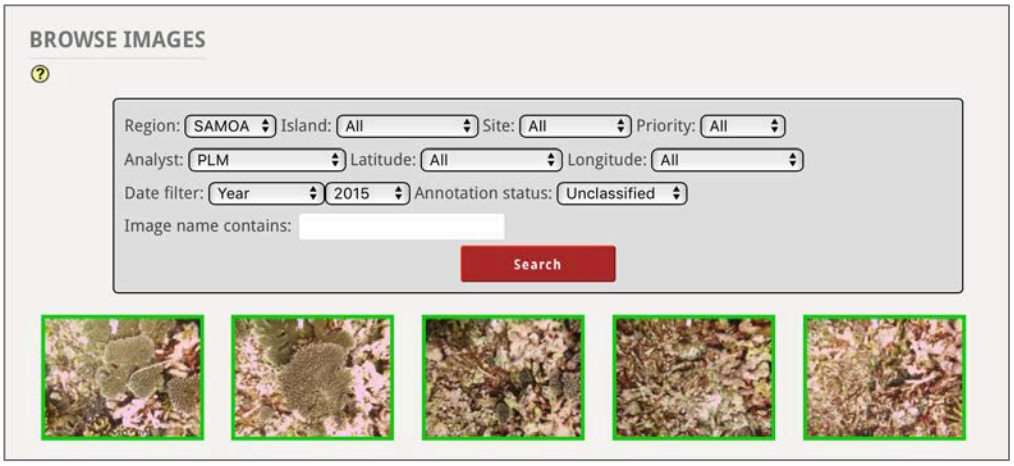
Prior to each benthic image analysis (BIA) production series, all analysts must participate in an inter-calibration process to check for inter-observer variability and bias. For CREP analyses, the inter-calibration process will begin with a pre-calibration exercise: a small number of images (3-5) with points already projected will be distributed to analysts who will analyze them using CPCe or CoralNet. The results of the pre-calibration exercise will be compiled and all analysts will participate in a meeting in which the images will be discussed in detail. Problematic identification categories (e.g. CCA, turf algae, blue-green macroalgae) and points will be highlighted to ensure analysts achieve a consensus identification for each point. This process will help build consistency among analysts that will increase the ability of the BIA process to discern trends and patterns in benthic cover across space and time. Following the pre-calibration exercise, analysts will annotate a series of 100 images with points already projected. The results of this exercise will be analyzed using multivariate and other means to assess similarities and discrepancies among analysts. Analysts who differ markedly will repeat the exercise. Analysts who exhibit a reasonable degree of similarity and consistency will proceed and begin the BIA series. CREP calibration exercises are accessed through the CoralNet 'CREP-Calibration Exercise (REA)' and 'CREP-Calibration Exercise (TDS)' source pages.

The Standard Operating Procedure for Calibration Exercises (for either REA or TDS images) is as follows:

a) **Selecting your assigned images**

1) Launch CoralNet on your preferred web browser and Sign In.
2) Under "Your Sources", select "CREP-Calibration Exercise *(TDS* or *REA)*".
3) On the source page, select "Images".

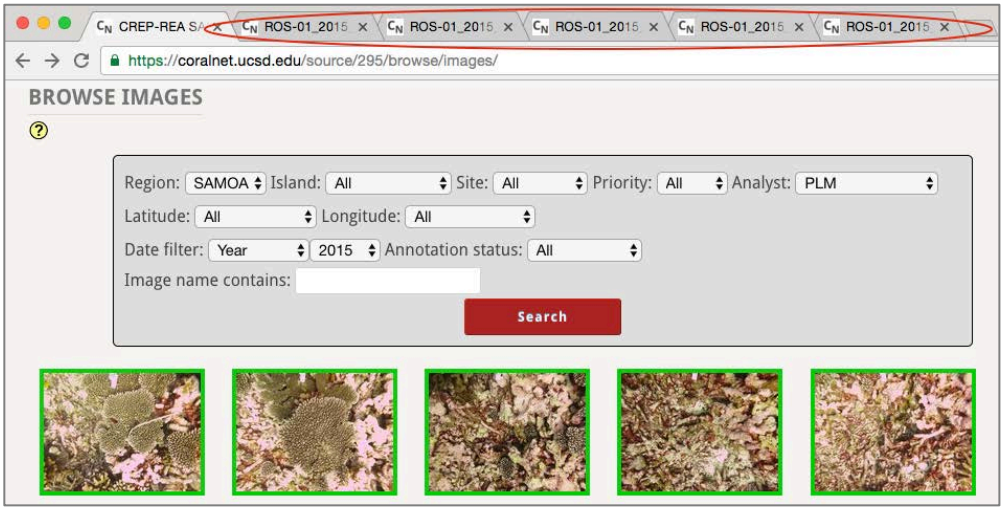
4) Use the dropdown menus to specify the **"Region"** from which the images you will be analyzing originated. Under **"Date filter: Year"**, select the corresponding year the images were collected. Set the **"Annotation status**" to either "All", "Unclassified", or "Unconfirmed" depending on your viewing preference. Then, most importantly, choose your initials under "**Analyst**".



5) Click on the **"Search"** button to display your selection.

Note: The image border color indicates the image's annotation status: red if it needs annotation, green if the image has been annotated/confirmed, and orange if the image has been machine-annotated but still needs to be confirmed by the analyst.

6) **Keep the image browser page tab open as you will be returning to this page to select and analyze your next set of images.**
7) In the image browser page, 20 of the selected images will be shown per page. **MOUSE-OVER** (do not click) all image thumbnails to view the filenames and ensure that the correct photoset has been displayed.
8) While holding the CTRL ^ (Windows) or CMD ⌘ (Mac) key, click on the first 5 un-annotated or unconfirmed image thumbnails on the image browser page. This will open each image on a separate tab on your web browser.



9) On your web browser, click on the tab displaying the first image.
10) On the **Image Details page**, ensure that the correct image was displayed by checking the image's metadata found on the lower left corner of the image.

Note: If the wrong image was displayed, close all 5 newly opened tabs and return to the tab displaying the CoralNet image browser. Repeat steps III.A.2.a.4–10 (pp.5–6).

Note: If you accidentally closed the tab displaying the CoralNet image browser, open a new tab on your web browser and repeat steps III.A.2.a (pp.4–5). If possible, drag this tab to the far left side of the web browser to easily identify and jump back to this page when opening a new set of images

11) Click on the **"Annotation Tool"** button on the upper right corner of the page to begin analysis.

b) **CoralNet Annotation Settings**

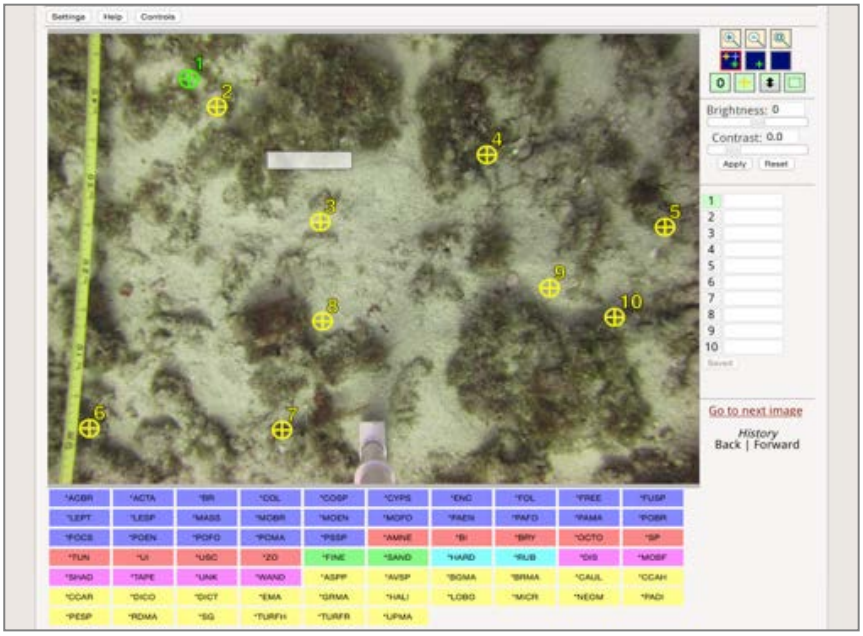
The following recommended settings only **apply to CoralNet calibration exercises**:

1) Click on the "Settings" button found on the upper left side of the image.
2) On the "Settings" pop-up box, select the following:
   Point marker: Crosshair and circle
   Point marker size: 12
   Point marker is scaled: *check*
   Point number size: 28
   Point number is scaled: *check*
   Point colors: *user's preference*
   Show machine annotations: ***uncheck***
3) Click on the "Save settings" button.
4) Click on the X button on the upper right corner to exit.

c) **Image Analysis Process**

1) Click on the first cell in the ID column found on the far right side of the screen.

2) The analysis point (#1) on the image will change to the color designated for the selected data point (green by default).



3) Identify the benthic category/label underneath the point's cross-hair:
Decide which benthic category lies directly underneath the point's cross-hair and choose the corresponding label from the label grid at the bottom of the screen. The category label is automatically entered in the cell, and the data point changes to the color chosen for the confirmed data point (blue by default).

Note: If all 10 cells have been populated with suggested annotations (in grey text), go back to step III.A.2.b (p. 7) to hide the machine-annotations.

4) After selecting the correct category, the cursor will automatically advance to the next point. For guidance on selecting the correct category, please see the III.A.4. Image Analysis Guideline section (p. 19).

Note: Click on the "Help" button above the image for further guidance on using the annotation tool. Similarly, click on the "Controls" button for navigation tips and keyboard shortcuts. Many of the controls are set up to provide similar functions as those available in CPCe. For example, buttons are available to the right of the image to show all points, the point under consideration only, or no points.

5) Repeat steps III.A.2.c.3–4 (pp. 7–8) until all points on the image are classified.
6) Click on "Save Progress" to save your annotations. "ALL DONE" will be displayed at the bottom of the column to indicate that all annotations on the each point have been saved and confirmed.
7) Close the web-browser tab of the recently annotated image and click on the tab of the next image to be analyzed.

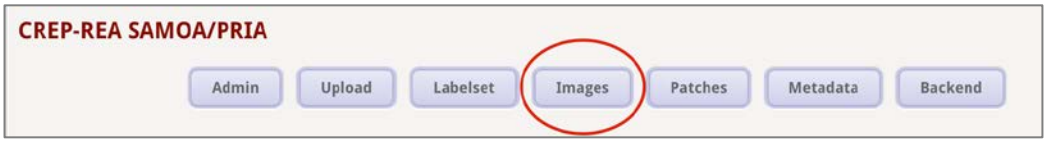
8) Repeat steps III.A.2.c. 1–7 (pp. 7–8) until all opened images have been analyzed.
9) Return to the tab displaying CoralNet's image browser page. To update the status of the selected images, click on "Search". The status of the recently annotated image/s has now been updated indicated by the green frame around the image thumbnail/s that has just been analyzed.
10) Select the next 5 images to analyze by repeating steps III.A.2.a.7–11 (pp. 5–6), followed by steps III.A.2.c.1–9 (pp. 7–8).
11) When the first 20 images have been analyzed, click the '>' below the field of image thumbnails to advance to the next page and display the next 20 images. Ensure that the appropriate **"Year", "Region",** and **"Analyst"** have been selected on the browse tool. Repeat steps III.A.2.a.6–11 (pp. 5–6) and III.A.2.c (pp. 7–8).

Note: Unlike CPCe, analysis via CoralNet will not involve exporting your results into an Excel spreadsheet. Exporting the data set will be the responsibility of the data manager or BIA coordinator. When all assigned images have been analyzed, please inform your BIA coordinator via email

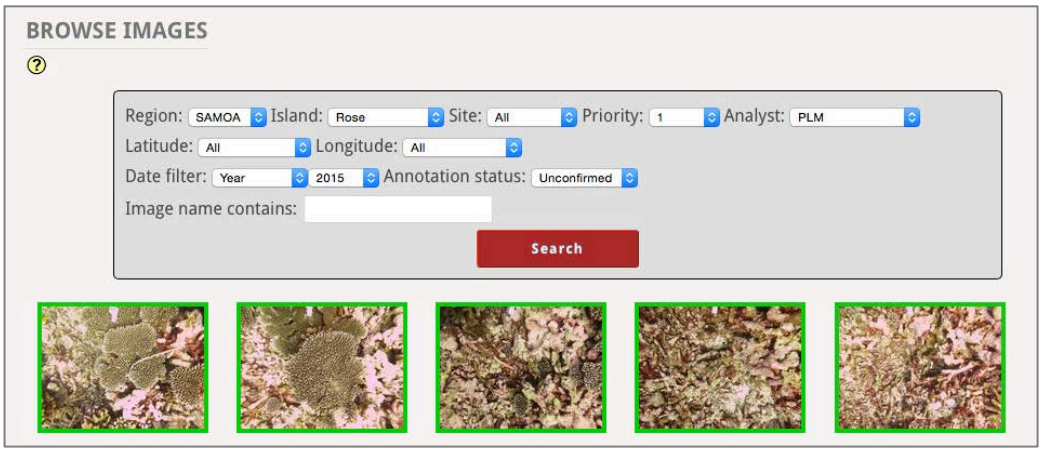
III.A.3. Analyzing Images

III.A.3.1. Analyzing Rapid Ecological Assessment (REA) Images

a) **Selecting your assigned images**
1) Launch CoralNet on your preferred web browser and Sign In.
2) Under "Your Sources", select "CREP-REA *region*" (e.g. "CREP-REA SAMOA", "CREP-REA HAWAII").
3) On the source page, select "Images".



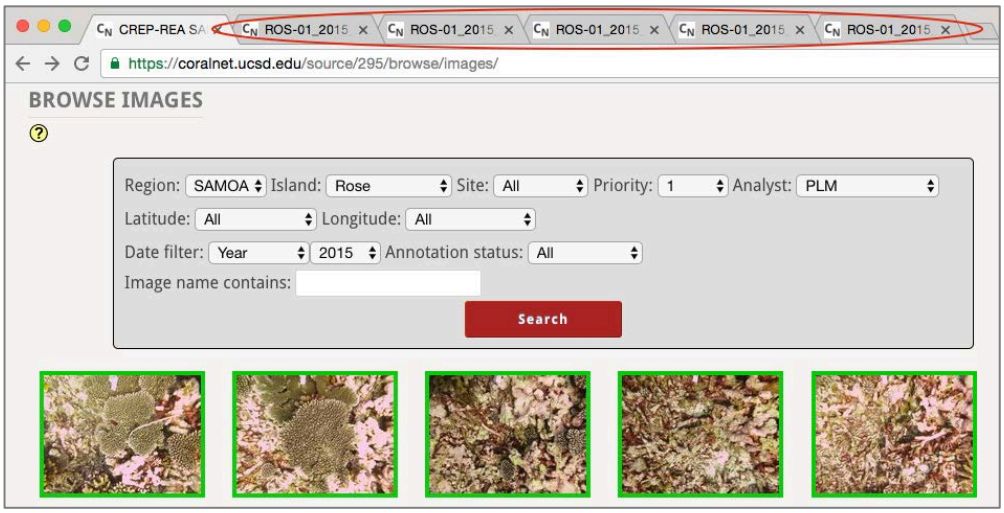
4) Use the dropdown menus to specify from which **"Region"** and/or **"Island"** the images you will be analyzing originated. If applicable, select the photoset **"Priority"** number (priority numbers are usually set by your BIA coordinator or project lead). Under **"Date filter: Year"**, select the corresponding year the images were collected. Set the **"Annotation status**" to either "All", "Unclassified", or "Unconfirmed" depending on your viewing preference. Then, most importantly, choose your initials under "**Analyst**".
5) Click on the **"Search"** button to display your selection.



Note: The image border color indicates the image's annotation status: red if it needs annotation, green if the image has been annotated/confirmed, and orange if the image has been machine-annotated[1] but still needs to be confirmed by the analyst.

6) **Keep the image browser page tab open as you will be returning to this page to select and analyze your next set of images.**
7) In the image browser page, 20 of the selected images will be shown per page. **MOUSE-OVER** (do not click) all image thumbnails to view the filenames and ensure that the correct photoset has been displayed (i.e., the name of the analyst will usually be included in the image name in CREP images on CoralNet; make sure your initials are found in all the image names)
8) While holding the CTRL ^ (Windows) or CMD ⌘ (Mac) key, click on the first 5 un-annotated or unconfirmed image thumbnails on the image browser page. This will open each image on a separate tab on your web browser.

[1] *At 12:03 AM HST (3:03 AM PST), CoralNet will read all annotations provided by the analysts and the robot will then provide annotations to the remaining images in the source. From this point on, all images that have not been previously analyzed by a human analyst will have an orange border and the analyst will have to confirm all suggested annotations in the next session.*



9) On your web browser, click on the tab displaying the first image.
10) On the **Image Details page**, ensure that the correct image was displayed by checking the image's metadata on the lower left corner of the image.

Note: If the wrong image was displayed, close the 5 newly opened tabs and return to the tab displaying the CoralNet image browser. Repeat steps III.A.3.1.a.4–10 (pp. 9–11).

Note: If you accidentally closed the tab displaying the CoralNet image browser, open a new tab on your web browser and repeat steps III.A.3.1.a (pp. 9–11). If possible, drag this tab to the far left side of the web browser to easily identify and jump back to this page when opening a new set of images.

11) Click on the **"Annotation Tool"** button on the upper right corner of the page to begin analysis.

b) **CoralNet Annotation Settings**

The following recommended settings will only **need to be applied once** during the image analysis process:

1) Click on the "Settings" button found on the upper left side of the image.
2) On the "Settings" pop-up box, select the following:

Point marker: Crosshair and circle

Point marker size: 12

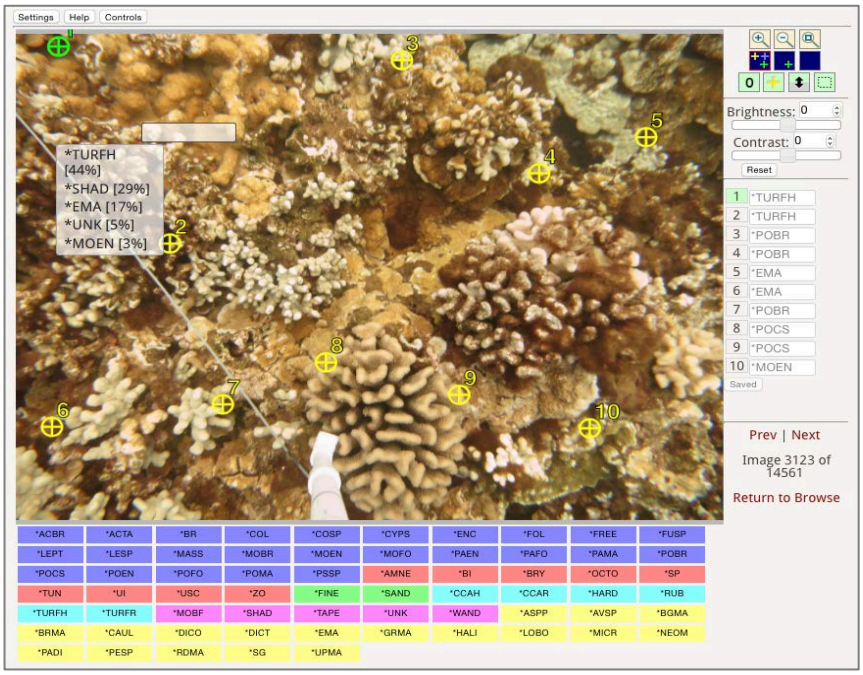
Point marker is scaled: *check*

Point number size: 28
Point number is scaled: *check*
Point colors: *user's preference*
Show machine annotations: *check*

3) Click on the "Save settings" button.
4) Click on the X button on the upper right corner to exit.

c) **Image Analysis Process**

1) Click on the first cell in the ID column found on the far right side of the screen.
2) The analysis point (#1) on the image will change to the color designated for the selected data point (green by default).



3) Identify the benthic category/label underneath the point's cross-hair.

***For un-annotated images (red border)**:*
Decide which benthic category lies directly underneath the point's cross-hair and choose the corresponding label from the label grid at the bottom of the screen. The category label is automatically entered in the cell, and the data point changes to the color chosen for the confirmed data point (blue by default).

For images with machine annotations (orange border):

If the image has been machine-annotated and the show annotations checkbox is checked in the Settings box, all 10 cells will contain suggested annotations (in grey text) that will need confirmation. Click on the first cell and select the correct category label on the field list (if available, probability scores that correspond to each of the suggested labels will be visible). If the correct category label is not among those on the field list, select the correct one from the label grid at the bottom of the screen. The annotation font color on the ID column will turn black once confirmed.

4) After selecting the correct category, the cursor will automatically advance to the next point. For guidance on selecting the correct category, please see the section III.A.4. Image Analysis Guidelines (p.19).

Note: Click on the "Help" button above the image for further guidance on using the annotation tool. Similarly, click on the "Controls" button for navigation tips and keyboard shortcuts. Many of the controls are set up to provide similar functions as those available in CPCe. For example, buttons are available to the right of the image to show all points, the point under consideration only, or no points.

5) Repeat steps III.A.3.1.c.3–4 (p.12) until all points on the image are classified.
6) **If the image quality is poor** (i.e, the entire image is blurry or a majority of the points cannot be determined with confidence), follow the protocols in III.A.4.c. (p. 19) of the Image Analysis Guideline section.
7) Click on "Save Progress" to save your annotations. "ALL DONE" will be displayed at the bottom of the column to indicate that all annotations have been saved and confirmed.
8) Close the web-browser tab of the recently annotated image and click on the tab of the next image to be analyzed.
9) Repeat steps III.A.3.1.c.1–7 (pp. 11–12) until all opened images have been analyzed.
10) Return to the tab displaying CoralNet's image browser page. To update the status of the selected images, click on "Search". The status of the recently annotated image/s has now been updated indicated by the green frame around the image thumbnail/s that has just been analyzed.
11) Select the next 5 images to analyze by repeating steps III.A.3.1.a.7–11 (p. 10), followed by steps III.A.3.1.c.1–9 (pp. 11–12).
12) When the first 20 images have been analyzed, click the '>' below the field of image thumbnails to advance to the next page and display the next 20 images. Ensure that the appropriate **"Year", "Island", "Site", "Analyst**" and **"Priority"** have been selected on the browse tool. Repeat steps III.A.3.1.a.6–11 (pp. 9–10) and III.A.3.1.c (pp. 11–13).

Note: Unlike CPCe, analysis via CoralNet will not involve exporting your results into an Excel spreadsheet. Exporting the data set will be the

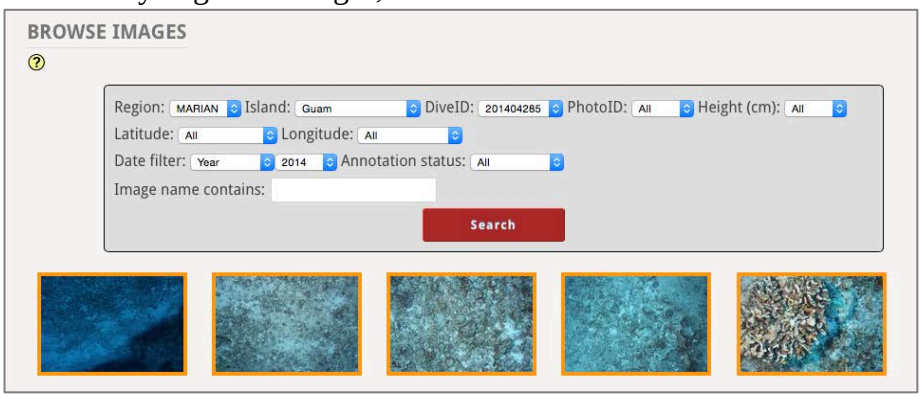
responsibility of the data manager or BIA coordinator. When all your assigned images have been analyzed, please inform your BIA coordinator via email.

III.A.3.2. Analyzing Towed-Diver Survey (TDS) Images

a) **Selecting your assigned images**

1) Launch CoralNet on your preferred web browser and Sign In.
2) Under "Your Sources", select "CREP-TOW IMAGES (ALL REGIONS)" (tow photosets from all regions are combined in the same Source page).
3) On the source page, select "Images" .

4) Use the dropdown menus to specify from which **"Region", "Island", and "DiveID"** the images you will be analyzing originated. Under **"Date filter: Year"**, select the corresponding year the images were collected. Then, most importantly, choose your initials under "**Analyst**".
5) When analyzing TDS images, set the "Annotation status" to **"All".**



6) Click on the **"Search"** button to display your selection.

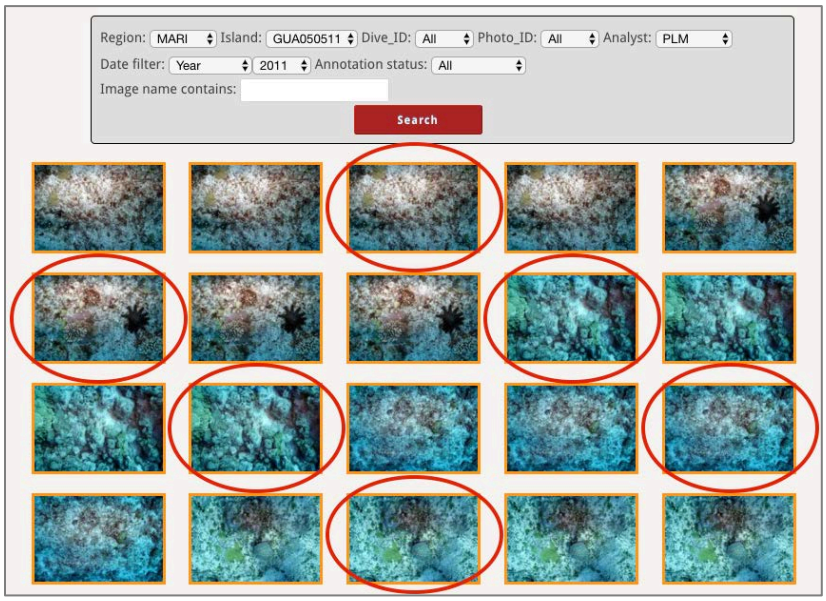
Note: Some TDS images taken at sub-optimal conditions will not be suitable for analysis. For this reason, analysts are only required to analyze approximately 70 images, which is the acceptable number of images (35%) needed to derive estimates for tow surveys.

Note: The image border color indicates the image's annotation status: red if it needs annotation, green if the image has been annotated/confirmed, and

orange if the image has been machine-annotated[2] and needs to be confirmed by the analyst.

7) **Keep the image browser page tab open as you will be returning to this page to select and analyze your next set of images.**
8) For tow photosets, each DiveID (tow) has approximately 200 images. In the image browser, groupings of 20 images will occur on each page. **MOUSE-OVER** (do not click) all image thumbnails to view the filenames and ensure that the correct photoset has been displayed.
9) **Select the images to be analyzed by clicking every third image**, to do so:

   a. Hold the CTRL ^ (Windows) or CMD ⌘ (Mac) key and click on every third un-annotated or unconfirmed image thumbnail on the image browser page.
   On the next page of images, you would start with the first thumbnail in the



   grid to maintain the proper sequence.

   b. The selected images will open as separate tabs on your web browser.

   c. If the originally selected image is unsuitable for analysis, choose the next image to analyze. For example, if the third image is not suitable, select and annotate the fourth image in its place. You would then return to the original

[2] *At 12:03 AM HST (3:03 AM PST), CoralNet will read all annotations provided by the analysts and the robot will then provide annotations to the remaining images in the source. From this point on, all images that have not been previously analyzed by a human analyst will have an orange border and the analyst will have to confirm all suggested annotations in the next session*

sequence of images, and select the sixth image as the next image to analyze (not the seventh).

10) On your web browser, click on the tab displaying the first image.
11) On the **Image Details page**, ensure that the correct image is displayed by checking the image's metadata found on the lower corner of the image.

Note: If the wrong image was displayed, close the newly opened tabs and return to the tab displaying the CoralNet image browser. Repeat steps III.A.3.2.a.4–12 (pp. 14–16).

Note: If you accidentally closed the tab displaying the CoralNet image browser, open a new tab on your web browser and repeat steps III.A.3.2.a (pp. 14–16). If possible, drag this tab to the far left side of the web browser to easily identify and jump back to this page when opening a new set of images.

12) Click on the **"Annotation Tool"** button on the upper right corner of the page to begin analysis.

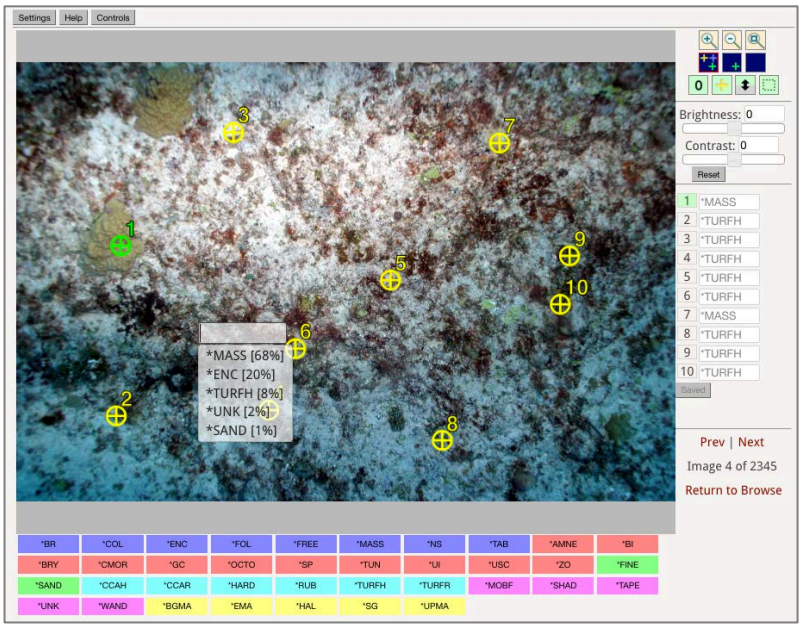
b) **CoralNet Annotation Settings**

The following recommended settings will only **need to be applied once** during the image analysis process:

1) Click on the "Settings" button found on the upper left side of the image.
2) On the "Settings" pop-up box, select the following:
   Point marker: Crosshair and circle
   Point marker size: 12
   Point marker is scaled: *check*
   Point number size: 28
   Point number is scaled: *check*
   Point colors: *user's preference*
   Show machine annotations: *check*
3) Click on the "Save settings" button.
4) Click on the × button on the upper right corner to exit.

c) **Image Analysis Process**

1) Click on the first cell in the ID column found on the far right of the screen.
2) The analysis point (#1) on the image will change to the color designated for the selected data point (green by default).



3) Identify the benthic category/label underneath the point's cross-hair.

***For un-annotated images (red border)**:*
Decide which benthic category lies directly underneath the point's cross-hair and choose the corresponding label from the label grid at the bottom of the screen. The category label is entered automatically in the cell, and the data point changes to the color chosen for the confirmed data point (blue by default).
For images with machine annotations (orange border):
If the image has been machine-annotated and the show annotations checkbox is checked in the Settings box, all 10 cells will contain suggested annotations (in grey text) that will need confirmation. Click on the first cell and select the correct category label on the field list (if available, probability scores that correspond to each of the suggested labels will be visible). If the correct category label is not among those on the field list, select the correct one from the label grid at the bottom of the screen. The annotation font color on the ID column will turn black once confirmed.

4) After selecting the correct category, the cursor will automatically advance to the next point. For guidance on selecting the correct category, please see the section III.A.4. Image Analysis Guidelines below (p. 19).

Note: Click on the "Help" button above the image for further guidance on using the annotation tool. Similarly, click on the "Controls" button for navigation tips and keyboard shortcuts. Many of the controls are set up to provide similar functions as those available in CPCe. For example, buttons are available to the right of the image to show all points, the point under consideration only, or no points.

5) Repeat steps III.A.3.2.c.3–5 (pp. 17–18) until all points on the image are classified.
6) **If the image quality is poor** (i.e. the entire image is blurry or a majority of the points cannot be determined with confidence), follow the protocols in III.A.4.c. (p. 19) of the Image Analysis Guideline section.
7) Click on "Save Progress" to save your annotations. "ALL DONE" will be displayed at the bottom of the column to indicate that all annotations have been saved and confirmed.
8) Close the web-browser tab of the recently annotated image and click on the tab of the next image to be analyzed.
9) Repeat steps III.A.3.2.c.1–8 (pp. 17–18) until the selected images have been annotated.
10) Return to the tab displaying CoralNet's image browser page. To update the status of the selected images, click on "**Search**". The status of the recently annotated image/s has now been updated indicated by the green frame around the image thumbnails that have just been analyzed.
11) Click the '>' below the field of image thumbnails to advance to the next page and display the next 20 images. Ensure that the appropriate **"Year", "Region", "Island", "DiveID"** and **"Analyst"** have been selected on the browse tool.
12) Select the next set of images that you want to analyze by repeating steps III.A.3.2.a.7–12 (pp. 15–16), followed by steps III.A.3.2.c.1–11 (pp. 17–18). Repeat this step until you reach the end of the series of images from that tow.
13) To analyze another set of tow images, return to the **Browse Images** page, repeat steps III.A.3.2.a.6 (p. 14), and select another "DiveID" that you have been assigned.

Note: Unlike CPCe, analysis via CoralNet will not involve exporting your results into an Excel spreadsheet. Exporting the data set will be the responsibility of the data manager or BIA coordinator. When all your assigned images have been analyzed, please inform your BIA coordinator via email.

III.A.4. Image Analysis Guidelines

a) **REFERENCES**

Aside from the guidelines included in this document, several references are available on the CREP Wiki and other websites:
CREP Wiki - Classification Tiers, Categories, Definitions for Tiers 1 and 2
CREP Wiki - Dichotomous Key for the Classification of Benthic Functional Groups
CREP Wiki - Annotated Training Images
Corals of the World (Veron et al.)
AIMS Coral Fact Sheets
Guam Reef Life

b) **WHEN IN DOUBT**

1) When in doubt, leave the point blank until you can consult with an expert or colleague who is familiar with the area.
2) If a subject matter expert is not available and/or you are still not able to confidently classify the point, use the **Unclassified** category.
3) **Do not guess if you are not able to confidently classify the point.**

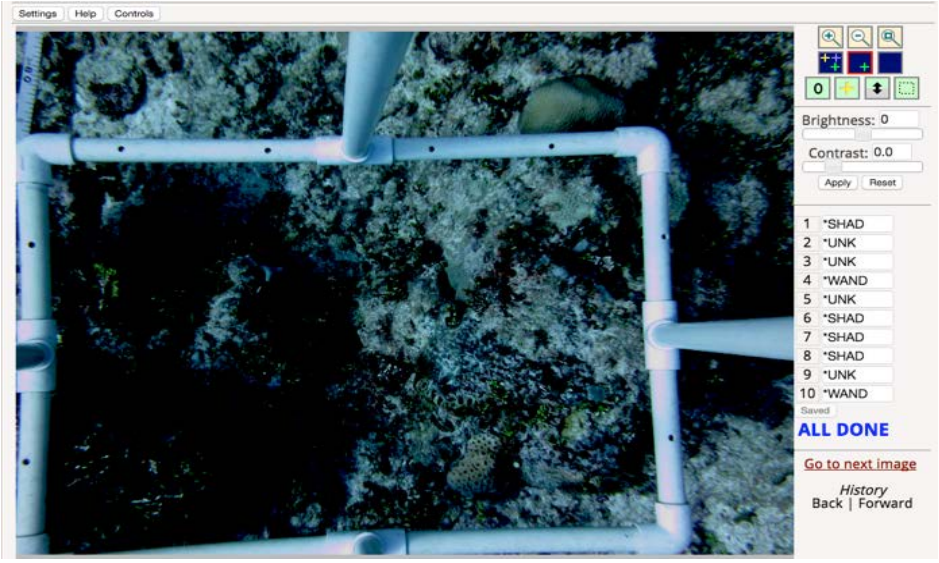
c) **POOR IMAGE QUALITY AND REGENERATING NEW POINTS**

If any photo has more than 5 combined points classified as Shadow (SHAD) or Unclassified (UNK), or more than 1 point classified as Tape or Wand (including points in the water column), please follow these steps:

1) Generate a new set of points to analyze by using the features on the **Image Details** page. To do so:
   a. Click on "**Image Details" button** on the upper right corner of the image.
   b. On the Image Details page, scroll down to the area below the image and metadata, and click on the **"Regenerate point locations"** hypertext at the right side of the screen.
   c. Scroll up and click on the **"Annotation Tool" button** to return to the annotation page where the newly generated points are visible.

   Note: The robot will not have run on these points; suggested identifications will not be available until the robot has run again.

2) Regenerate the points **no more than 3 times**. If > 5 combined UNK and SHAD or > 1 TAPE or WAND points persist on the image, **annotate all 10 points as is,** and then click on "Save Progress" to save your annotations.



Note: Prior to database ingestion, CREP's Data Management team will run a validation script that will flag images that have been annotated >5 UNK and SHAD or >1 TAPE or WAND.

d) **MULTIPLE GROWTH FORMS**

1) For REA image analysis: under Tier 3b classification, three genera have been further subdivided into growth forms (*Montipora*, *Pavona*, and *Porites*). Refer to the Benthic Classification Tiers that map certain genera and/or species with multiple morphologies to its corresponding Tier 3b code/label.
2) If a point falls on a colony that has multiple growth forms, classify the point based on the morphology directly under the point rather than the overall colony morphology. For example, *Porites rus* may have both "branching" (POBR or BR; Tier 3b and Tier 2, respectively) and "foliose" (POFO or FOL) morphologies on the same colony.

Note: The growth forms available in BIA are more limited than those used during field identification. For example, parts of a P. rus *colony that may appear columnar should be classified as branching, and those that appear plating or laminar should be classified as foliose.*

e) **POINT BETWEEN TWO BENTHIC CATEGORIES**

1) If a point falls precisely between multiple coral growth morphologies or on the border between multiple benthic categories (e.g., coral-algae), the benthic category occupying the greatest area within the symbol (circle wrapping the cross-hairs) will be classified.
2) If the multiple benthic categories occupy an equal space within the symbol, the benthos falling on the top left quadrant within the point symbol will be classified.

f) **UNCLASSIFIED/UNKNOWN, SHADOW, WATER COLUMN**

1) The category **Shadow** should be used when the point falls on an area that is dark and the nature of the benthos cannot be assessed due to diminished light.
2) The category **Unclassified** should be used when the nature of the benthos cannot be determined due to image quality or unfamiliarity with the type of benthos.
3) In rare cases when the point falls on the water column, classify the point as **TAPE** to remove it from the benthic cover estimate. (Note: the categories Tape and Wand are excluded from percent cover estimates).

g) **NAVIGATION TIPS**

1) Enlarge the view under an active point by using the zoom buttons  . Alternatively, left click on an image or SHIFT + ↑. To zoom out, right click, CTRL + left click or SHIFT + ↓.
2) Hide or view the points on an image by using the point display buttons  . You can turn off all the random points except the one to be classified by using the "isolation mode" (middle icon).
3) If the benthos in the image is simple (e.g. sand with a few small rubble areas) and most points have the same classification (e.g. sand), you can categorize those few points that are different (e.g. rubble). Use the selection buttons  for this purpose. Zoom in on each point to ensure small sections of other benthos are not present, as these may not be initially apparent when fully zoomed out. For example, small sections of CCA may be present in what otherwise appears to be TURF.
4) **To select multiple points**: Use  (select all, click on image to select, draw on image to select). Alternatively, you can hold CTRL (Windows) or CMD (Mac) and left click on the numbers that you would like to assign the same category. As above, each point must be carefully assessed prior to assigning them a group to ensure that they all should be assigned to the same category.
5) **To deselect all**: Click on the  button.
6) If you need to **clear all the annotations on an image**, click on the “Image Details” button above the upper-right corner of the image. On the “Image

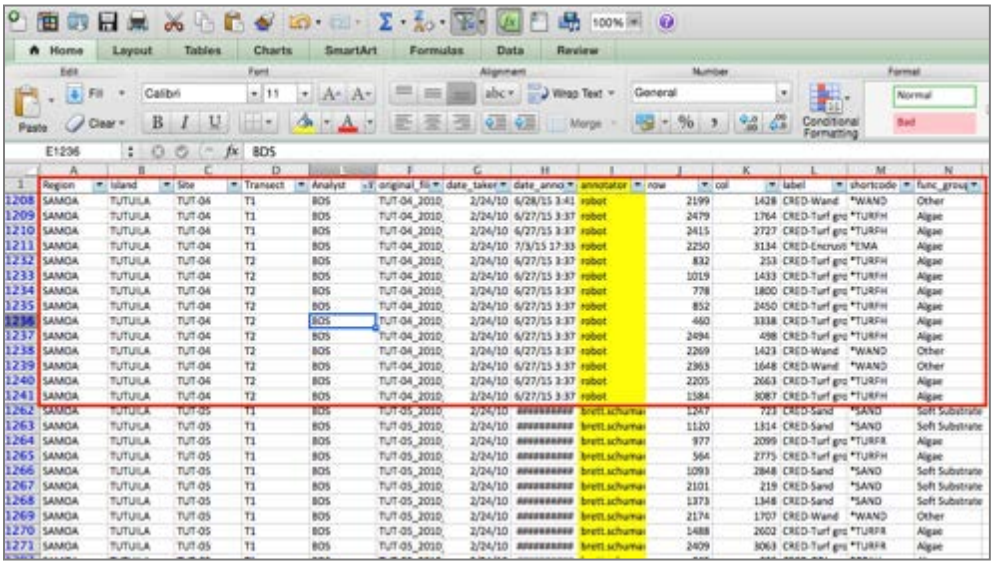
Details" page, scroll down to the bottom below the image and click on the "Clear Annotations" button. Scroll up and click on the "Annotation Tool" button to return to the annotation page.

Note: Click on the "Help" button above the image for further guidance on using the annotation tool. Similarly, click on the "Controls" button for navigation tips and keyboard shortcuts.

III.A.5. Tracking Your Progress

a) Searching for images that have not been analyzed can be done through CoralNet using the browse tool. Simply filter by **"Analyst"** and set the drop-down option in "Annotation status" to "**Unclassified"** or **"Unconfirmed**". Any image thumbnails framed in red or orange are un-annotated images.

b) Another option is to export a partial results page via CoralNet's data export tool[3]:
   1) From the selected Source page, click on "Images".
   2) Use the dropdown menus to specify from which photoset you want to export, and click on the "Search" button.
   3) At bottom of the page, set the **"Enter Annotation Tool"** dropdown menu to "Export". Select "Annotations, Full" for "All ### image results", and click on the "Go" button.
   4) An "annotations_full.csv" file will be automatically downloaded to your default download folder.
   5) Open the .csv file on Excel and use the Data Filter tool to sort by "Analyst" and "annotator".

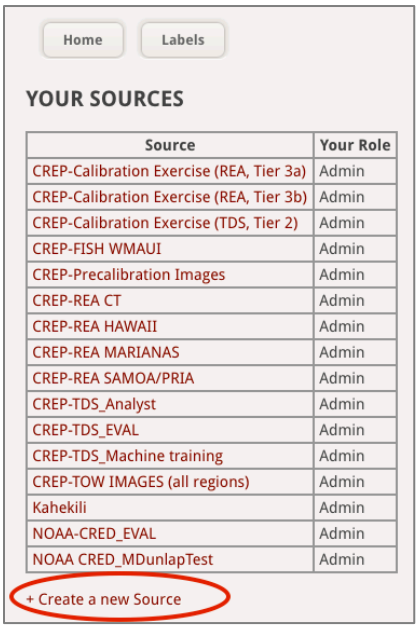


[3] *Note that on very large data sets, it may take over an hour for the download to process. The annotations file also contains a record for every* ***point,*** *not every image so there will be ten lines for every image. The "Export" feature also allows for the export of image metadata and percent cover data (check the "About" page for more information)*

6) The user account name (e.g. *john.doe*) will be displayed under the "annotator" column for images that have already been analyzed and "*robot*" for images that have not been analyzed.
7) Use the information from your most recent export to determine which sets of images to select on your next session.

III.B. Setting Up a New Source in CoralNet

III.B.1. Creating a New Source



a) Log in to your CoralNet user account.

b) On your Home page, click on **+Create a New Source link** found at the bottom of the Source list box.

c) In the CREATE A NEW SOURCE page, fill in the necessary Source information. For CREP image analysis purposes, enter the following information:

General Information

- **Name**: CREP-*region* (e.g. "CREP-REA SAMOA")
- **Visibility**: Private
- **Affiliation**: Coral Reef Ecosystem Program
- **Description**: Coral reef surveys by the Ecosystem Sciences Division - Coral Reef Ecosystem Program (CREP) at the US National Oceanic and Atmospheric Administration (NOAA), Pacific Island Fisheries Science Center (PIFSC)

Location Keys

REA

- **Key 1**: Region
- **Key 2**: Island
- **Key 3**: Site
- **Key 4**: Priority
- **Key 5**: Analyst

TDS

- **Key 1**: Region
- **Key 2**: Island
- **Key 3**: DiveID
- **Key 4**: PhotoID
- **Key 5**: Analyst

Image Annotation

- **Default image height**
  REA - Default image height coverage (centimeters): 100
  TDS - Default image height coverage (centimeters): 150

- **Default image annotation area**
  REA
  Left boundary X: 2.5% Right boundary X: 97.5%
  Top boundary Y: 2.5% Bottom boundary Y: 97.5%

  TDS
  Left boundary X: 8% Right boundary X: 92%
  Top boundary Y: 8% Bottom boundary Y: 92%

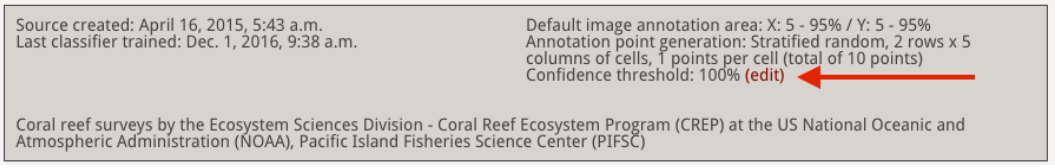
- **Point generation method**
  Point generation type: Stratified Random (Random within a cell of the annotation area)
  Number of cell rows: 2
  Number of cell columns: 5
  Points per cell: 1

- **Level of alleviation**
  Confidence threshold (%): 100

World Location

Latitude: *region dependent*
Longitude: *region dependent*
You can also search the region/area's coordinates from latlong.net

d) Click on **Save Changes**. You will be redirected to your newly created Source.
e) On the Source page, check that the entered Source information is correct. The Source page information and annotation settings can be modified by clicking on the **(edit) link** next to "Confidence threshold".



III.B.2. Creating a Labelset

a) **Background**

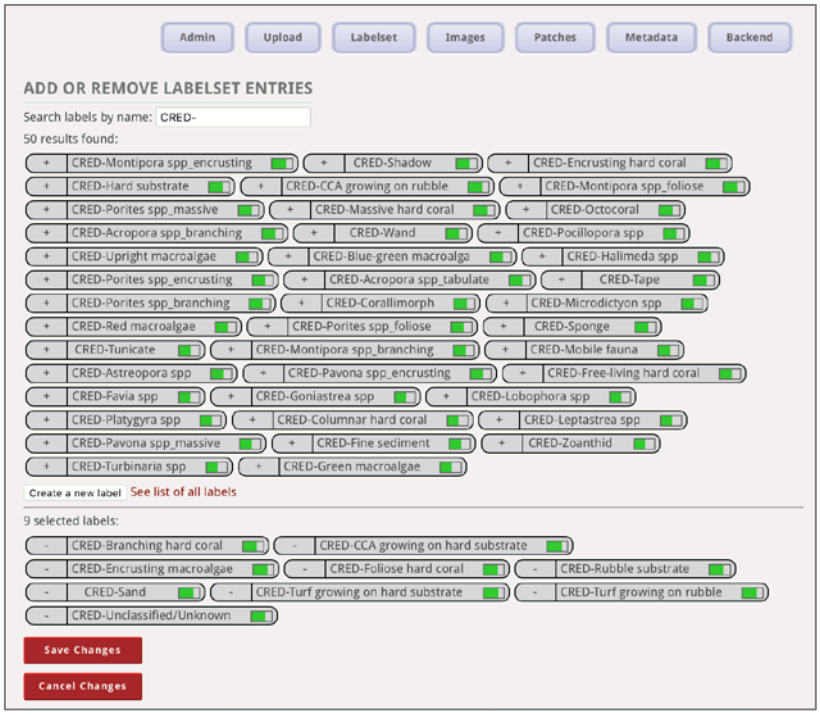
1) CoralNet's ALL LABELS page contains a table with ~ 2,000 labels (as of 2016) created by users of different public and private CoralNet Sources. Each label is currently categorized among 7 functional groups (e.g. Other Invertebrates, Hard Coral, Soft Substrate, Hard Substrate, Other, Algae, Seagrass).
2) For consistency with the CREP's historical benthic image analysis-derived data, new labels were created on CoralNet that afforded a one-to-one match with the program's previous image analysis benthic categories. Each CREP's label name includes a "CRED" or "CREP" prefix (e.g. "CRED-Isopora"), and its corresponding short code includes an asterisk * prefix (e.g. " *ISSP ").

b) **Process**

1) From your Source home page, click on the blue **LabelSet** button.

2) Click on **"Choose labels for your labelset".**

3) Type “CRED” or “CREP” on the search bar, and select (click on the + sign) any or all of the 94 pre-made labels.



Full list of ESD-CREP Tier 3b labels and shorts codes

Name	Short Code	Functional Group
CRED-Acanthastrea spp	*ACAS	Hard coral
CRED-Acropora spp_branching	*ACBR	Hard coral
CRED-Acropora spp_tabulate	*ACTA	Hard coral
CRED-Astreopora spp	*ASSP	Hard coral
CRED-Branching hard coral	*BR	Hard coral
CRED-Columnar hard coral	*COL	Hard coral
CRED-Coscinaraea spp	*COSP	Hard coral
CRED-Cyphastrea spp	*CYPS	Hard coral
CRED-Diploastrea spp	*DISP	Hard coral
CRED-Echinophyllia spp	*ECHL	Hard coral
CRED-Echinopora spp	*ECHP	Hard coral
CRED-Encrusting hard coral	*ENC	Hard coral
CRED-Euphyllia spp	*EUSP	Hard coral
CRED-Favia spp	*FASP	Hard coral
CRED-Favites spp	*FAVS	Hard coral
CRED-Foliose hard coral	*FOL	Hard coral
CRED-Free-living hard coral	*FREE	Hard coral

Name	Short Code	Functional Group
CRED-Fungia spp	*FUSP	Hard coral
CRED-Galaxea spp	*GASP	Hard coral
CRED-Goniastrea spp	*GONS	Hard coral
CRED-Goniopora\Alveopora spp	*GOAL	Hard coral
CRED-Heliopora spp	*HCOE	Hard coral
CRED-Hydnophora spp	*HYSP	Hard coral
CRED-Hydrocoral	*HYCO	Hard coral
CRED-Isopora spp	*ISSP	Hard coral
CRED-Leptastrea spp	*LEPT	Hard coral
CRED-Leptoria spp	*LPHY	Hard coral
CRED-Leptoseris spp	*LESP	Hard coral
CRED-Lobophyllia spp	*LOBS	Hard coral
CRED-Massive hard coral	*MASS	Hard coral
CRED-Merulina spp	*MESP	Hard coral
CRED-Millepora spp	*MISP	Hard coral
CRED-Montastraea spp	*MONS	Hard coral
CRED-Montipora spp_branching	*MOBR	Hard coral
CRED-Montipora spp_encrusting	*MOEN	Hard coral
CRED-Montipora spp_foliose	*MOFO	Hard coral
CRED-Oulophyllia spp	*OUSP	Hard coral
CRED-Pachyseris spp	*PACS	Hard coral
CRED-Pavona spp_encrusting	*PAEN	Hard coral
CRED-Pavona spp_foliose	*PAFO	Hard coral
CRED-Pavona spp_massive	*PAMA	Hard coral
CRED-Platygyra spp	*PLSP	Hard coral
CRED-Plerogyra spp	*PLER	Hard coral
CRED-Pocillopora spp	*POCS	Hard coral
CRED-Porites spp_branching	*POBR	Hard coral
CRED-Porites spp_encrusting	*POEN	Hard coral
CRED-Porites spp_foliose	*POFO	Hard coral
CRED-Porites spp_massive	*POMA	Hard coral
CRED-Psammocora spp	*PSSP	Hard coral
CRED-Stylophora spp	*STYS	Hard coral
CRED-Symphyllia spp	*SYSP	Hard coral

Name	Short Code	Functional Group
CRED-Turbinaria spp	*TURS	Hard coral
CRED-Anemone	*AMNE	Other Invertebrates
CRED-Bivalve	*BI	Other Invertebrates
CRED-Bryozoan	*BRY	Other Invertebrates
CRED-Corallimorph	*CMOR	Other Invertebrates
CRED-Giant clam	*GC	Other Invertebrates
CRED-Octocoral	*OCTO	Other Invertebrates
CRED-Sponge	*SP	Other Invertebrates
CRED-Tunicate	*TUN	Other Invertebrates
CRED-Unclassified sessile invertebrate	*UI	Other Invertebrates
CRED-Unclassified soft coral	*USC	Other Invertebrates
CRED-Zoanthid	*ZO	Other Invertebrates
CRED-Fine sediment	*FINE	Soft Substrate
CRED-Sand	*SAND	Soft Substrate
CRED-Hard substrate	*HARD	Hard Substrate
CRED-Rubble substrate	*RUB	Hard Substrate
CRED-CCA growing on hard substrate	*CCAH	Hard substrate
CRED-CCA growing on rubble	*CCAR	Hard substrate
CRED-Turf growing on hard substrate	*TURFH	Hard substrate
CRED-Turf growing on rubble	*TURFR	Hard substrate
CRED-Mobile fauna	*MOBF	Other
CRED-Shadow	*SHAD	Other
CRED-Tape	*TAPE	Other
CRED-Unclassified\Unknown	*UNK	Other
CRED-Wand	*WAND	Other
CRED-Asparagopsis spp	*ASPP	Algae
CRED-Avrainvillea spp	*AVSP	Algae
CRED-Blue-green macroalga	*BGMA	Algae
CRED-Brown macroalgae	*BRMA	Algae
CRED-Caulerpa spp	*CAUL	Algae
CRED-Dictyopteris\Dictyota spp	*DICO	Algae
CRED-Dictyosphaeria spp	*DICT	Algae
CRED-Encrusting macroalgae	*EMA	Algae

Name	Short Code	Functional Group
CRED-Green macroalgae	*GRMA	Algae
CRED-Halimeda spp	*HALI	Algae
CRED-Lobophora spp	*LOBO	Algae
CRED-Microdictyon spp	*MICR	Algae
CRED-Neomeris spp	*NEOM	Algae
CRED-Padina spp	*PADI	Algae
CRED-Peyssonnelia spp	*PESP	Algae
CRED-Red macroalgae	*RDMA	Algae
CRED-Seagrass	*SG	Algae
CRED-Upright macroalgae	*UPMA	Algae

*Note: For ESD-CREP, you can also import a premade labelset (Tier 3b, Tier 3a, Tier 2, Tier 1) by clicking on **"Import a labelset from a CSV file"**. The CSV files can be imported from the network folder: OPTICAL/ANALYSIS/CoralNet Labelsets.*

4) When all the labels have been selected, scroll down to the bottom of the table and click on the "**Create Labelset"** button. You will be redirected to a table containing your Source's Labelset.
5) To edit your Labelset, scroll down to the bottom of the table and click on the "**Add/Remove labels"** button. Select or deselect the appropriate labels and when done, scroll down to the bottom of the table and click "**Save Changes"** button.
6) Once the LabelSet has been finalized, click on the Source's name to return to the home page.

III. C. UPLOADING IMAGES TO CORALNET

III.C.1. FORMATTING IMAGE FILENAMES

a) Prior to being transferred to the CREP's file server, the Program's optical data go through a validation process that also automates the image renaming process and archives the images in a hierarchical folder system.
b) For non-CREP users, it is recommended that all image files are uniquely named using an easy-to-identify naming convention and are copied to a single folder for ease in batch uploads (see III.C.2, pp. 30–31). Depending on the preferred upload method, the images can be renamed based on the following format:

1) Uploading without a metadata file:

REGION_SITE_TRANSECTID_PHOTOID_ANALYST_YYYY-MM-DD.JPG
e.g. SAMOA_OFU-651_A_01_INI_2015-01-01.JPG

REGION_TOWID_DIVEID_PHOTOID_ANALYST_YYYY-MM-DD.JPG
e.g. SAMOA_OFU013015_1_001_INI_2015-01-01.JPG

2) Uploading with a metadata file:

SITEID_YYYY_TRANSECTID_PHOTOID.JPG
e.g. OFU-651_2015_A_01.JPG

TOWID_DIVEID_PHOTOID.JPG
e.g. OFU013015_1_001.JPG

c) Refer to CoralNet's upload instructions to obtain additional information on manually entering image metadata values or automating metadata fields based on the image file names

III.C.2. CONSOLIDATING IMAGE FILES

For optical data archived in a hierarchical folder structure, images will need to be consolidated in a single folder prior to batch upload. To do so:

a) Download PKZip/Secure Zip or a similar program that allows the compression of multiple files in different folders in a single operation.
b) Build an image list:
   1) CREP's Data Management team will provide a text file that will contain a list of images of a specific production series. The image text files are located in the network folder: OPTICAL/ANALYSIS/CoralNet Image Lists/*YYYY*.
      a. Open Secure Zip and click on **"Add Files".**
      b. Click on **"Load List"** and then navigate to appropriate image text file location.
      c. Select the appropriate text file and click on **"Open".**
         Note: Depending on the photoset size, it may take a few minutes for the list to load.
      d. On the Add File window, ensure that the **"Encrypt"** box is unchecked.

e. Click on the **Options** button.
f. Click on "OK" and proceed to III.C.2.c.

2) For non-CREP users, build a list of files through PKZIP/Secure Zip.
   a. In the Add Files dialog, build a list of files selected from different folders by searching and selecting each image file in the directory and clicking on "**Add List".**
   b. Once all files are added to the list, click on "OK" and proceed to III.C.2.c.

c) On the Add File window, leave the **"Encrypt files" box unchecked.**

d) Click on the Options button and under "Save folder name", set the field as **"No path information"** and the click "OK".

e) When prompted, navigate to your Desktop or a folder in your local drive where you would like to save the zip file.

Note: Ensure that the drive in which you are saving the .zip file has enough disk space to accommodate both the .zip file and the extracted, color-corrected files.

f) Under Filename, type *YYYY_REGION* (e.g. 2014_MARIANA) or any easily identifiable file name. Click on "Save".

Note: Depending on the size of the photoset, it may take between a few minutes up to an hour to compress the image files into a zip file.

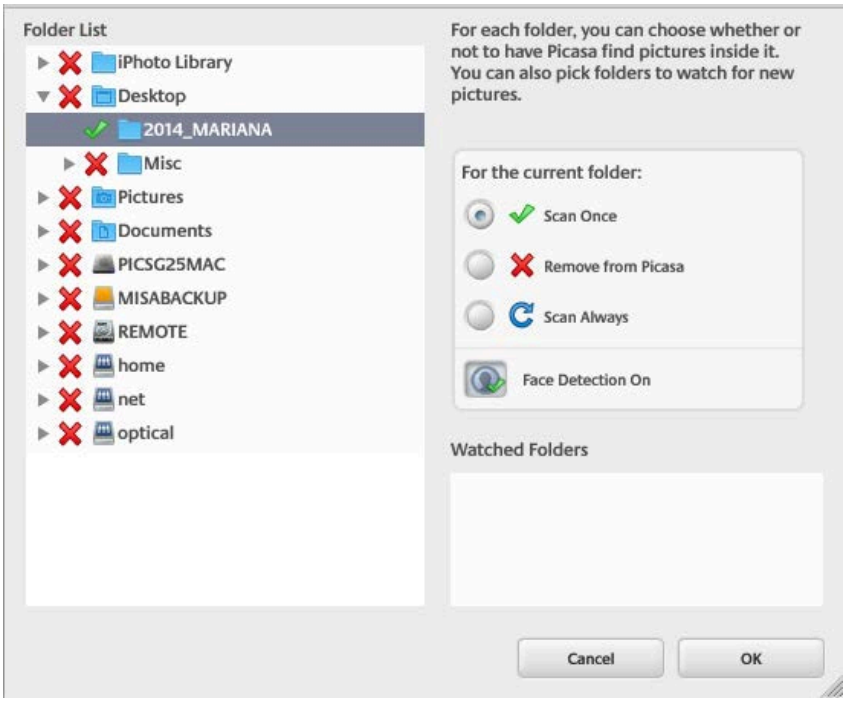
g) Once the zip file has been created, extract the files using Secure Zip.
   1) Navigate to your Desktop or a folder on your local drive where you would like to save the images.
   2) Create a new folder and rename it to *YYYY_REGION* (e.g. 2014_MARIANA) or any easily identifiable folder name.
   3) Open Secure Zip and click on **"Extract Files".**
   4) When prompted, navigate to the folder that you created.
   5) Click on **"Extract".**

Note: Depending on the size of the photoset, it may take between a few minutes up to an hour to extract the image files.

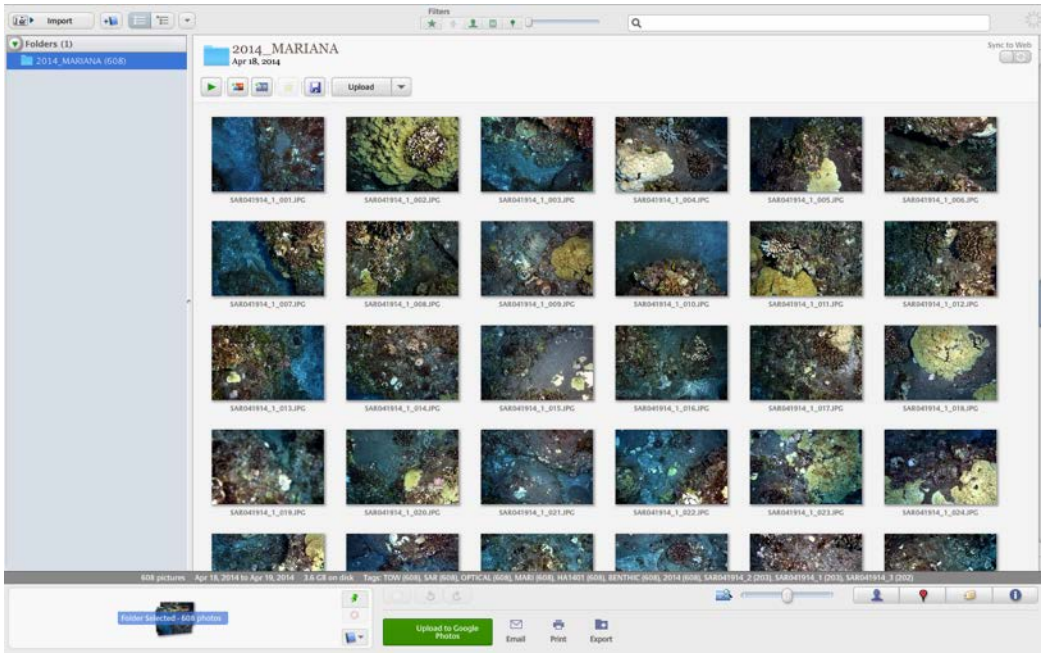
III.C.3. IMAGE COLOR-CORRECTION VIA PICASA

Due to the quality of the images collected from towed-diver surveys, CREP uses Picasa to color correct and pre-screen images prior to CoralNet upload and analyses. **For REA images, this step may be skipped.**

a) Download and install the most current version of Picasa.
b) Launch and configure Picasa as follows:
c) Under the Tools menu, select "**Options**" (for Mac OS: Picasa menu > Preferences).
d) On the General tab, ensure **"Delete from disk without confirmation" is not checked** and select "OK".
e) Under the View menu, select **"Thumbnail Caption".**
f) Select **"Filename".**
g) Add the folder that contains the photos you intend to analyze.
    1) On the File menu, select **"Add folder to Picasa".**
    2) In the left panel of the Folder Manager window, navigate to the folder containing the consolidated image files (see III.C.2, pp. 30–31 if you have not consolidated all image files into a single folder).
    3) On the right panel of the Folder Manager window, select the green check mark **"Scan Once"**, then select "OK".



c) On the left panel of the main Picasa window, select the folder name added from the previous step. Note that there may be other images/folder already on display.



d) Rotate all photos that are in Portrait orientation to **Landscape orientation.**

1) Hold the CTRL (Windows) or CMD ⌘ (Mac OS) and select the photos requiring rotation. Once selected, a blue border should appear around the image to highlight that it has been selected.
2) Select the appropriate rotation arrow on the bottom of the Picasa window.

e) Select all the images to be color corrected by clicking on the Edit Menu, then choose "Select All". Alternatively, you can hold CTRL (Windows) or CMD ⌘ (Mac OS) and the A key.

f) On the Picture menu, select **"Batch Edit"**, then select **"I'm Feeling Lucky".** Picasa will begin correcting the images. These adjustments will only be visible within Picasa at this point (i.e. no permanent changes).

Note: Depending on the size of the photoset, it may take a few minutes for the process to finish. If working with a large photoset, it may be more efficient to color-correct in smaller batches.

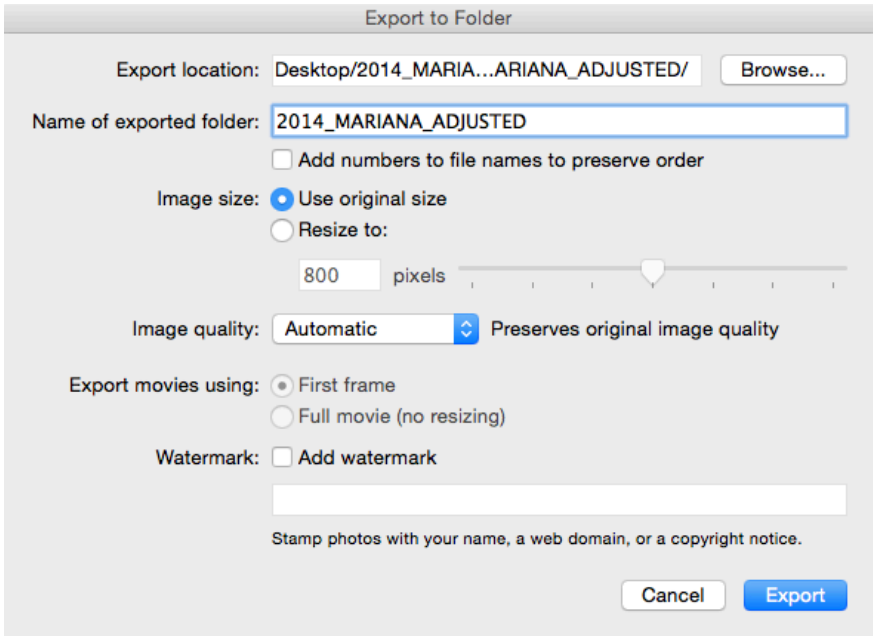
g) When color correction is complete, sort the files by name and **clear the photo selection.**

1) Under the Folder menu, select Sort By, then select Name.

2) Under the Edit menu, select Clear Selection.

h) **Export** the edited images.

1) On the File menu, select **"Export Picture to Folder".**
2) From the "Export to Folder window", select the "Browse" button, and navigate to the new folder created from the last step (e.g. Desktop/2014_MARIANA),
3) In the "Name of exported folder", type ***YYYY_REGION*_ADJUSTED** (e.g. 2014_MARIANA_ADJUSTED).
4) Ensure **"Use original size"** is selected.
5) Ensure "Image quality" is set to **"Automatic".**
6) Click on **"Export".**



i) When working with a large batch of images, you may **delete the original image files on your local drive** to recover disk space.

Note: It is important to export the photos to the appropriate folder, and attention must be given to avoid mistakes. DO NOT OVERWRITE FILES UNDER ANY

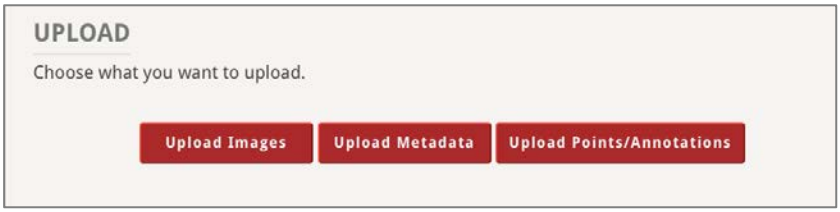
CIRCUMSTANCE if prompted to do so. If the files do not appear in the YYYY_REGION_ ADJUSTED *folder as expected, look for a folder called* ***"export"*** *or image files with* ***"-1"*** *appended to their name. Both occurrences are indicative of an improperly specified export folder. If this is the case, move and rename the exported images to the proper* YYYY_REGION_*ADJUSTED folder before proceeding to the next steps.*

III.C.4. UPLOADING IMAGE FILES AND ANNOTATIONS

a) Log in to CoralNet and open the Source to which you willupload the image.
b) From the Source home page, click on the blue **Upload button.**
c) The upload process is conducted in the following order: (1) upload the image files, then (2) the metadata files, and if applicable, (3) upload the fixed points or historical annotations. Below are the guidelines for each uploading step:

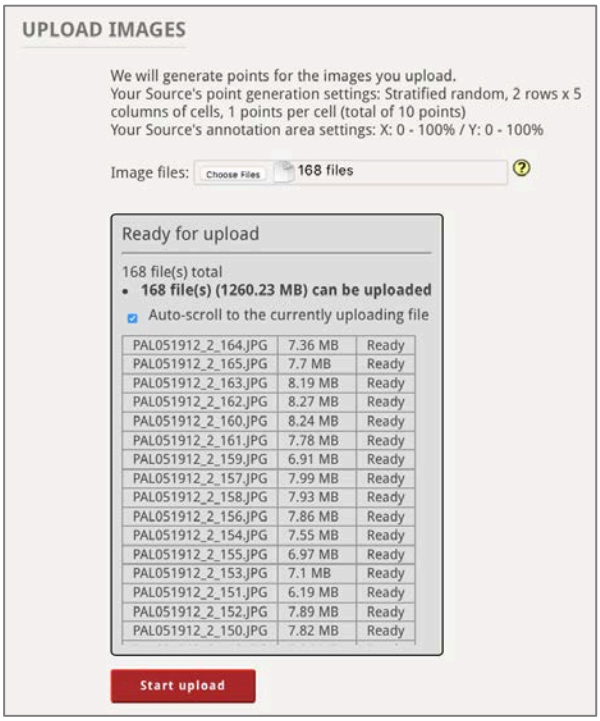
1) Uploading the Images

a. To upload the images, click on the **"Upload Images"** button.



b. Under **"Images files"**, click on the **"Choose files"** button, navigate to the folder where the image files have been compiled (see III.C.2 for instructions on consolidating files into a single repository), and select the files.

c. Click on the "**Start Upload"** button. Once upload is complete, if necessary, click on the "**Upload more images"** button to upload another batch of images.



2) Uploading the Metadata

a. When all the images have been uploaded, return to the UPLOAD home page by clicking on the blue **"Upload"** button and click on **"Upload Metadata".**

b. Under **"CSV file"**, click on the **"Choose files"** button, navigate to the appropriate folder directory (e.g. V:\OPTICAL\ANALYSIS\CoralNet

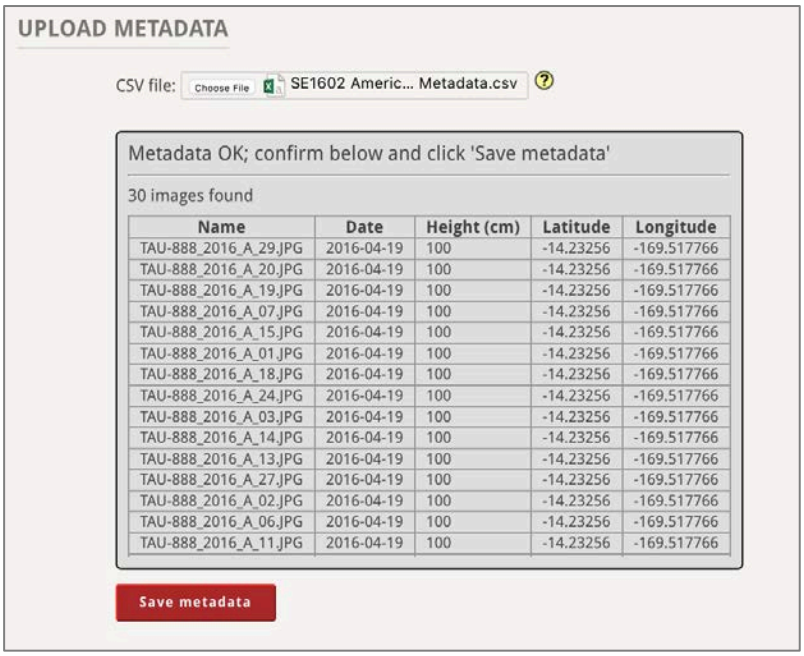
Metadata Files\2015\BIA**HA1501 CREP-SAMOA CoralNet Benthic Image Analysis Metadata.csv**), and select the CSV file.

c. Click on **"Save metadata",** then click on the blue **"Upload"** button to upload more images/metadata, or click on the Source name to return to the home page.

Note: For ESD-CREP, the Data Manager generates the image metadata file. This file contains 10 metadata values, 5 of which correspond to the Location Keys specified when entering the Source information (see III.B.1.c, pp.23-24).

For non-CREP users, please refer to CoralNet's Upload Instructions to get additional information on manually entering image metadata values or creating your own metadata file, etc.

d. Click on **"Save metadata",** then click on the blue **"Upload"** button to upload more images/metadata, or click on the Source name to return to the home page.



3) Uploading Points and Annotations for Calibration Exercises

a. **Create a Source page strictly for Calibration Exercises.** To do so, follow steps III.B.1–2 (pp. 23–28).

b. To upload a calibration exercise **with fixed points and annotations** from a previous calibration exercise photoset:

1. Copy all the images where the calibration exercise was based, to a folder on your local drive. This photoset is typically 100 randomly-selected images from a region or a set of islands.
2. Using a batch file renaming program (e.g. Bulk Rename Utility), rename each set of 100 images by adding a suffix of the analyst's 3 or 2-letter initials (e.g. "PLM").
   Example:
   ROS-03_A_13_**PLM**.JPG
   ROS-23_A_07_**PLM**.JPG
   ROS-409_A_15_**PLM**.JPG
   ROS-422_A_25_**PLM**.JPG
   ROS-427_A_03_**PLM**.JPG

   Repeat this process until each analyst, who participated (or will participate) in the calibration exercise, ha this or her own set of images. That is, if there are 100 calibration images and 5 analysts, you will be uploading 500 images to CoralNet, with each image file renamed with each of the analysts' initials (image file names uploaded to the same Source page on CoralNet must be unique).

3. Create the associated **image metadata file.**

   Note: For ESD-CREP, the Data Manager generates the image metadata file. This file contains 10 metadata values, 5 of which correspond to the Location Keys specified when entering the Source information (see III.B.1.c, pp.23-24).

   For non-CREP users, please refer to CoralNet's Upload Instructions to get additional info on manually entering image metadata values or creating your own metadata file, etc.

4. Create a points/annotations CSV file based on the data copied from the results of each of the analysts' previous calibration exercise using the following guidelines:

   The CSV file should have one row per point. The first row must contain column headers that specify which column is which.
   Example:

Name	Row	Column	Label
ROS-03_A_13_**PLM**.JPG	853	486	*CCAH
ROS-03_A_13_**PLM**.JPG	1646	465	*MOBR
ROS-03_A_13_**PLM**.JPG	325	1011	*TURFH
ROS-03_A_13_**PLM**.JPG	1619	1176	*TURFH
ROS-03_A_13_**PLM**.JPG	1013	1743	*ACBR
ROS-03_A_13_**PLM**.JPG	1333	1300	*MOBF
ROS-03_A_13_**PLM**.JPG	374	2251	*UNK
ROS-03_A_13_**PLM**.JPG	1760	1984	*UNK
ROS-03_A_13_**PLM**.JPG	900	2577	*TURFH
ROS-03_A_13_**PLM**.JPG	1126	2534	*POEN

   Name is the image name. *Row* is the pixel row of the point. *Column* is the pixel column of the point. *Label* is the label code used to annotate the point. (Label is optional. If specified, both a point and an annotation will be created. If not specified, only a point will be created).

5. When all the image files, metadata, and points/annotations CSV files are ready, click on the blue **"Upload"** button on CoralNet and repeat steps III.C.4.c. 1–2 (pp. 35–36).
6. Return to the main Upload page by clicking on the blue **"Upload"** button.
7. Click on the **"Upload Points/Annotations"** button
8. Under **"CSV file",** click on the **"Choose files"** button, navigate to the folder where the points/annotations CSV file is stored, and select the CSV file.
9. Click on **"Save points/annotations",** then click on the blue **"Upload"** button to upload more images/metadata, or click on the Source name to return to the home page.

c. To create a **new** calibration exercise **with no fixed points/annotations**:
   1. Randomly select 100 images from a previous photoset, typically collected from a region or set of islands.

2. Copy the images to a folder on your local drive.
3. Using a batch file renaming program (e.g. Bulk Rename Utility), rename each set of 100 images by adding a suffix of the analyst's 3 or 2-letter initials (e.g. "PLM").

   Example:
   ROS-03_A_13_**PLM**.JPG
   ROS-23_A_07_**PLM**.JPG
   ROS-409_A_15_**PLM**.JPG
   ROS-422_A_25_**PLM**.JPG
   ROS-427_A_03_**PLM**.JPG

   Repeat this process until each participating analyst has his/her own set of images. For example, if there are 100 calibration images and 5 analysts, you will be uploading 500 images to CoralNet, with each image file renamed with each of the analysts' initials (image file names uploaded to the same Source page on CoralNet must be unique).

4. Create the associated **image metadata file.**

   Note: For ESD-CREP, the Data Manager generates the image metadata file. This file contains 10 metadata values, 5 of which correspond to the Location Keys specified when entering the Source information (see III.B.1.c, pp.23-24).

   For non-CREP users, please refer to CoralNet's Upload Instructions to get additional info on manually entering image metadata values or creating your own metadata file, etc.

5. Create a ("fixed") points CSV file based on the point coordinates generated by CoralNet on one set of images. To do so, click on the blue **"Upload"** button on CoralNet, and then click on **"Upload Images".**
6. Under **"Images files"**, click on the **"Choose files"** button, and navigate to the folder where all of the calibration exercise image files have been compiled.
7. Select **one** set of images (i.e., the first 100 images belonging to one analyst), and click on the **"Start Upload"** button
8. Follow steps III.C.4.2 (p. 36) to upload the metadata.

9. Click on the blue **“Images”** button to return to the Image browse page.
10. Browse by “Region”, “Year”, or “Analyst” to search for the photoset that you just uploaded and click on the **“Search”** button.
11. Scroll down to the bottom of the page, and set the **“Enter Annotation Tool”** dropdown menu to “Export”. Select **“Annotations, Full”** for “All 100 image results” and click on the “Go” button

12. An “annotations_full.csv” file will be automatically downloaded to your default download folder.
13. Open the CSV file in Excel, and copy the images’ point coordinates under the “Row” and “Column” headers.
14. Create a points/annotations CSV file using the following guidelines:

    The CSV file should have one row per point. The first row must contain column headers that identify each column.

    Example:

Name	Row	Column	Label
ROS-03_A_13_**PLM**.JPG	853	486	*CCAH
ROS-03_A_13_**PLM**.JPG	1646	465	*MOBR
ROS-03_A_13_**PLM**.JPG	325	1011	*TURFH
ROS-03_A_13_**PLM**.JPG	1619	1176	*TURFH
ROS-03_A_13_**PLM**.JPG	1013	1743	*ACBR
ROS-03_A_13_**PLM**.JPG	1333	1300	*MOBF
ROS-03_A_13_**PLM**.JPG	374	2251	*UNK
ROS-03_A_13_**PLM**.JPG	1760	1984	*UNK
ROS-03_A_13_**PLM**.JPG	900	2577	*TURFH
ROS-03_A_13_**PLM**.JPG	1126	2534	*POEN

    Name is the image name. *Row* is the pixel row of the point. *Column* is the pixel column of the point. *Label* is the label code used to annotate the point. (Label is optional. If specified, both a point and an annotation will be created. If not specified, only a point will be created).

15. Paste the images' point coordinates copied from the annotations_full.csv export to their corresponding columns in the new points CSV file. Copy and paste the same set of point coordinates to the to the set of photos of each analyst.
16. When all the image files, metadata, and points/annotations CSV files are ready, click on the blue **"Upload"** button on CoralNet and repeat steps III.C.4.c. 1–2 (pp. 35–36).
17. Click on the **"Upload Points/Annotations"** button.
18. Under "CSV file", click on the "Choose file" button, navigate to the folder where the points CSV file is stored, and select the CSV file.
19. Click on **"Save points/annotations",** then click on the blue **"Upload"** button to upload more images/metadata, or click on the Source name to return to the home page.

IV. GUIDES

IV.A. Benthic Image Analysis – Classification Guide (Tier 3b) For Rapid Ecological Assessment (REA) Images

CREP uses a hierarchical system to classify benthos. This system has three different levels, or 'Tiers.' **Tier 1** is the most general level, with categories such as Coral, Sediment, Invertebrate, and Macroalgae. **Tier 2** subdivides some these groups into a mix of taxonomic and ecological functional designations. For example, Invertebrate is divided into taxonomic groups such as Anemone, Bivalve, and Sponge. Corals are divided functionally by growth form, into categories such as Branching, Encrusting, and Massive.[4] **Tier 3** was developed to further divide Tier 2 groups into more specific categories such as coral and algal genera, and some combined taxon-functional group designations (e.g. *Porites* spp. massive/non-massive, *Montipora spp.* encrusting/non-encrusting.). Some Tier 2 functional groups were retained in the Tier 3 classification in instances where a precise identification was not possible. Tier 3 classification was implemented by the ESD-Coral Reef Ecosystem Program's Benthic team from 2013 to 2015.It was the result of the merging of numberous disparate yet similar benthic image analysis classification strategies that were used historically within the program and its research partners.

Tier 3b is the result of the most recent refinement of the categories based on practical experience with Tier 3. Tier 3b added some coral genera and mid-level taxonomic groups for algae (e.g. red algae (Rhodophyta)), and removed unused algal genera. Tier 3b consists of 94 benthic categories, 27 of which are new from the previous Tier 3 list. This classification guide provides a

[4] *Note that 'massive' does not refer to the size of the colony. Massive corals are those characterized by forming raised mounds or rounded heads with hemispherical to sub-hemispherical morphologies. See description on p. 87 for more detail.*

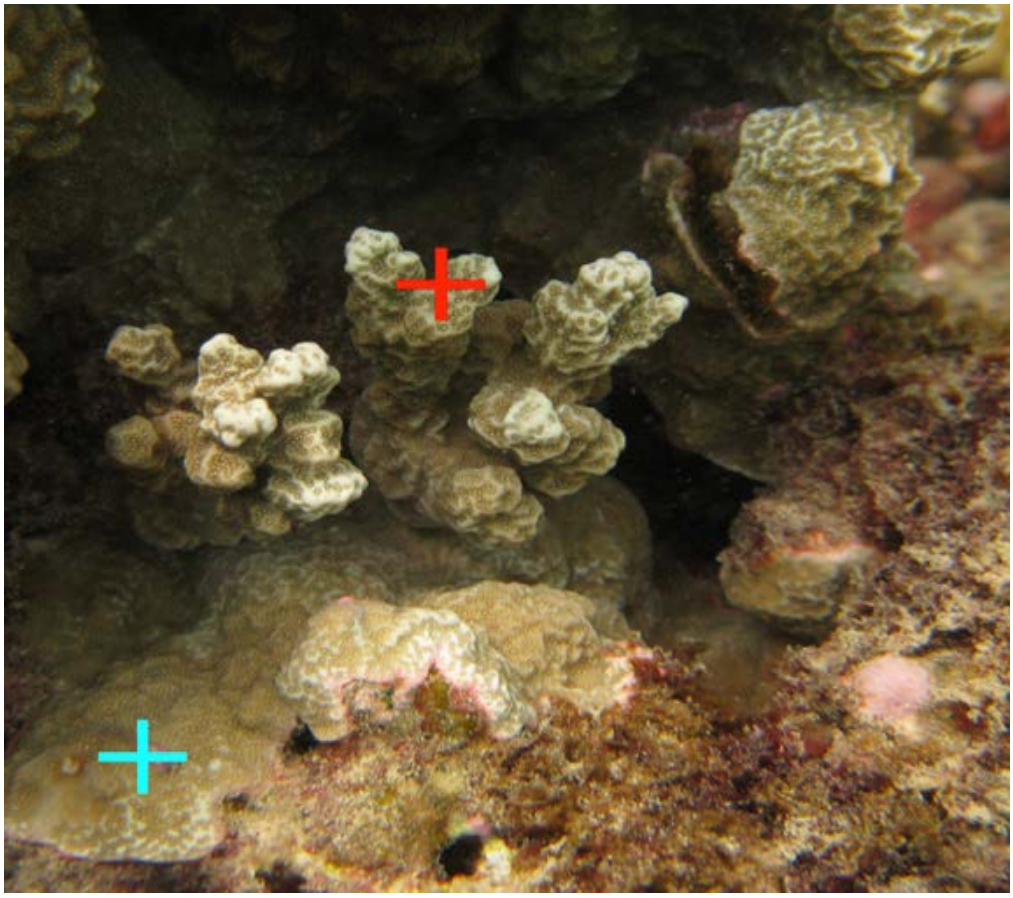
comprehensive list of benthic categories (Tier 3b) specific to image analysis. The list includes a summary of category definitions and sample photos. Categories are presented as groups per their Tier 1 designation. Within each designation, groups are presented with generic groups first, followed by functional or broad taxonomic groups if applicable. Within those categories, groups are presented alphabetically.

NEW CATEGORIES IN TIER 3b		
Diploastrea spp.	*Montastrea* spp.	*Platygyra* spp.
Euphyllia spp.	*Montipora* spp. branching	*Plerogyra* spp.
Fungia spp.	*Montipora* spp. foliose	*Porites* spp. branching
Heliopora spp.	*Oulophyllia* spp.	*Porites* spp. encrusting
Leptoria spp.	*Pachyseris* spp.	*Porites* spp. foliose
Lobophyllia spp.	*Pavona* spp. encrusting	*Symphyllia* spp.
Merulina spp.	*Pavona* spp. foliose	Hydrocoral
Millepora spp.	*Pavona* spp. massive	
MACROALGAE FUNCTIONAL GROUPS		
Brown macroalgae Green macroalgae Red macroalgae		
MISCELLANEOUS		
Discard (not included in this guide)		
CATEGORIES REMOVED IN TIER 3b		
MACROALGAE GENERA *Acanthophora spp.* *Amansia spp.* *Boodlea spp.* *Chlorodesmis spp.* *Ganonema/Liagora spp.* *Galaxaura spp.*		
CONDITION CATEGORIES		
Bleaching Predation		
CORAL GENERA		
Nine proposed corals in the ESA list		
CATEGORIES THAT WERE SPLIT/REPLACED IN TIER 3b		
Lobophyllia/Symphyllia - split to *Lobophyllia* spp. and *Symphyllia* spp. ***Montipora* non-encrusting** - split to *Montipora* branching, encrusting and foliose spp. **Non-scleractinian corals** - split to *Millepora* spp., *Heliopora* spp. and (other) Hydrocorals ***Pavona* spp**. - split to *Pavona* encrusting, massive and foliose spp. ***Platygyra/Leptoria* spp**. - split to *Platygyra* spp. and *Leptoria* spp. ***Porites* non-massive** - split to *Porites* branching, encrusting, foliose and massive spp.		

IV. A.1. Coral

a) The corals classified under this Tier 1 category are not all Scleractinian corals. The blue octocoral *Heliopora coerulea* and hydrozoans such as *Millepora* are included because they form carbonate skeletons that contribute to coral reef formation and accretion.
b) If possible, corals should be identified to genera (e.g. *Pocillopora, Favia*). If it is not possible to identify a coral to this level, identify it by its growth form (e.g. branching, encrusting). Also, under Tier 3b classification, three genera (*Montipora, Pavona,* and *Porites*) have been further subdivided into growth forms (e.g. *Montipora* spp. branching, encrusting, and foliose). Descriptions below provide details about these categories.

c) If a point falls on a colony that has multiple growth forms, classify the point based on the morphology directly under the point rather than the overall colony morphology.[5]



NOAA photos

IV.A.1.A. Coral Genera

The functional group mapping is given for each genus. This group equates to its Tier 2 classification.

Acanthastrea spp. (ACAS)

Colonies most often occur in shallow reef environments and they have encrusting or massive morphologies and are usually flat. Colonies have thick "fleshy-looking" tissue over skeleton. Corallites are cerioid or subplocoid, monocentric, either circular or angular in shape. Septo-costae are thick near the corallite wall, thinning near the columella, and have tall mussid teeth.

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1. [5] *The lists of growth forms available in BIA are more limited than those used during field identification. For example, parts of a* P.rus *colony that may appear columnar should be classified as branching, and those that appear plating or laminar should be classified as foliose.*

Polyps are thick-walled, and tentacles are extended only at night. These corals are common. The most common species is *A. echinata.*

Tier 2 group mapping: Encrusting coral (ENC)

guamreeflife.com

***Acropora* spp._branching (ACBR)**

Colonies are most often found in shallow reef environments, reef flats, and upper reef slope habitats. Branch tips often have a different shade/color than the rest of the colony. Polyp tentacles are usually only extended at night. These corals are common. The most common species are A. *humilis, A. nobilis,* and *A. robusta.*

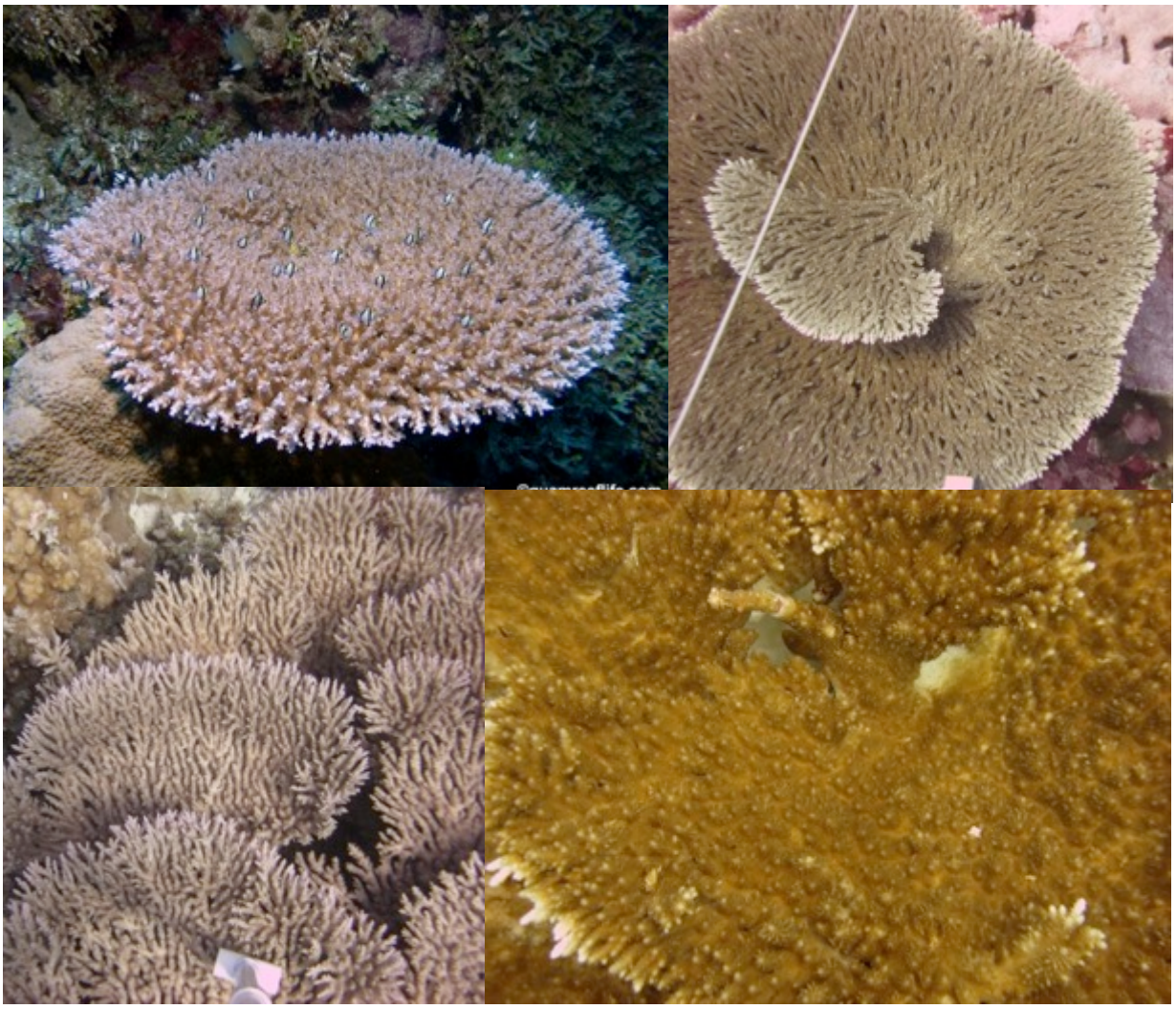
Tier 2 group mapping: Branching coral (BR)

guamreeflife.com; aims.gov.au

***Acropora* spp._table (ACTA)**

Colonies are most often found in shallow reef environments, reef flats, and upper reef slope habitats. Plate-like or table-like morphology with encrusting bases encompass this category. Plate edges often appear lighter in color than the rest of the colony. Polyp tentacles are usually extended only during the night. These corals are common. The most common species are A. *hyacinthus, A. clathrata, A. cytherea,* and *A. paniculata.*

Tier 2 group mapping: Table coral (TA)



aims.gov.au; guamreeflife.com; NOAA photos

***Astreopora* spp. (ASSP)**

Found in many reef environments including protected water areas, these colonies have massive, laminar, or encrusting morphology. Corallites are generally conical – they can be evenly spaced and uniform or face different directions with mixed sizes yielding a "chaotic appearance". These colrals are abundant. The most common species are *A. myriophthalma* and *A. randalli.*

Tier 2 group mapping: Encrusting coral (ENC)

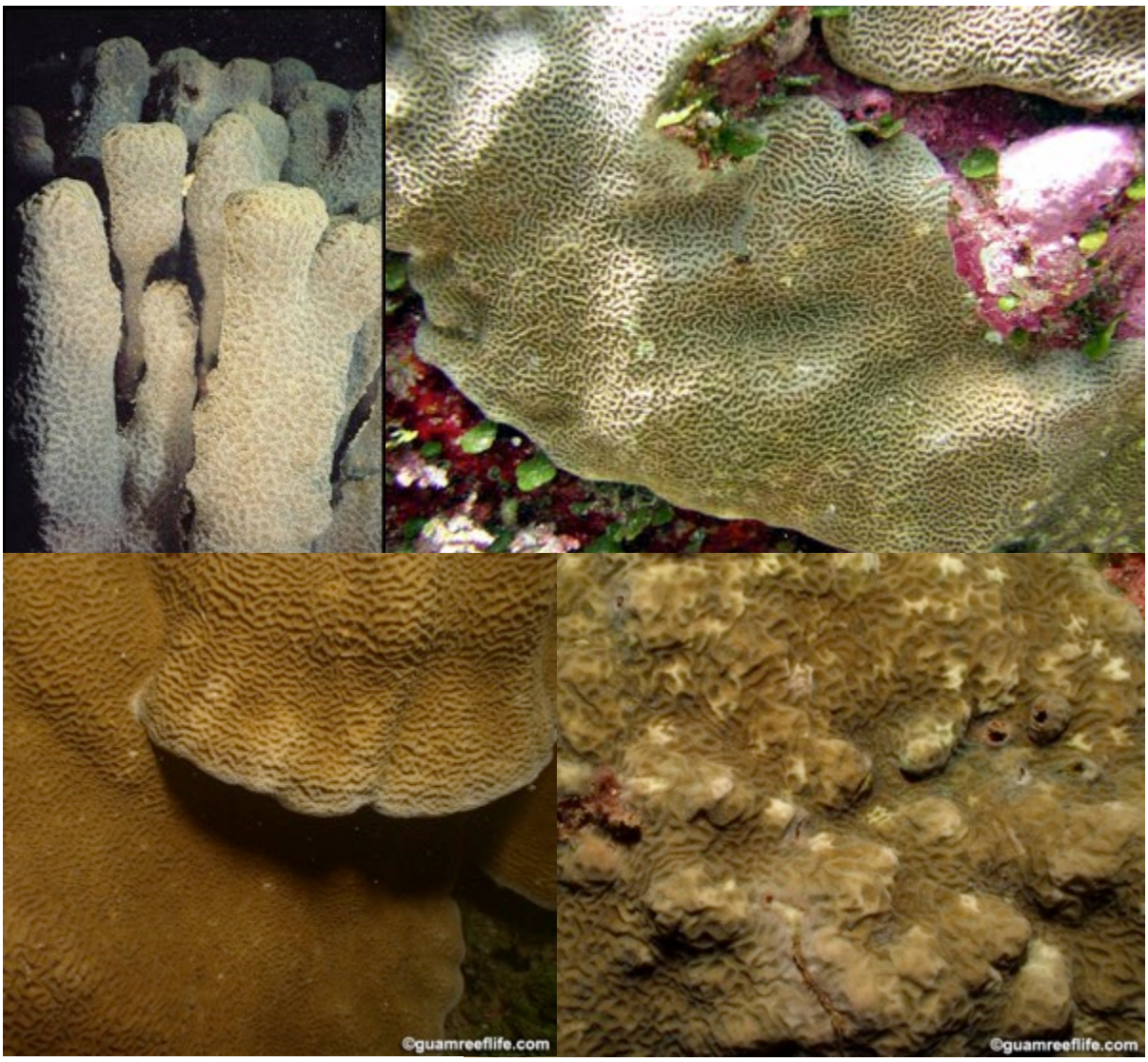
guamreeflife.com

***Coscinaraea* spp. (COSP)**

Colonies are often found in shallow reef habitats. Colonies have columnar, massive, encrusting, or laminar morphologies. Corallites are in short shallow valleys and have indistinct walls. Tentacles are often extended during the day, yielding a “fuzzy” appearance. Color is typically

dark grey or brown. These corals are uncommon. The most common species are *C. exesa* and *C. columna.*

Tier 2 group mapping: Encrusting coral (ENC)



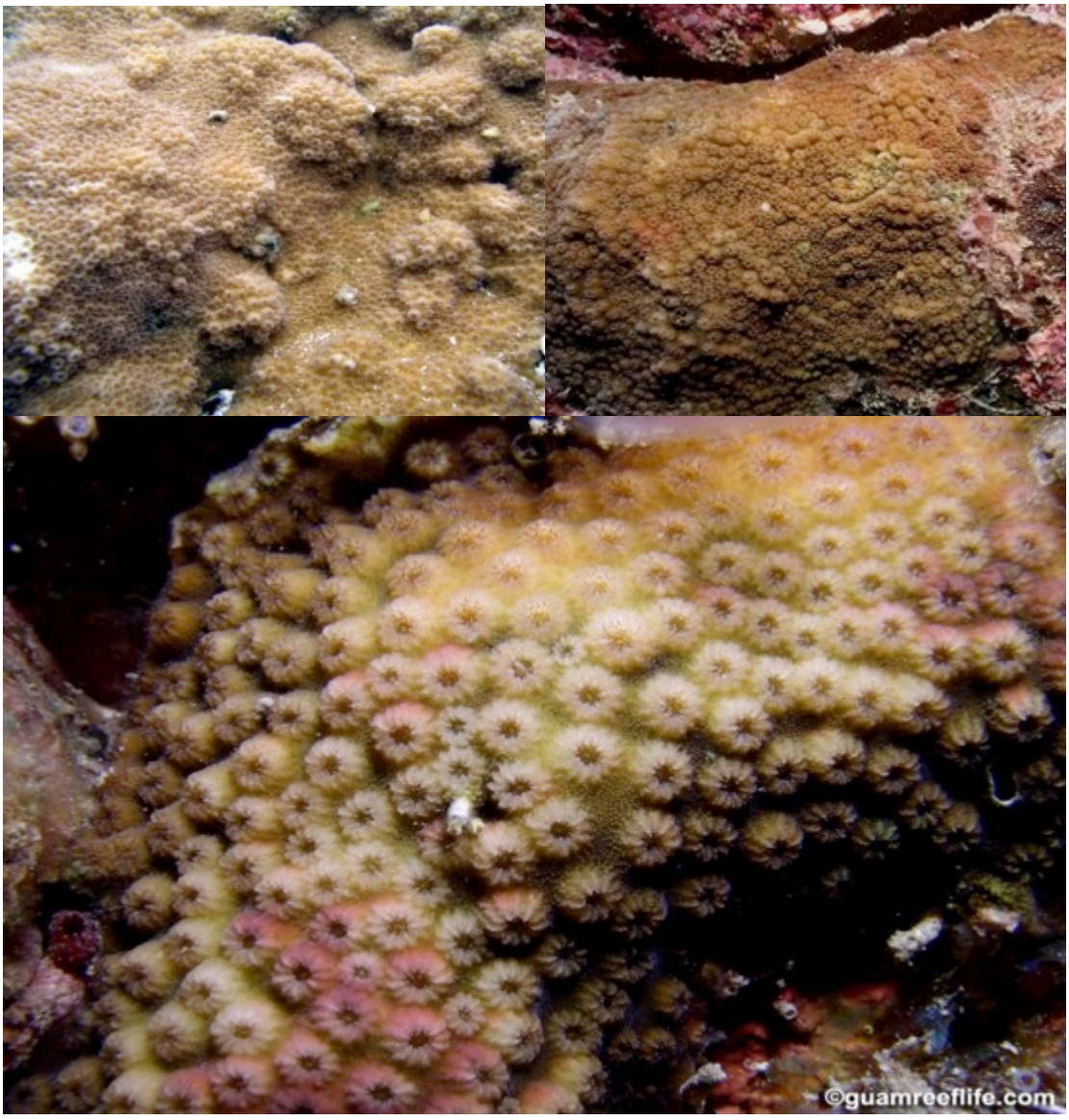
guamreeflife.com; aims.gov.au; NOAA photos

Cyphastrea spp. (CYPS)

Colonies are found in nearly all reef environments, including rocky foreshores. Colonies have massive and encrusting morphologies. Corallites are conical or round and often have strongly

alternating costae which are easily visible. Corallites may be widely spaced and arecommon. The most common species is *C.chalcidicum*.

Tier 2 group mapping: Encrusting coral (ENC)



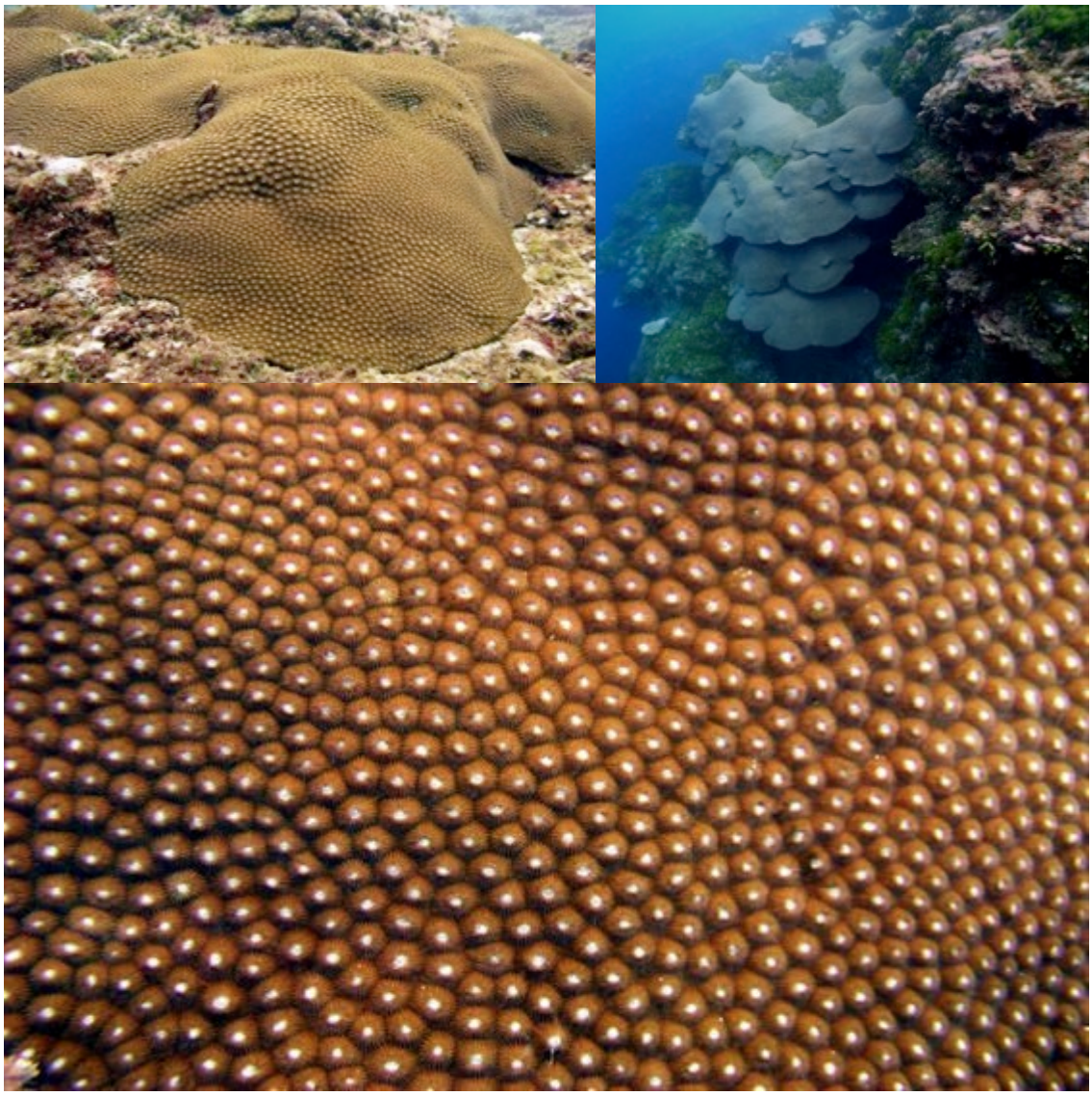
guamreeflife.com

***Diploastrea* spp. (DISP)**

Colonies are found in both exposed and protected reef environments. Colonies have massive and sub-massive morphologies. Massive colonies are often dome-shaped. Colonies can be very large

(> 5 m diameter). Corallites are large, thick walled, and form low cones with small openings. Corallites are very uniform and tightly spaced. Colony skeleton is very dense. These corals are uncommon. There is only one species in genus: *D. heliopora*.

Tier 2 group mapping: Massive coral (MASS)

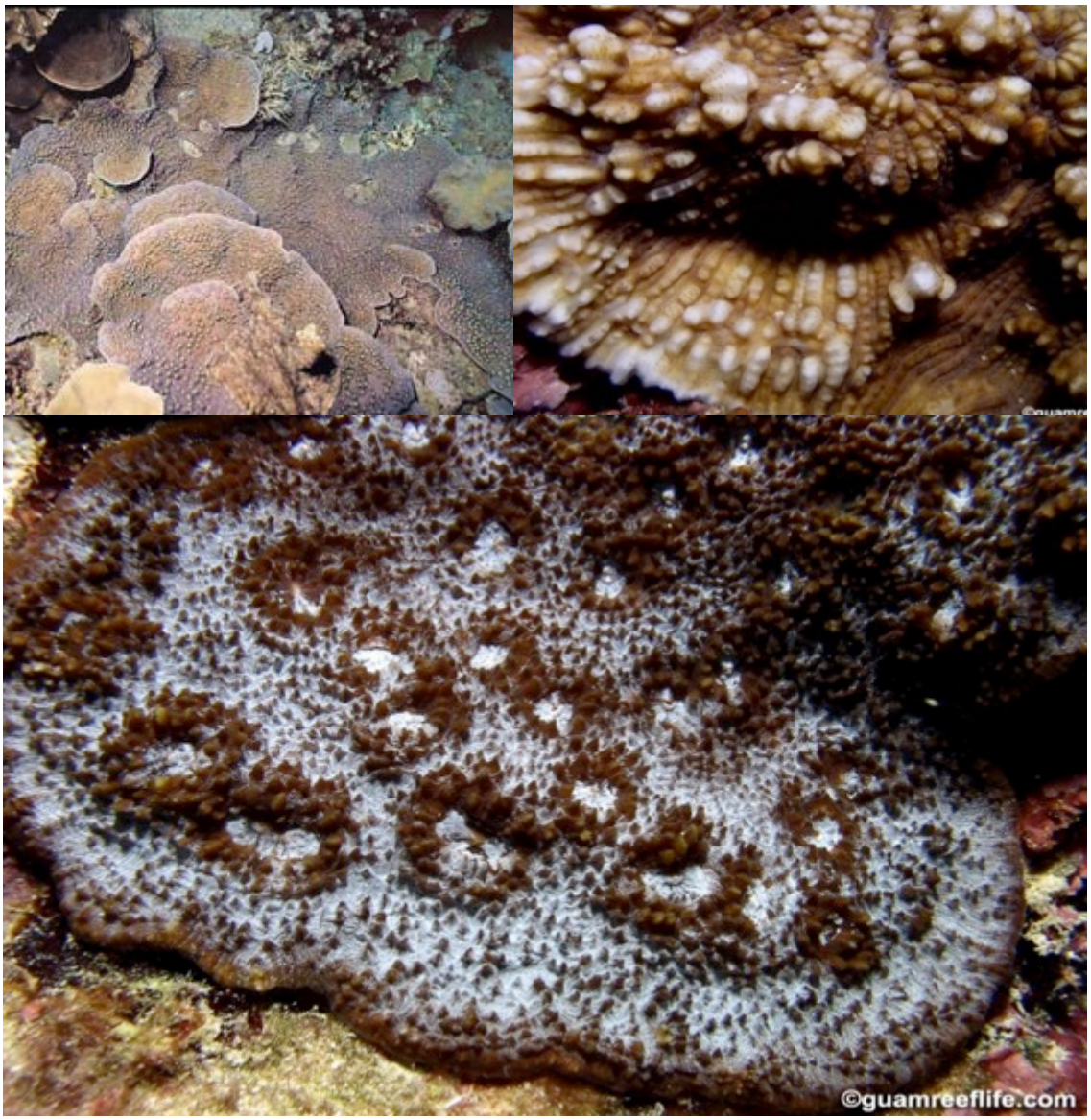


guamreeflife.com

Echinophyllia* spp. (ECHL*)

Colonies are found in most reef environments, particularly on lower reef slopes and in lagoons. Colonies have encrusting or laminar morphologies, and may form whorls or have central parts that are hillocky. Corallites have toothed costae. Brown, green, and red color morphs are most common, with polyps usually having a red or green oral disc. These corals are common.

Tier 2 group mapping: Encrusting coral (ENC)

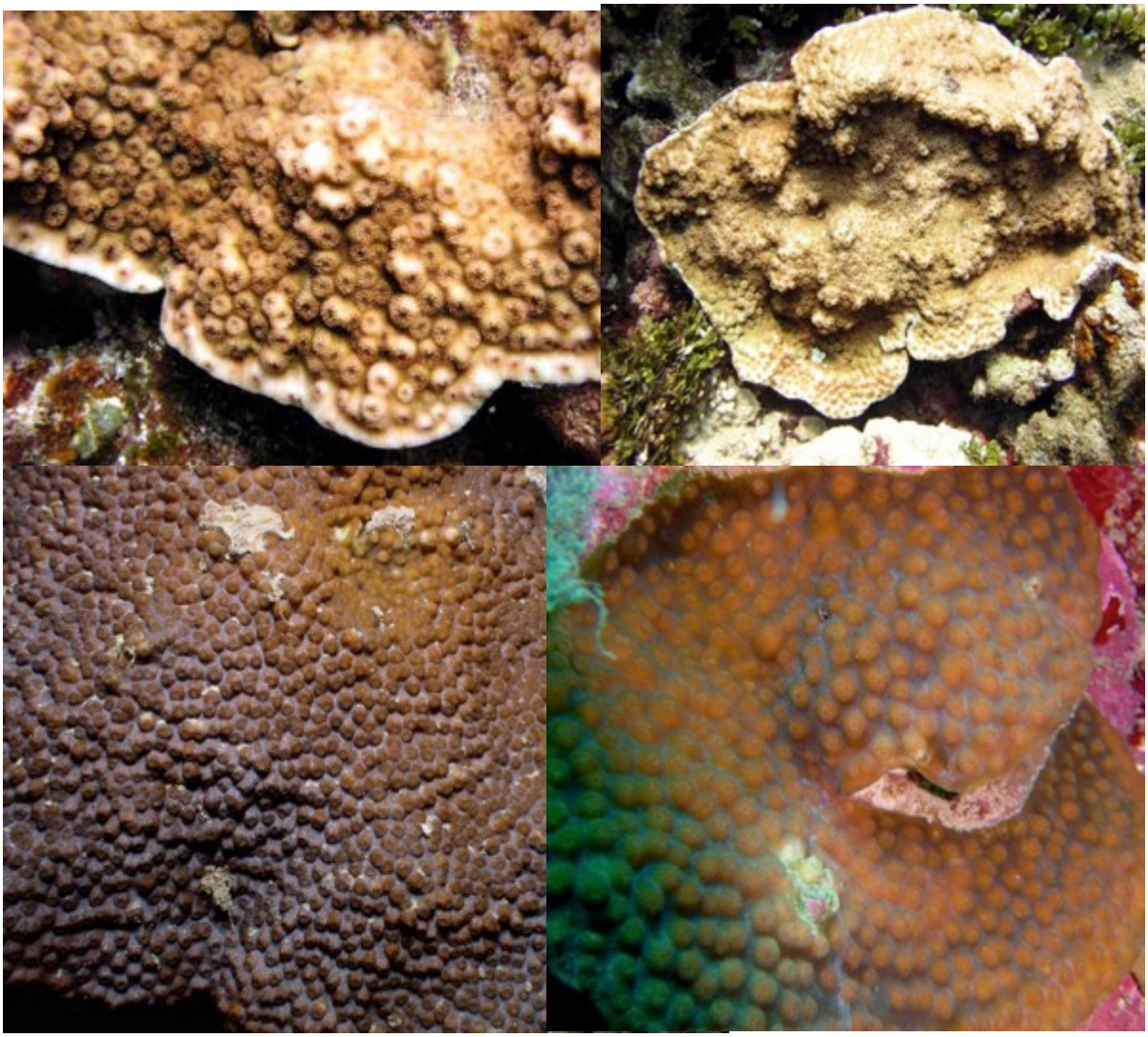


guamreeflife.com; aims.gov.au

***Echinopora* spp. (ECHP)**

Colonies are found in shallow reef environments. Colonies have encrusting, laminar (forming whorls or tiers), massive, or arborescent (tree-like) morphologies. Colonies may form large stands > 5 m across. Corallites are thin-walled and small. Coenosteum is often granulated, with a “sand-paper” like appearance; often amber, pale to dark brown, or greenish in color with darker brown or green calices. These corals are common.

Tier 2 group mapping: Encrusting coral (ENC)



guamreeflife.com

***Euphyllia* spp. (EUSP)**

Colonies have phaceloid or flabello-meandroid morphologies. Corallites are large (20- to 30-mm diameter) and widely spaced (15- to 30-mm apart). Corallites have thin walls with septa not exert and lacking columellae. Corallite structure cannot be seen with tentacles extended. Polyps have large tubular tentacles with knobby tips giving it an appearance similar to an anemone. These corals are relatively uncommon. There are four species documented: *E. cristata, E. glabrescens, E. paraanocroa, E. paradivisa.*

Tier 2 group mapping: Branching coral (BR)

guamreeflife.com

***Favia* spp. (FASP)**

Colonies are found in most reef environments. Colonies typically have massive morphologies and can be flat or dome shaped. Corallites are usually monocentric and plocoid (not sharing walls). Corallites can vary in size between species from small (< 8-mm diameter), to medium (8- to 12-mm diameter), or large (>12-mm diameter). Oral discs may have a similar or contrasting color to the rest of the polyp. These corals are abundant. They can appear similar to *Favites* or *Montastraea* spp. The most common species are *F. matthaii*, and *F. stelligera.*

Tier 2 group mapping: Massive coral (MASS)

guamreeflife.com

***Favites* spp. (FAVS)**

Colonies are found in most reef environments. Colonies typically have massive morphologies and can be flat or dome shaped. Corallites are usually monocentric and ceroid, occasionally sub-plocoid. Corallites can vary in size between species, from very small (< 6-mm diameter), to small (6- to 10-mm diameter), medium (10- to 14-mm diameter), or large (> 14-mm diameter). Corallites usually have thick, shared walls. They are most similar in appearance to *Favia* spp. These corals are common. The most common species is *F. russelli.*

Tier 2 group mapping: Massive coral (MASS)

guamreeflife.com

***Fungia* spp. (FUSP)**

Corals are often found on reef slopes and in lagoons. Corals are free-living/solitary, can be circular or elongate, and domed or flattened. They often have pits between costae on the lower surface. Primary septa begin with a tall tentacular lobe. Usually brown, blue, or yellow in color, they may have brighter tentacular lobes. These corals are common. The most common species is *F. scutaria*, which is oval in shape and thick.

Tier 2 group mapping: Free-living coral (FREE)

guamreeflife.com; aims.gov.au

***Galaxea* spp. (GASP)**

Colonies are found in protected reef environments. Colonies have massive, sub-massive, columnar, and encrusting morphologies. Colonies of some species can be very large: > 2 – 5 m across. Corallites do not share walls and can be elongated. Polyps have a “flower-like” appearance. Tentacles are usually extended during day. These corals are abundant. The most common species is *G. fascicularis.*

Tier 2 group mapping: Encrusting coral (ENC)

guamreeflife.com

***Goniopora/Alveopora* spp. (GOAL)**

Colonies of both genera are found in many reef environments. *Goniopora*, which is more common, can be found in sub-tidal areas, lagoons, and protected reef slopes. Colonies have massive, branching, or encrusting morphologies and are irregular in shape. Polyps are large and fleshy, often extended both day and night. In situ, the two genera can be distinguished by the number of tentacles: *Alveopora* (12) and *Goniopora* (24). It is often difficult to confidently distinguish *Alveopora* from *Goniopora* in images collected for photoquadrats; thus, both genera are classified under the same category.

Tier 2 group mapping: Encrusting coral (ENC)

guamreeflife.com; aims.gov.au

***Goniastrea* spp. (GONS)**

Colonies occur in shallow-water habitats, including the intertidal. Colonies usually have a spherical, massive morphology, but may form thick plates. Corallites are monocentric and ceroid to polycentric and meandroid. Corallites are round or four to six sided. Corallites may form ridges and valleys creating a “brain coral” like appearance. These corals are abundant. The most common species are *G. retiformis* and *G. edwardsi*.

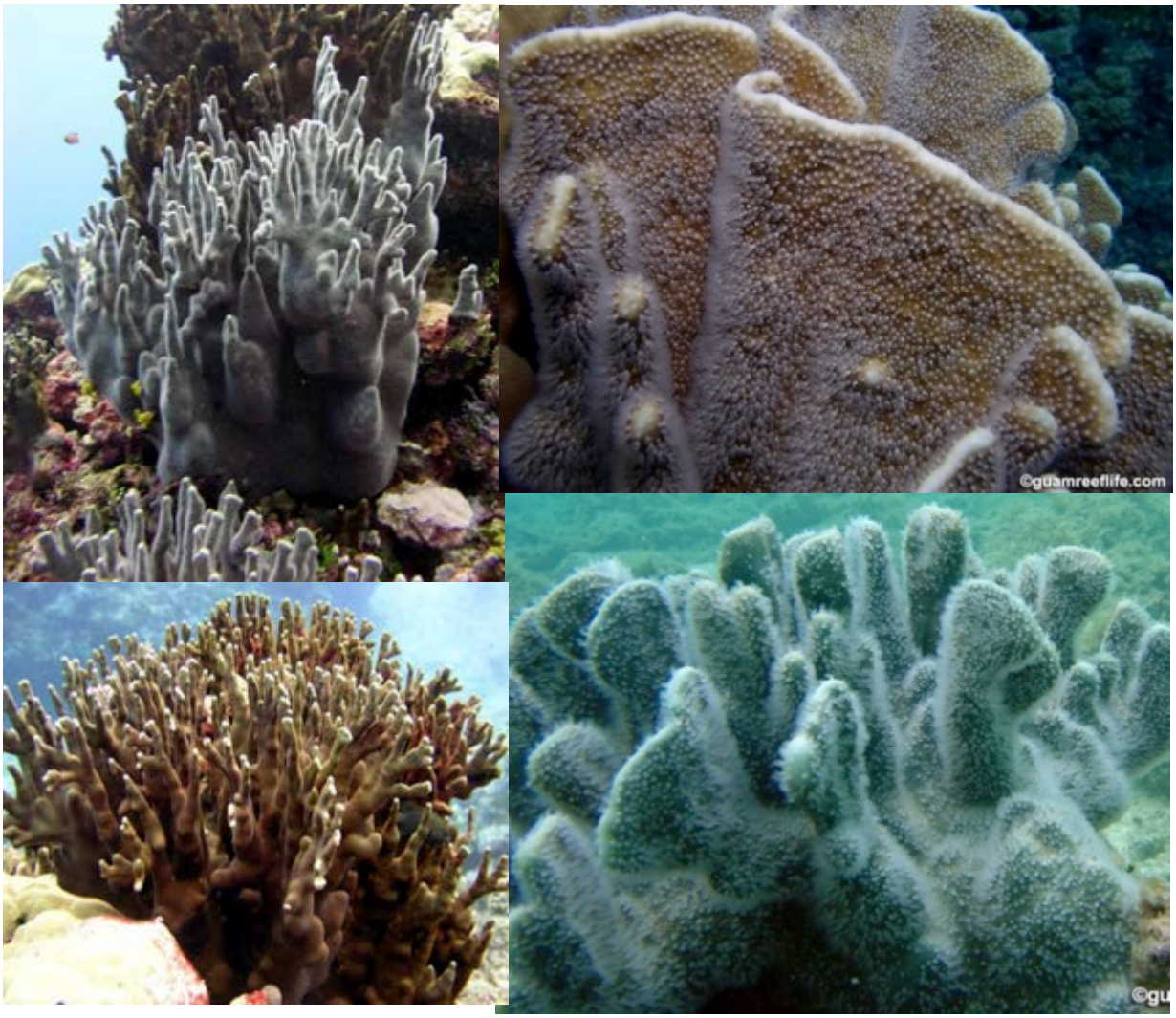
Tier 2 group mapping: Massive coral (MASS)

guamreeflife.com

***Heliopora* spp. (HCOE)**

This octocoral is commonly called Blue Coral. It is found in intertidal and subtidal environments with branching (flattened lobes) and columnar morphologies. It is brown to blue in color with a powder blue internal skeleton. There is only one species in the genus, *H. coerulea.*

Tier 2 group mapping: Non-scleractinian coral (NS)



guamreeflife.com; aims.gov.au

***Hydnophora* spp. (HYSP)**

These corals can be found in all reef habitats, but primarily occur in lagoons and protected areas. Colonies have massive, sub-massive, encrusting, or sub-arborescent morphologies. Characterized by the presence of monticules, hydnophores formed where sections of common wall between corallites intersect and develop into conical mounds. Short tentacles surround the base of each monticule and, in some species, may be extended both day and night. These corals are relatively common; the most common species is *H. microconos* (uniform monticules and polyps not extended during the day).

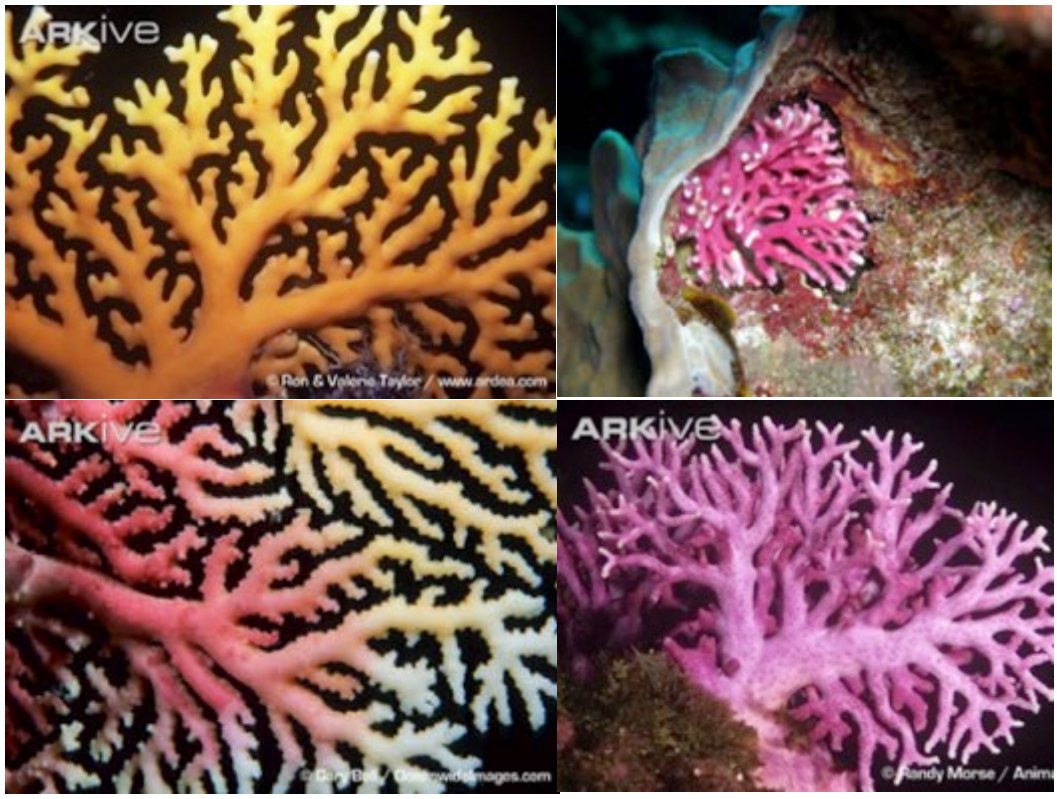
Tier 2 group mapping: Massive coral (MASS)

guamreeflife.com

Hydrocoral (HYCO)

The category includes two genera that are a part of Class Hydrozoa, *Distichopora* and *Stylaster*. These small branching “lace corals” are azooxanthellate and are generally found in shaded areas, such as in crevices and around ledges.

Tier 2 group mapping: Non-scleractinian coral (NS)

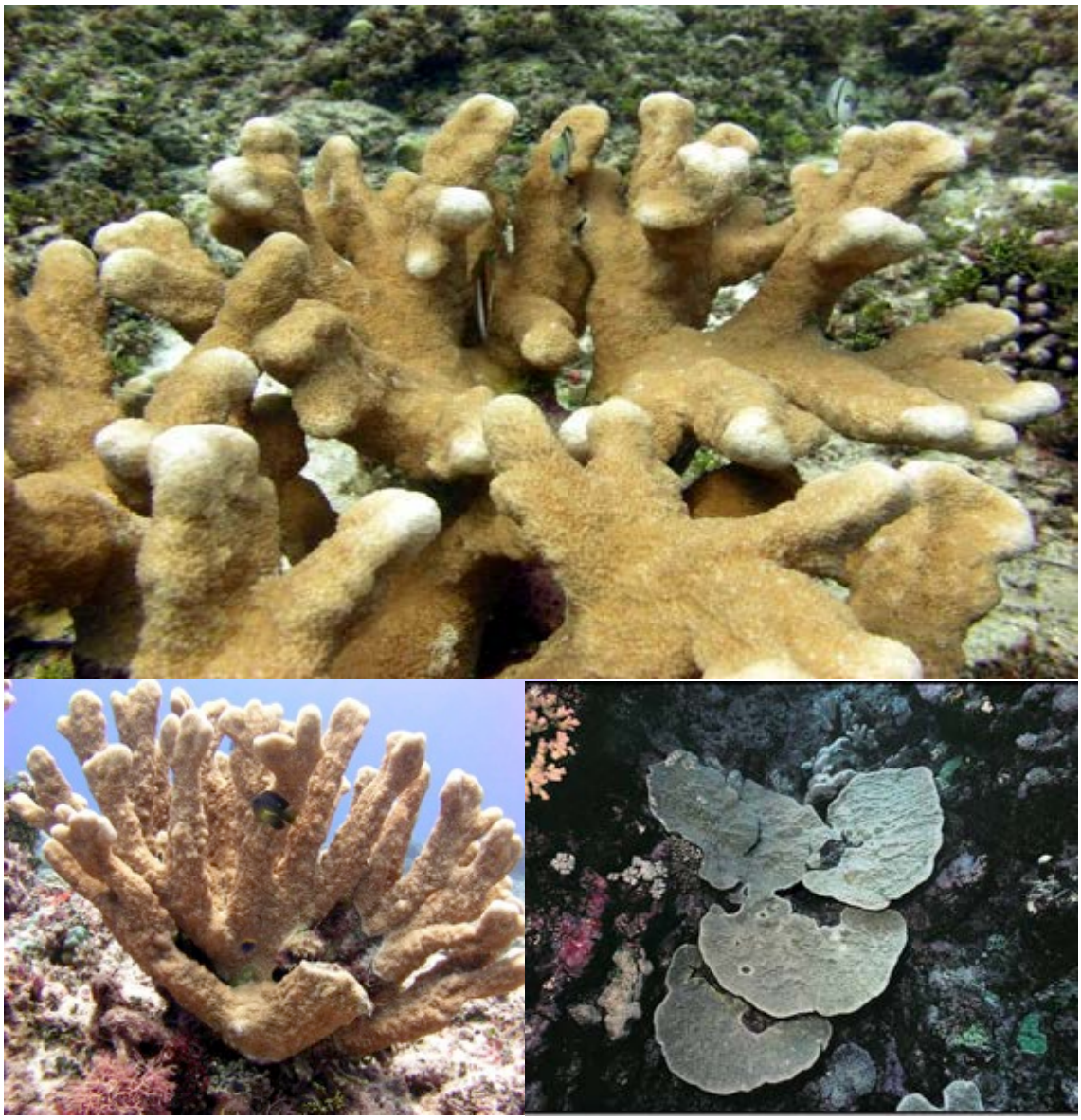


arkive.org

***Isopora* spp. (ISSP)**

These corals were considered a subgenus of *Acropora* until recently. Colonies have branching or encrusting morphologies. Individual species can be distinguished only based on coenosteum microstructure. Polyps resemble those of *Acropora* species, but *Isopora* colonies lack the apical polyp on branch tips that is characteristic of *Acropora*. Skeleton is very heavy and dense with robust branches. The robustness is similar to the Atlantic *A. palmata* and theycan be locally common. Three species have been recorded, *I. palifera, I. cuneata, and I. crateriformis.*

Tier 2 group mapping: Encrusting coral (ENC)

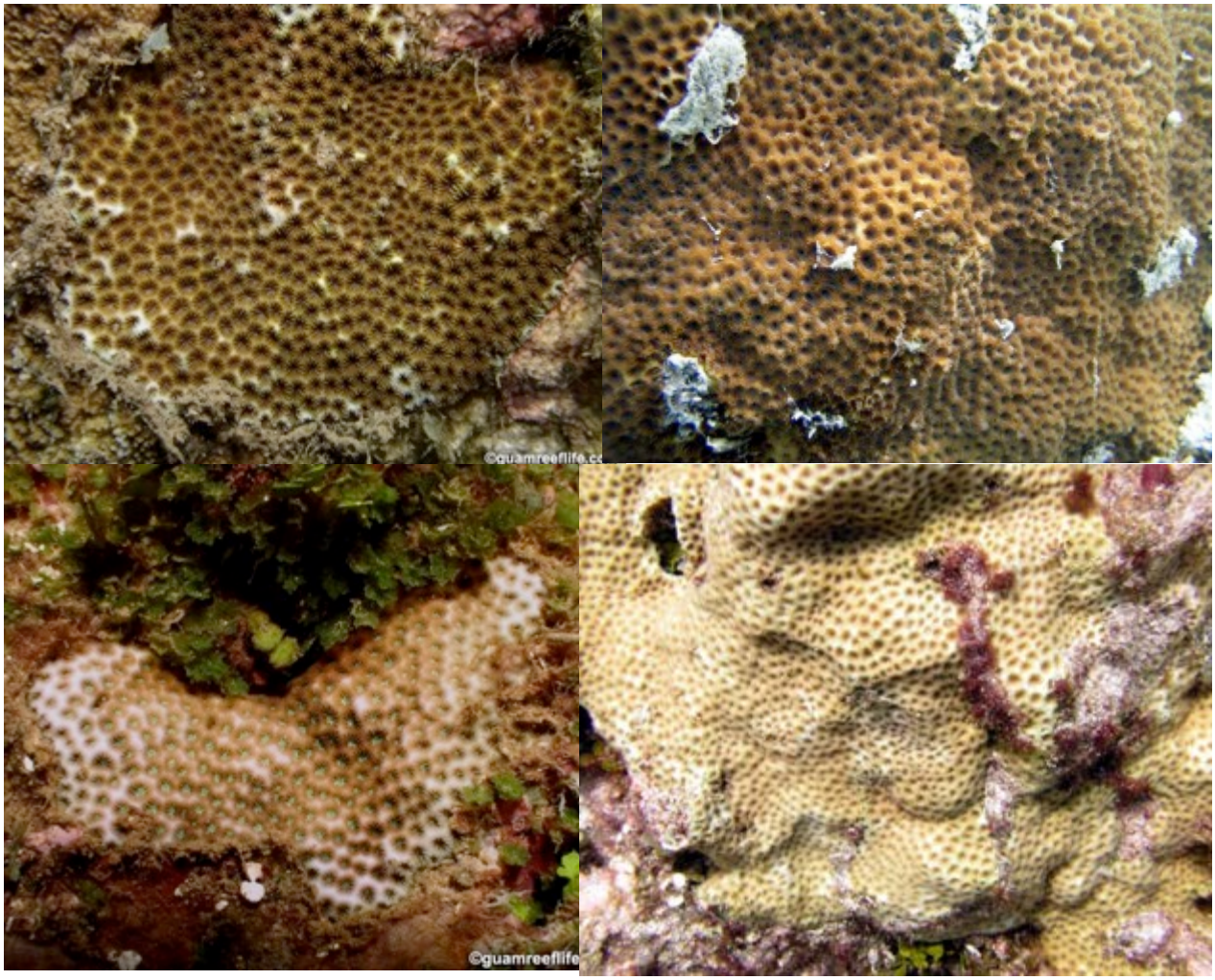


guamreeflife.com; aims.gov.au; NOAA photos

***Leptastrea* spp. (LEPT)**

Colonies are found in a wide variety of reef environments. Colonies are encrusting and are usually flat or dome-shaped. Corallites are small and cylindrical, separated by only a fine groove. Septa have inward projecting teeth. Tentacles may be extended during the day. Upper surfaces of intertidal colonies are usually pale. Surface has a “golf ball” like appearance. These corals are common. The most common species is *L. purpurea.*

Tier 2 group mapping: Encrusting coral (ENC)

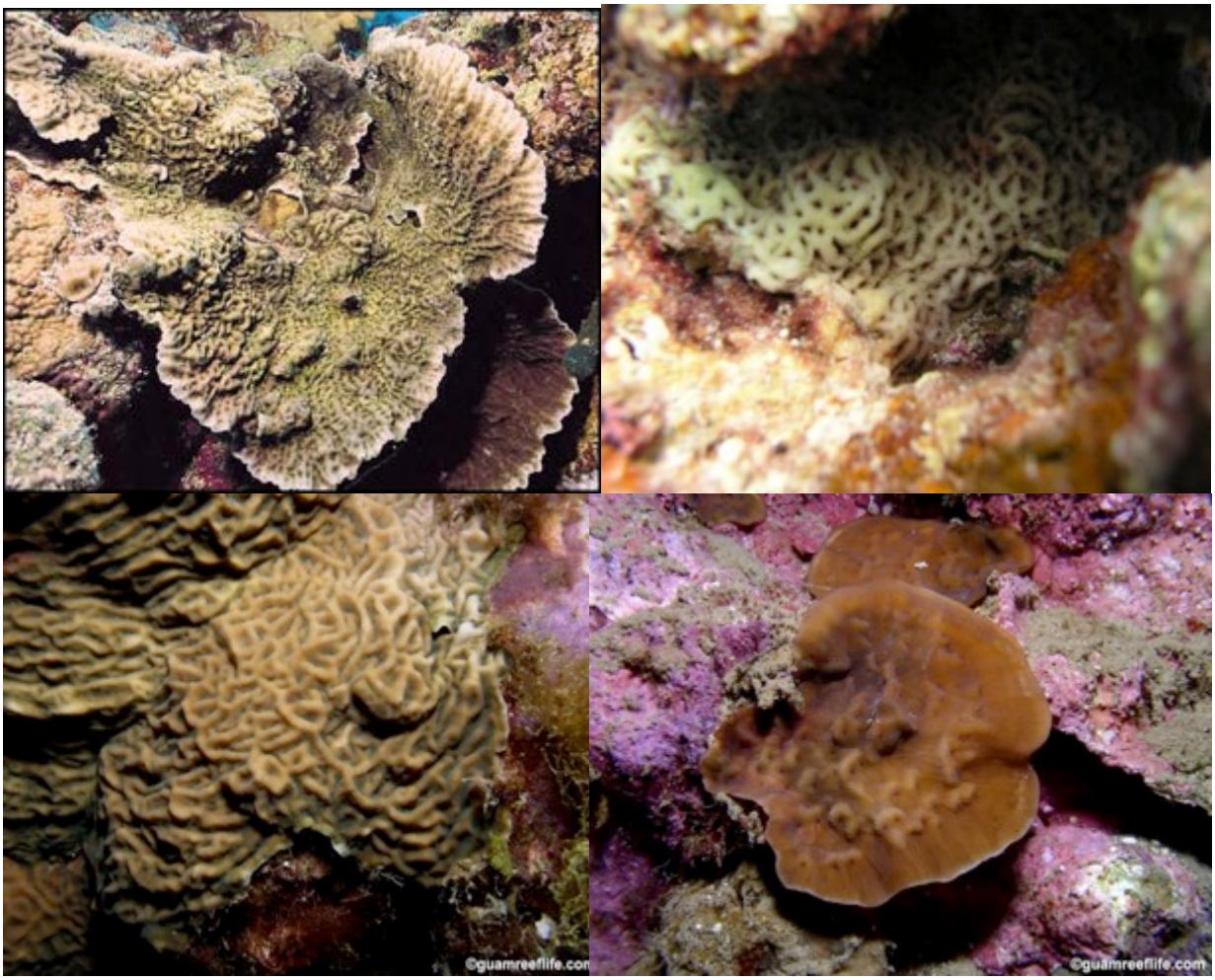


guamreeflife.com

***Leptoseris* spp. (LESP)**

Colonies are found in many reef environments, but are most often seen in shallow areas and on walls/overhangs. Colonies typically are unifacial and have laminar or encrusting morphologies. Corallites are shallow depressions with poorly defined walls. Septo-costae are thin and usually and radiate outward giving the colony a pin-striped appearance. Some laminar colonies have radiating ridges. These corals are common. The *Pavona* genus is similar. The most common species is *L. incrustans.*

Tier 2 group mapping: Encrusting coral (ENC)

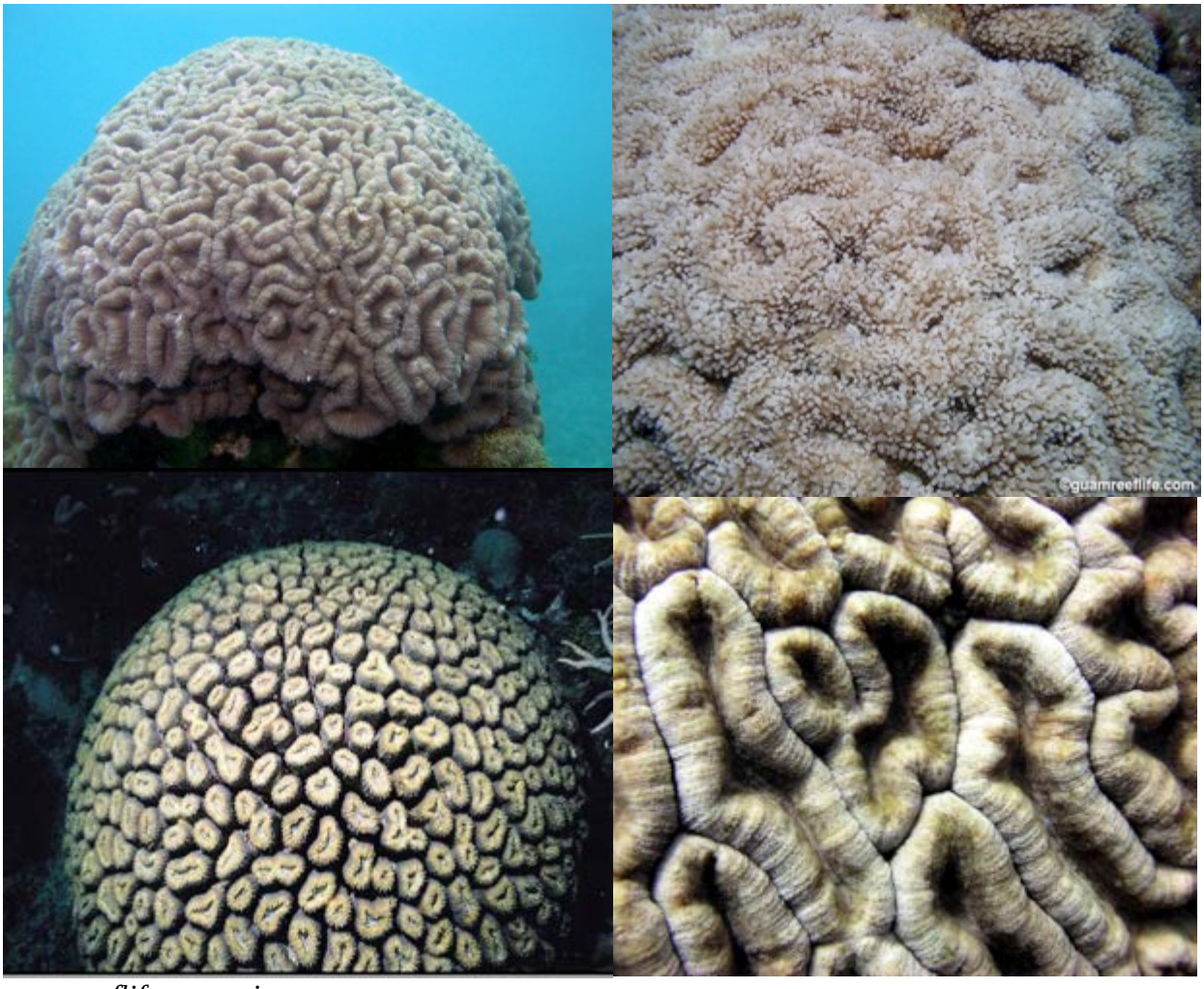


guamreeflife.com

***Lobophyllia* spp. (LOBS)**

These corals are found in most reef environments. Colonies are usually monocentric and rarely polycentric; polyps are solitary and do not share walls. Septa slope up from columella to an indistinct wall, then costae slope down to the perimeter, giving the fleshy looking tissue a concentric pattern. Primary septa have large, regular, blunt teeth.

Tier 2 group mapping: Massive coral (MASS)



guamreeflife.com; aims.gov.au

***Leptoria* spp. (LPHY)**

Colonies are found in most reef environments including upper reef slopes and non-turbid areas. Colonies are massive to encrusting and exhibit sinuous valleys and neatly arranged, with equal septa. Collumellae do not form centers. Colonies are cream, brown, or green in color with walls and valleys of contrasting colors; colonies have a "brain coral" appearance. These corals are common. There is only one species recorded, *L. phrygia.*

Tier 2 group mapping: Massive coral (MASS)

guamreeflife.com; aims.gov.au

***Merulina* spp. (MESP)**

Colonies are found in many reef environments, but predominantly in lagoons and forereefs. Colonies have laminar and sub-arborescent morphologies, which often occur simultaneously in large colonies. They have short, straight valleys which radiate from the center outward fan out before dividing. Flat surfaces often have concentric growth lines. They are often pale blue or brown in color and are uncommon. The two species documented are *M. ampliata* and *M. scabricula.*

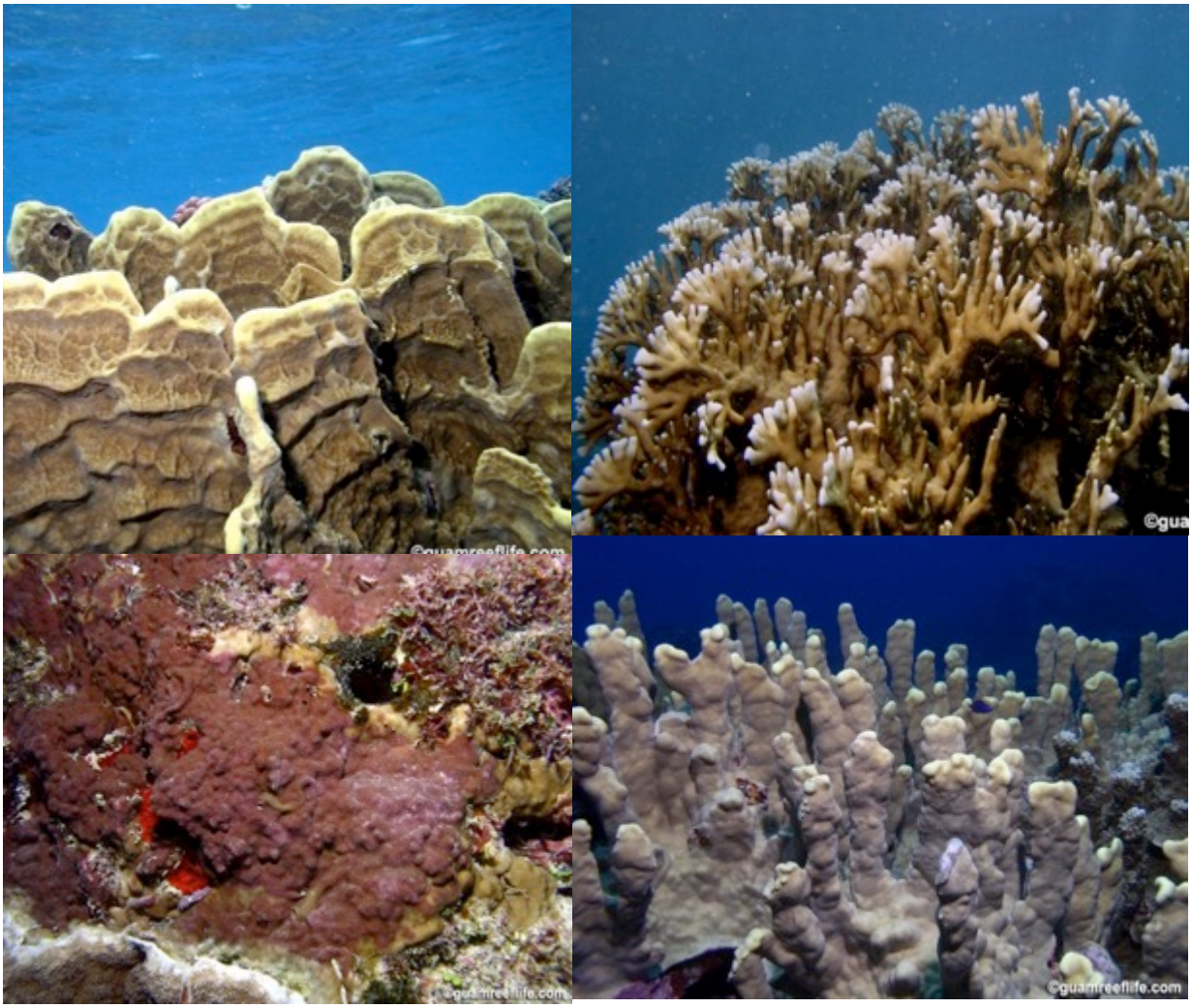
Tier 2 group mapping: Foliose coral (FOL)

guamreeflife.com; aims.gov.au

***Millepora* spp. (MISP)**

These hydrozoans are commonly called Fire Coral and are found in many reef environments. They have encrusting, branching, columnar, and sub-massive morphologies and are orange, tan, brown, or pale in color. Branch tips and edges are sometimes lighter in color or white. They will "burn" (sting) skin if touched and leave welts.

Tier 2 group mapping: Non-scleractinian coral (NS)



guamreeflife.com

***Montipora* spp._branching (MOBR)**

Found in most reef environments including upper reef slopes, under overhangs and within crevices. Colonies in this category exhibit a branching/arborescent morphology. May have smooth or knobby surface with immersed corallites. Some species have tuberculae (rice krispie looking bumps). Commonly brown and cream colors, but may be blue or purple. Some brown colonies will have polyp tentacles that are blue/purple. Abundant.

This category includes the following species: *M. capitata* and *M. incrassata.*

Tier 2 group mapping: Branching coral (BR)

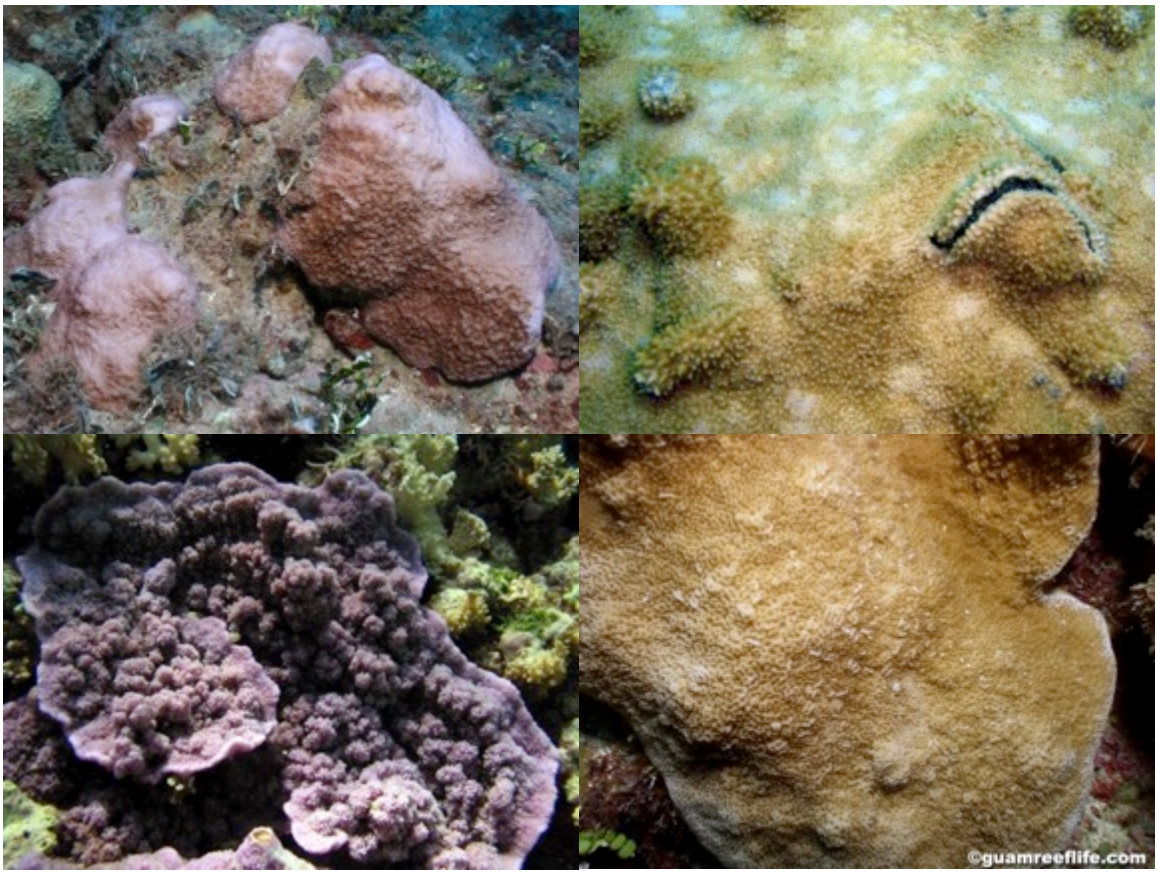
guamreeflife.com

***Montipora* spp._encrusting (MOEN)**

These corals are found in most reef environments including upper reef slopes, under overhangs, and within crevices. Colonies in this category exhibit an encrusting morphology. They may have a smooth or knobby surface with immersed corallites. Some species have tuberculae (rice krispie looking bumps). Though commonly brown and cream colors, they may also be blue or purple. Some brown colonies have polyp tentacles that are blue/purple. This type of coral is abundant.

This category includes the following species: *M. caliculata, M. capitata, M. flabellata, M. foveolata, M. patula, M. peltiformis, M. tuberculosa, M. turgescens, M. venosa, M. verrilli, M. verrucosa.*

Tier 2 group mapping: Encrusting coral (ENC)



guamreeflife.com

***Montipora* spp._foliose (MOFO)**

These corals are found in most reef environments including upper reef slopes, under overhangs, and within crevices. Colonies in this category exhibit a foliose or laminar morphology. They may have a smooth or knobby surface with immersed corallites. Some species have tuberculae (rice krispie looking bumps). Though commonly brown and cream colors, they may also be blue or purple. Some brown colonies will have polyp tentacles that are blue/purple. This type of coral is sbundant.

This category includes the following species: *M. aequituberculata, M. capitata, and M. verrilli.*

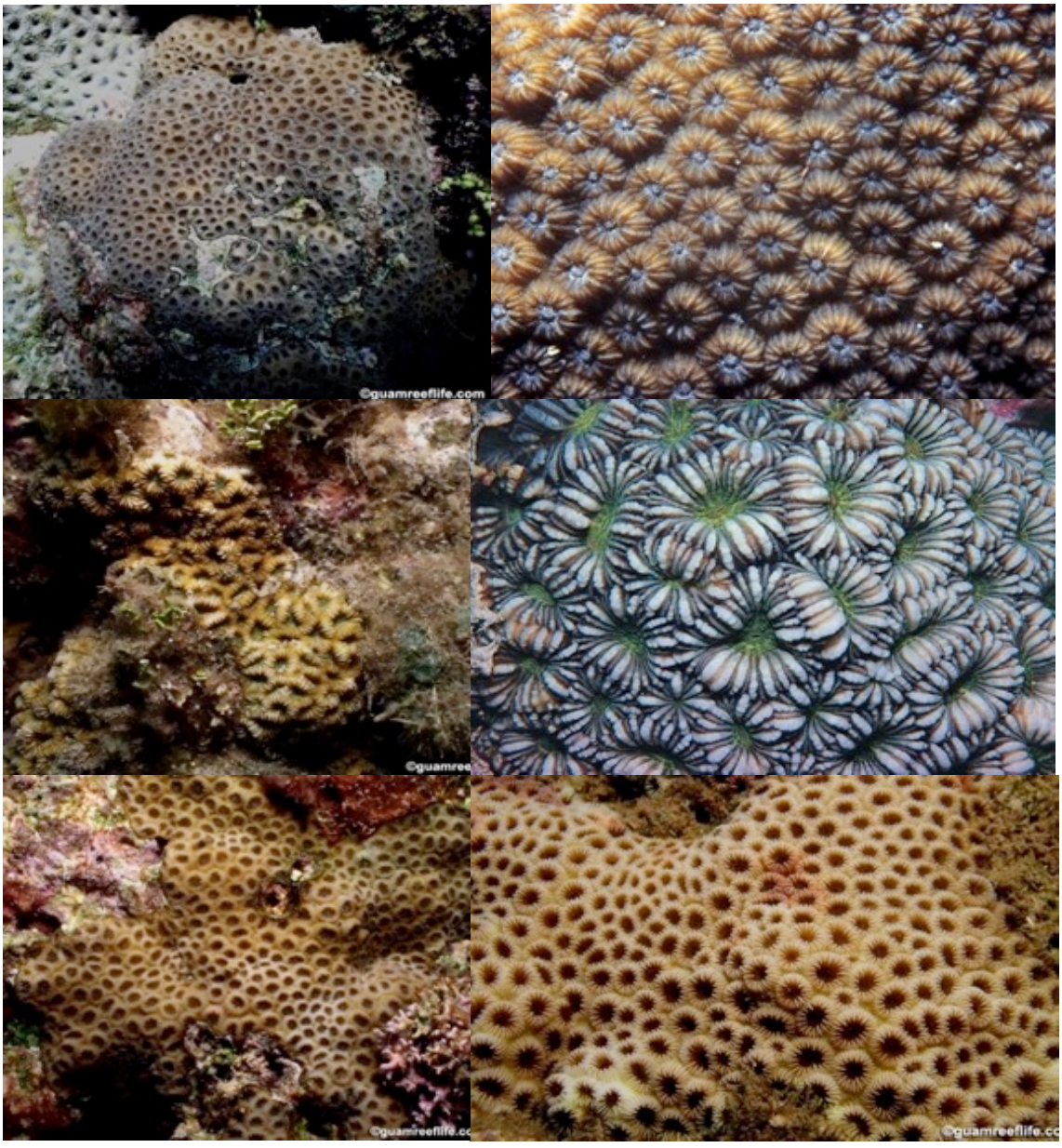
Tier 2 group mapping: Foliose coral (FOL)

guamreeflife.com; aims.gov.au

Montastraea* spp. (MONS*)

Colonies are found in most reef environments. Colonies generally have a massive morphology and may be flat or dome-shaped. Corallites can be round and flush or conical. Corallite spacing varies between widely spaced and closely compacted. Corallites have “doughnut-like” appearance and are cream to orange or brown in color. Color patterns are often concentric or oral discs. These corals are abundant. Documented species include *M. curta, M. valciennesi.*

Tier 2 group mapping: Massive coral (MASS)



guamreeflife.com

***Oulophyllia* spp. (OUSP)**

Colonies are found in most reef environments, especially lagoons and forereefs. Colonies generally have a massive morphology and are monocentric to meandroid. Colonies may be large, > 1-m diameter, and have broad valleys with widely spaced “ragged” septa and thin walls. They are similar in appearance to “Brain coral”. Valleys are V-shaped and have sharp upper margins. Tentacles extend only at night, and when retracted, the polyps have a coarse “reptilian” texture. These corals are common. One species has been documented, *O. crispa.*

Tier 2 group mapping: Massive coral (MASS)

guamreeflife.com; aims.gov.au

***Pachyseris* spp. (PACS)**

Colonies are unifacial or bifacial laminae, usually horizontal, but may develop upright ridges or columns. More than one row of corallites may occur between ridges. Columellae are absent. These corals are pale brown to deep grey in color andabundant over a wide range of habitats. Colonies are seldom over 2-m in diameter.

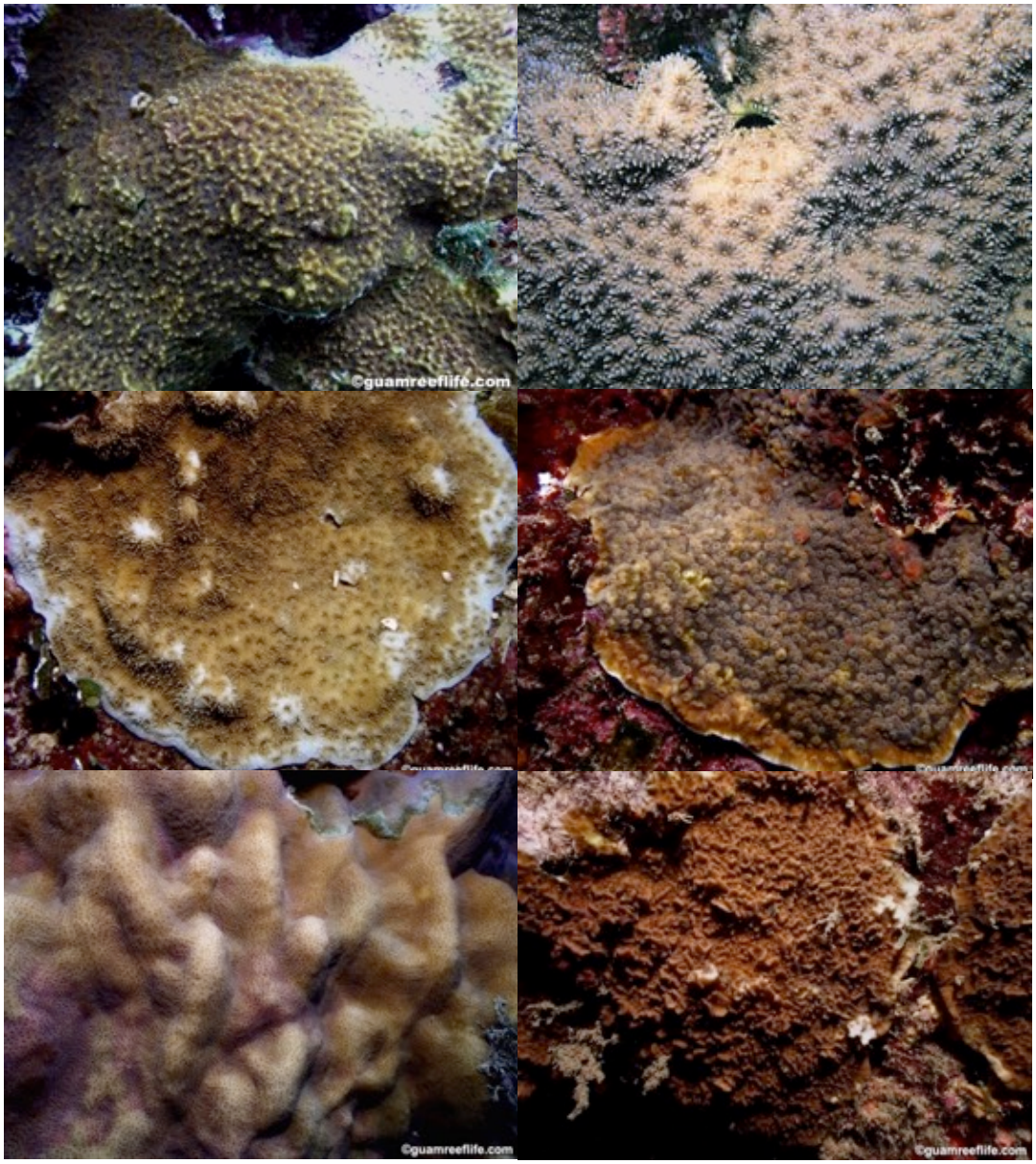
Tier 2 group mapping: Foliose coral (FOL)

guamreeflife.com; aims.gov.au

***Pavona* spp._encrusting (PAEN)**

Colonies are found in many reef environments including shallow, high current, and strong wave action areas. Colonies in this category exhibit an encrusting morphology. Corallites are deep and often have a “star-like” appearance. Primary septa are very exsert. These corals are abundant. Common species in this category are *P. chiriquiensis, P. diffluens, P. explanulata, P. maldivensis, P. minuta, P. varians.*

Tier 2 group mapping: Encrusting coral (ENC)



guamreeflife.com

***Pavona* spp._foliose (PAFO)**

Colonies are found in many reef environments including shallow, high current, and strong wave action areas. Colonies in this category exhibit a laminar or foliose morphology. Corallites are deep and often have a “star-like” appearance. Primary septa are very exsert. These corals are abundant. The most common species in this category are *P. cactus, P. decussata,* and *P. frondifera.*

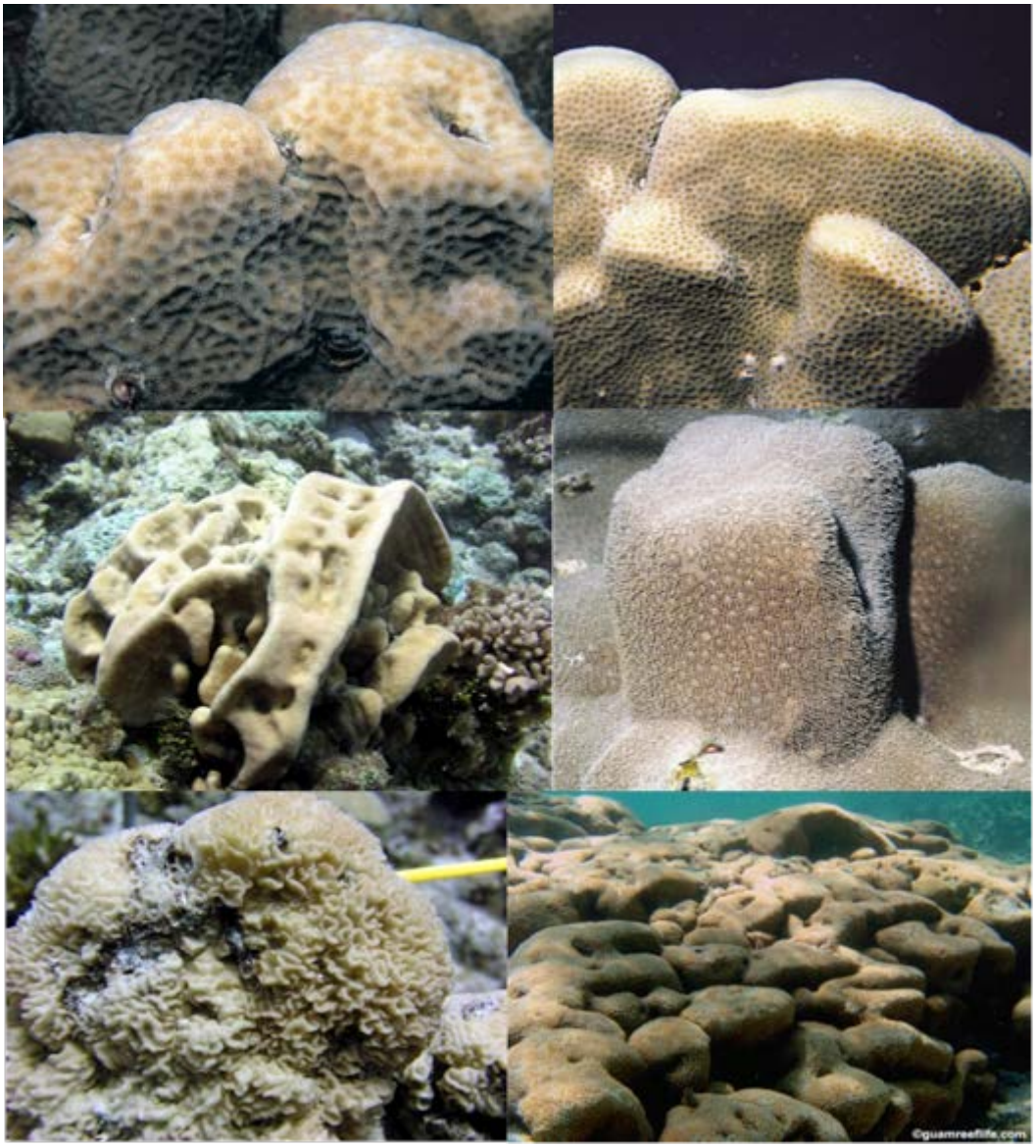
Tier 2 group mapping: Foliose coral (FOL)

guamreeflife.com

***Pavona* spp._massive (PAMA)**

Colonies are found in many reef environments including shallow, high current, and strong wave action areas. Colonies in this category exhibit massive and sub-massive morphologies. It is important to note that massive does not necessarily describe the *size* of the colony; it is a description of the *growth form.* PAMA is used for parts of colonies that possess a solid, thick shape that is neither encrusting nor foliose. Corallites are deep and often have a "star-like" appearance. Primary septa are very exsert. These corals are abundant. The most common species in this category are *P. clavus, P. duerdeni*, and *P. explanulata.*

Tier 2 group mapping: Massive coral (MASS)



guamreeflife.com; aims.gov.au

***Platygyra* spp. (PLSP)**

Colonies are found in most reef environments. They generally have a massive morphology and may be flat or dome-shaped. Corallites are usually meandroid; septa are uniformly exsert and evenly spaced. Colonies have contrasting valley floors and may be pale along the ridge tops. They are similar in appearance to “brain coral” and are abundant. The most common species is *P. pini*.

Tier 2 group mapping: Massive coral (MASS)

guamreeflife.com

***Plerogyra* spp. (PLER)**

These corals are found in shallow, protected reef environments, particularly in turbid water. Colonies are either branching, forming phaceloid colonies, or flabello-meandroid with valleys connected by a light blistery coenosteum. Living parts of colonies may be separated by dead basal parts. Vesicles are approximately the size of grapes and often the same shape, but may be tubular, bifurcated, or irregular, depending primarily on the state of inflation. These corals are uncommon. Species include *P. sinuosa, P. discus, P. simplex.*

Tier 2 group mapping: Branching coral (BR)

guamreeflife.com

***Pocillopora* spp. (POCS)**

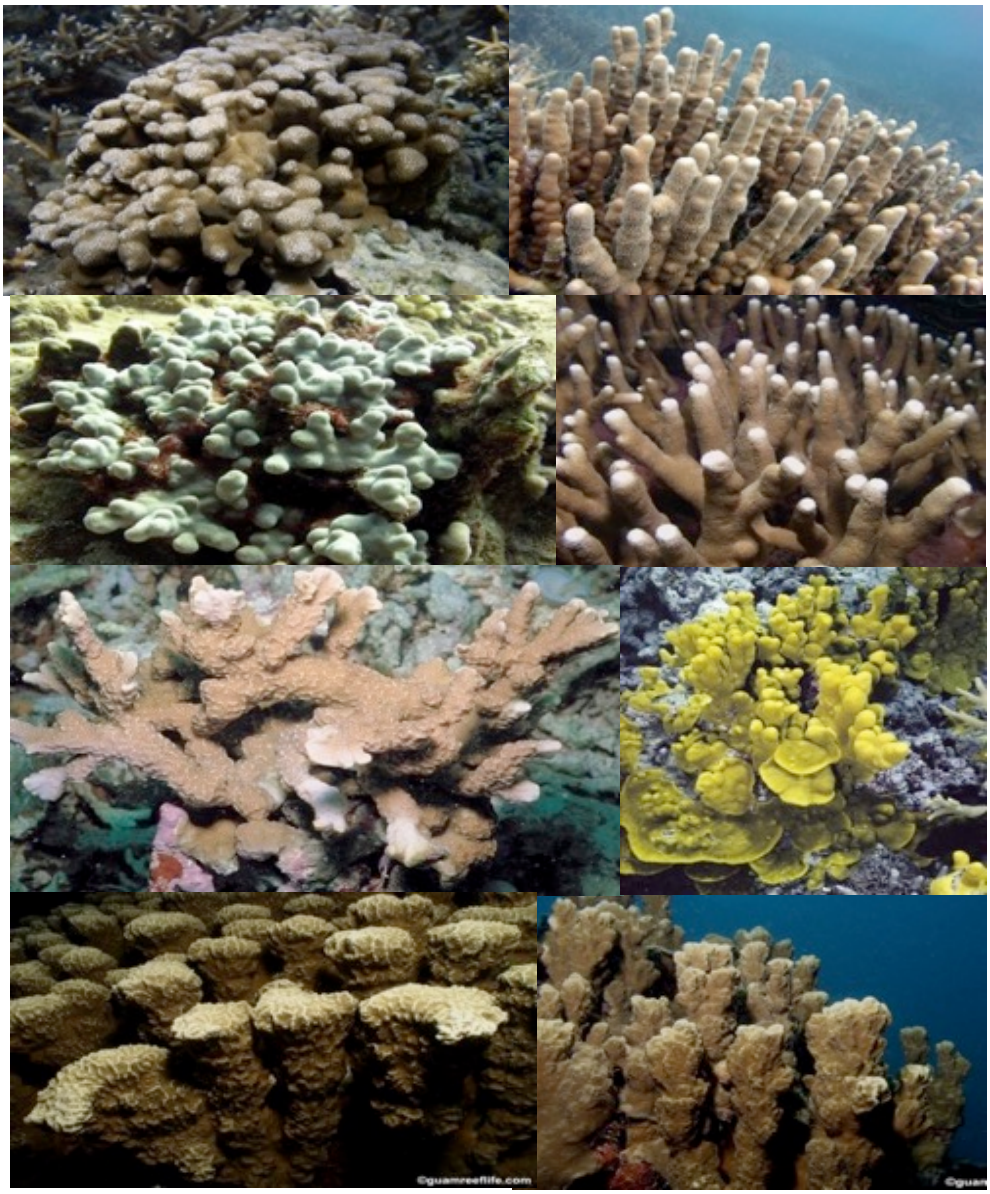
Colonies are found in many reef environments. Colonies have branching morphologies and are covered with verrucae with immersed corallites. Tentacles are most often extended at night. These corals are abundant. The most common species are *P. eydouxi*, *P. meandrina*, and *P. verrucosa.*

Tier 2 group mapping: Branching coral (BR)
guamreeflife.com; aims.gov.au

***Porites* spp._branching (POBR)**

Colonies can be found in many reef environments including along fringing reefs , reef slopes, back reef areas, and lagoons. Colonies in this category exhibit a branching morphology. Colonies can grow to be very large (>5 m diameter). Corallites are generally small and immersed. These corals are often yellow to gold to brown in color and are abundant. The most common species in this category are *P. annae, P. compressa, P. cylindrica, P. duerdeni, P. horizontalata, P. lichen, P. monticulosa, P. rus.*

Tier 2 group mapping: Branching coral (BR)

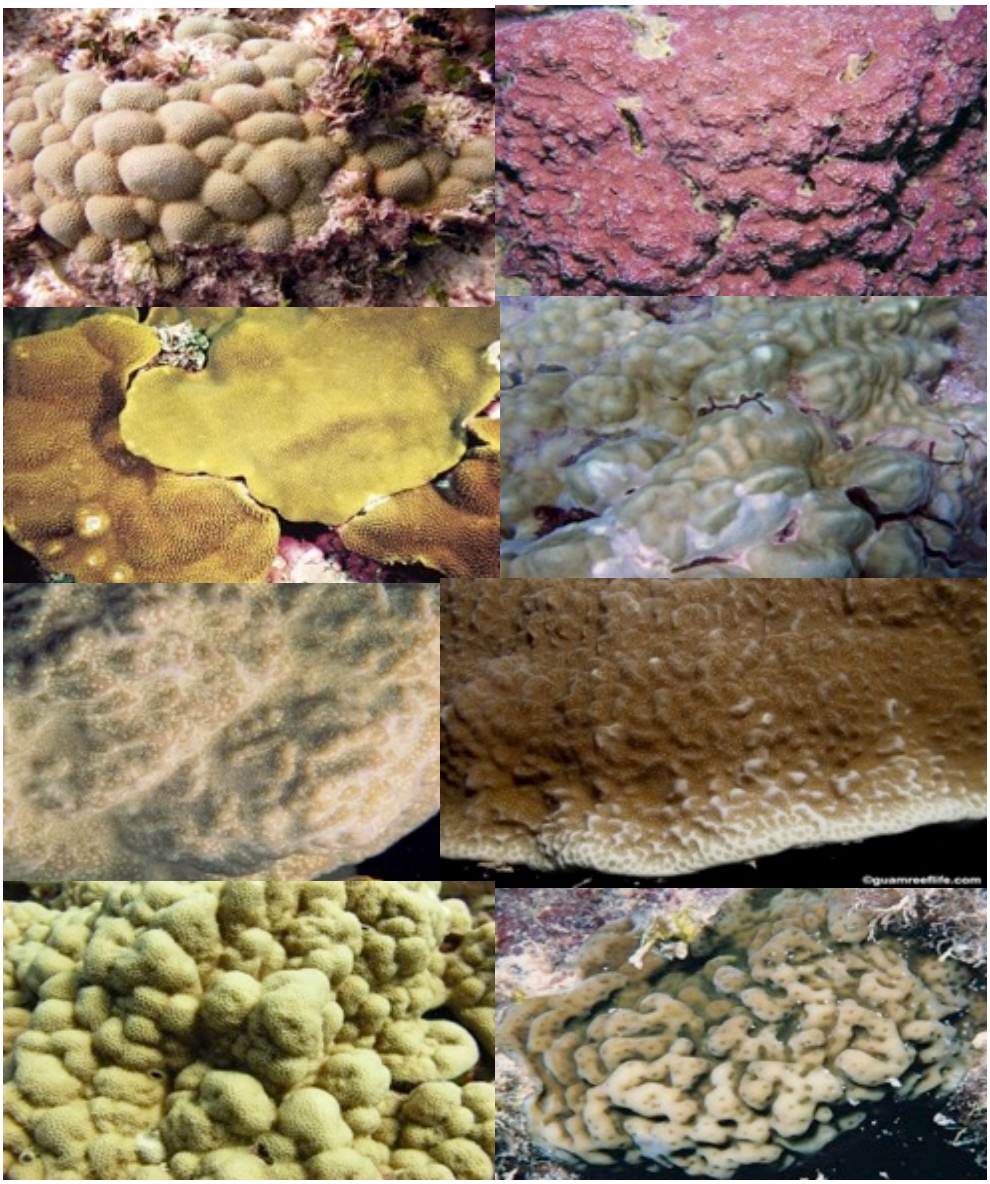


guamreeflife.com

***Porites* spp._encrusting (POEN)**

Colonies can be found in many reef environments including along fringing reefs, reef slopes, back reef areas and lagoons. Colonies in this category exhibit an encrusting morphology. Colonies can grow to be very large (>5 m diameter). Corallites are generally small and immersed. These corals are often yellow to gold to brown in color and are abundant. The most common species in this category are: *P. bernardi*, *P. brighami*, *P. horizontalata*, *P. lichen*, *P. lobata*, *P. lutea*, *P. monticulosa*, *P. murrayensis*, *P. rus*, *P. solida*, and *P. vaughani*.

Tier 2 group mapping: Encrusting coral (ENC)



guamreeflife.com

***Porites* spp._foliose (POFO)**

Colonies can be found in many reef environments including along fringing reefs, reef slopes, back reef areas and lagoons. Colonies in this category exhibit a laminar or foliose morphology. Colonies can grow to be very large (>5 m diameter). Corallites are generally small and immersed. These corals are often yellow to gold to brown in color and areabundant. The most common species in this category are: *P. arnoudi*, *P. horizontalata*, *P. monticulosa*, and *P. rus.*

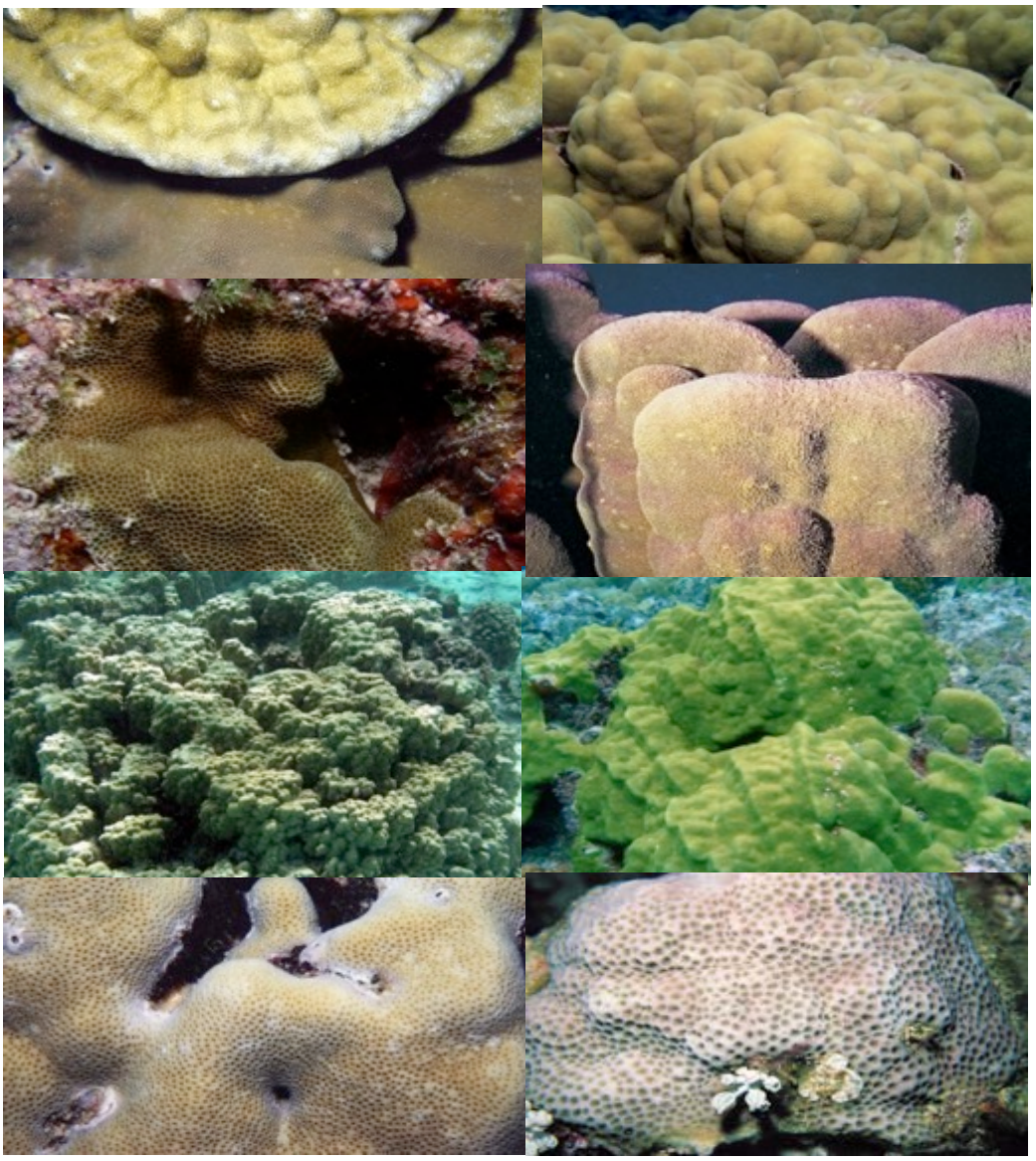
Tier 2 group mapping: Foliose coral (FOL)

guamreeflife.com; aims.gov.au

***Porites* spp._massive (POMA)**

Colonies can be found in many reef environments including along fringing reefs, reef slopes, back reef areas and lagoons. Colonies in this category exhibit massive and sub-massive morphologies. Colonies can grow to be very large (>5 m diameter). Corallites are generally small and immersed. Surface may be knobby. These corals are often yellow to gold to brown in color and are abundant. The most common species in this category are: *P. arnaudi, P. australiensis, P. densa, P. evermanni, P. lobata, P. lutea, P. murrayensis,* and *P. solida.*

Tier 2 group mapping: Massive coral (MASS)

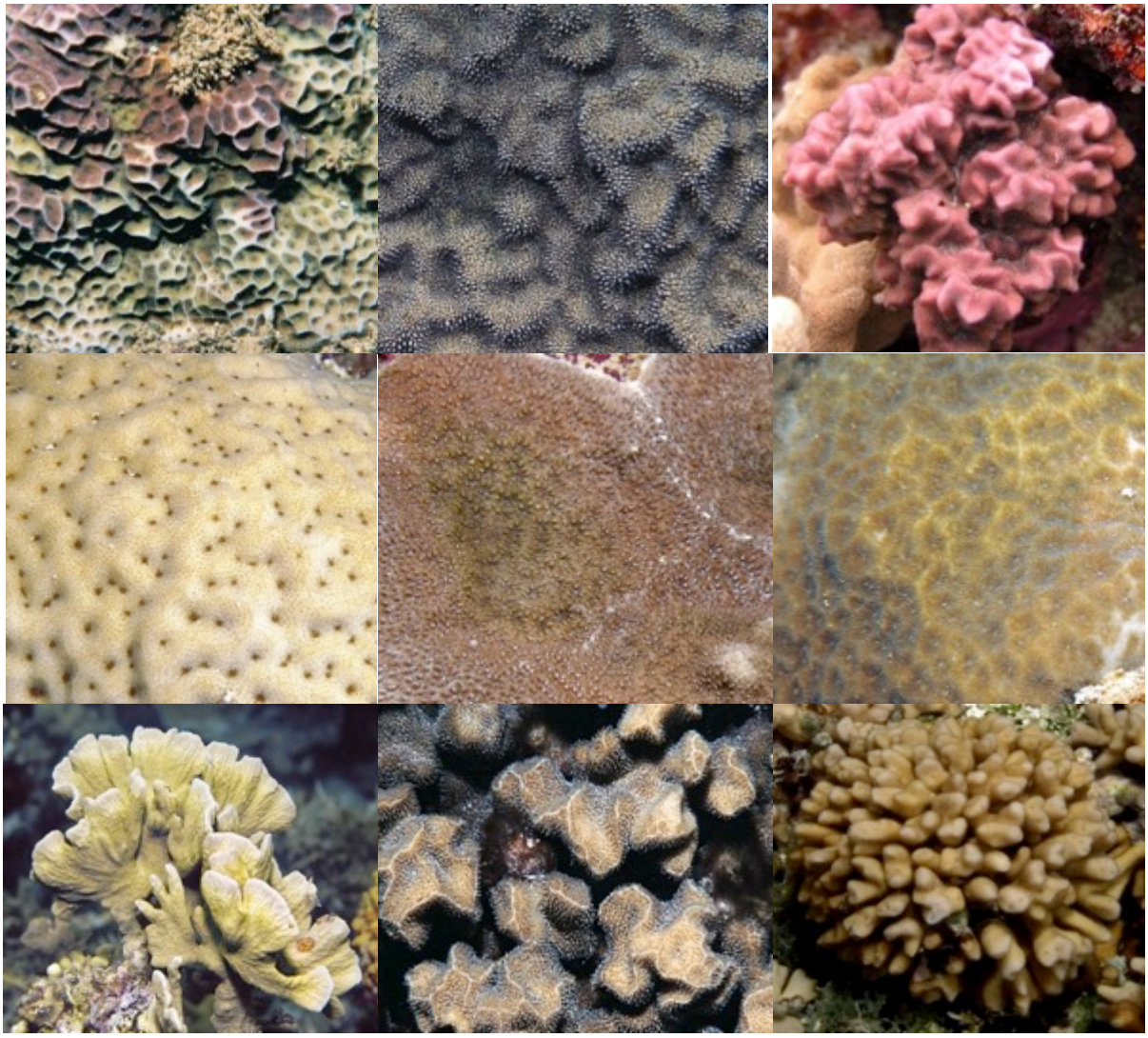


guamreeflife.com

***Psammocora* spp. (PSSP)**

Colonies are found in shallow reef environments particularly ones exposed to strong wave action. Colonies have massive, columnar, laminar, or encrusting morphologies. Corallites are often situated at the bottom of depressions/short valleys or can be distributed independently of valleys. Colony surface often has a “rough” or “pocked” appearance. These corals are often grey or brown in color but can also be brightly colored, and they are common. The most common species are *P. haimeana , P. nierstraszi,* and *P. stellata.*

Tier 2 group mapping: Encrusting coral (ENC)

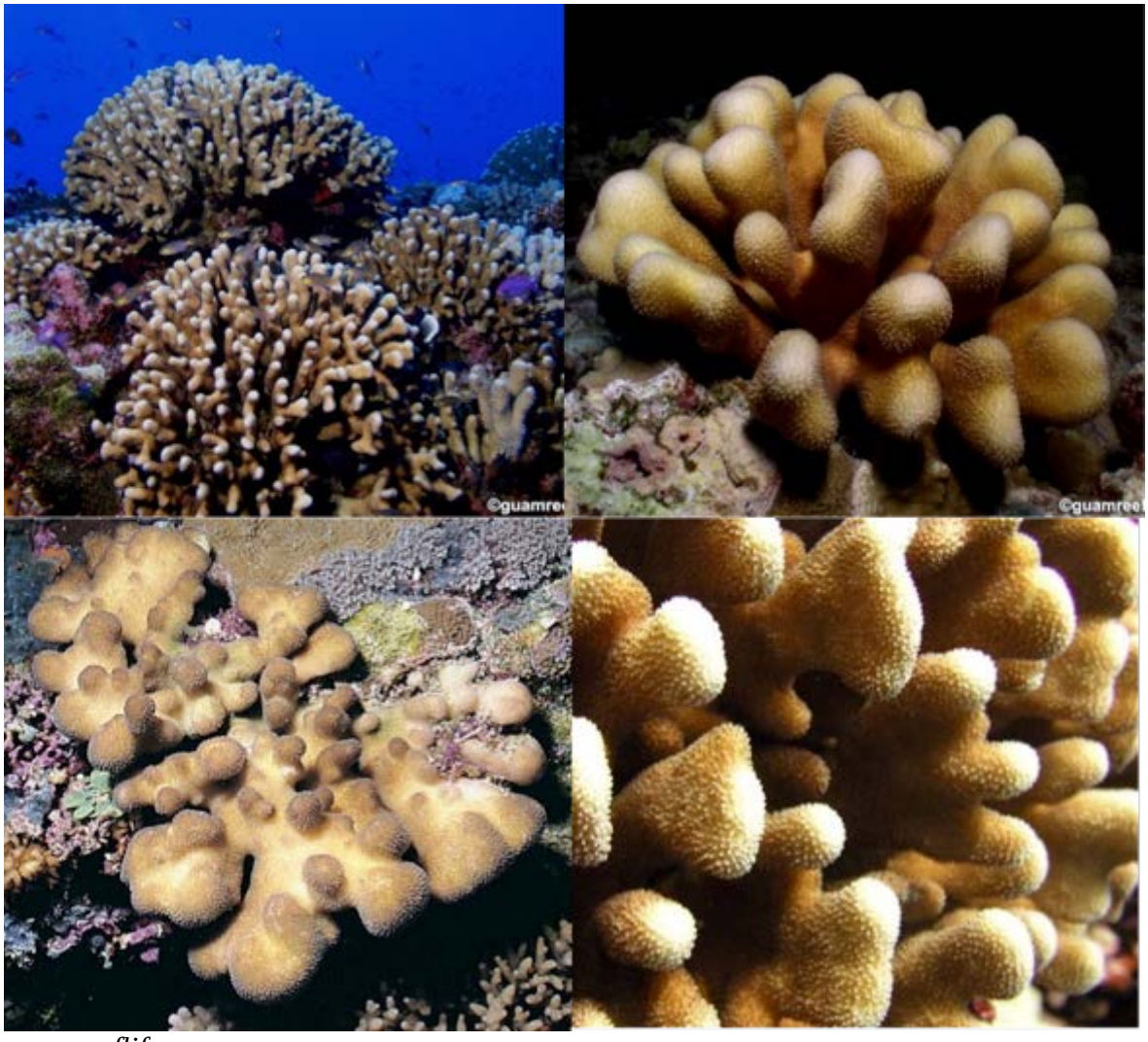


guamreeflife.com; aims.gov.au

***Stylophora* spp. (STYS)**

Colonies are most commonly found in shallow reef environments including areas exposed to strong wave action. Colonies have branching to sub-massive morphologies. Corallites can be immersed, hooded, or conical. Colonies are uniform in color and can be cream, pink, blue, or green. These corals resemble a “smooth *Pocillopora* sp.,” and they are abundant. The most common species is *S. pistillata.*

Tier 2 group mapping: Branching coral (BR)



guamreeflife.com

***Symphyllia* spp. (SYSP)**

Colonies are found on reef slopes and fringing reefs. They have meandroid morphology and are generally flat or dome shaped. Ridges and valleys are large and wide (>10mm). A groove usually runs along the top of the walls. Septa are large with long teeth. Ridges/walls and valleys are usually contrasting in color And resemble “brain coral.” Four species have been recorded: *S. agaricia, S. radians, S. recta, S. valenciennesii.*

Tier 2 group mapping: Massive coral (MASS)

guamreeflife.com

***Turbinaria* spp. (TURS)**

Often found in shallow fringing reef environments, rocky foreshores, and upper reef slopes, these colonies have laminar or encrusting morphologies. Laminar morphologies can be irregular, forming whorls and cups. Corallites are widely spaced and can be immersed to conical. These corals are common to abundant. Recorded species are: *T. mensenterina, T.peltata, T. stellulata.* and *T. reniformis*.

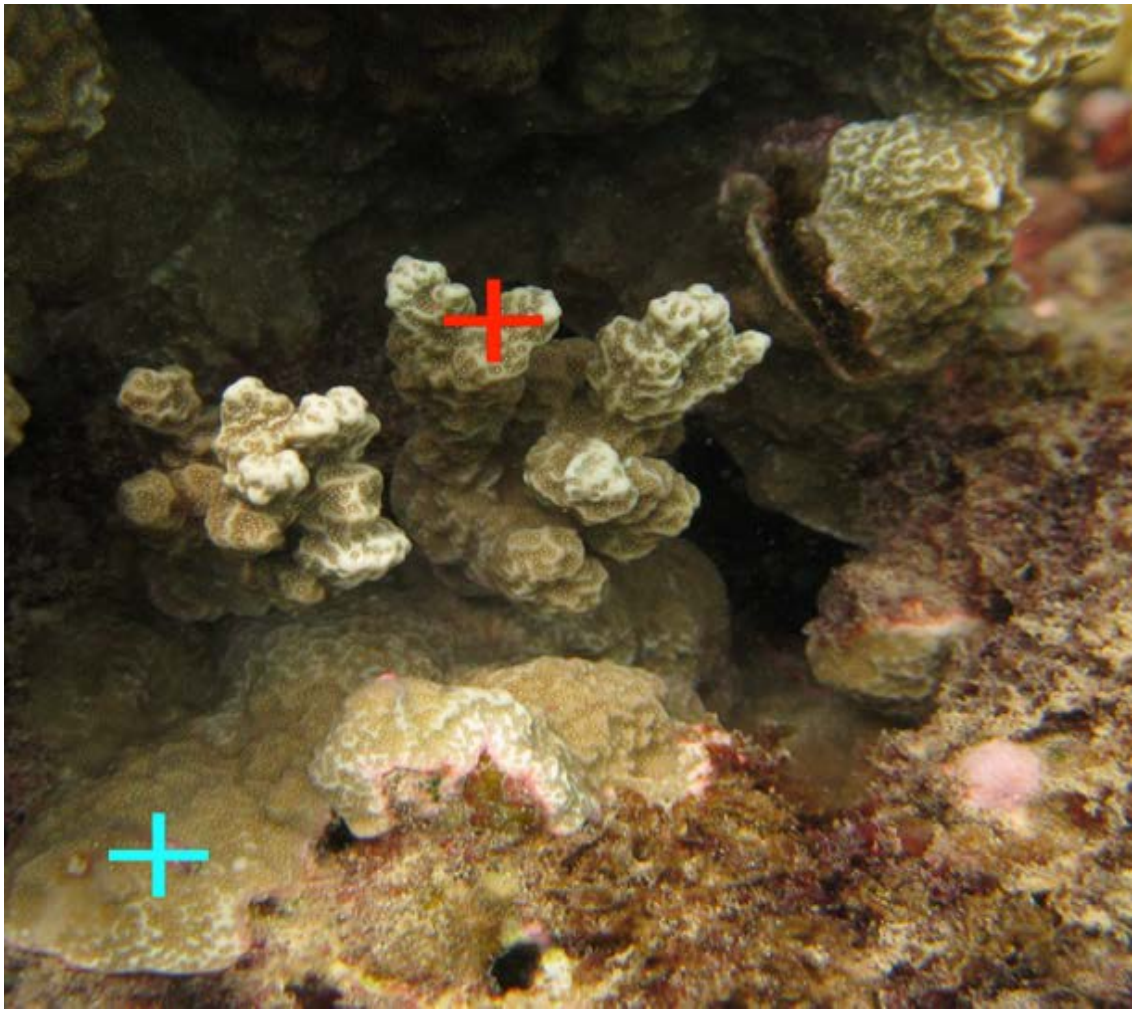
Tier 2 group mapping: Foliose coral (FOL)

guamreeflife.com; aims.gov.au

IV.A.1.B. CORAL FUNCTIONAL GROUPS

If a point falls on a coral colony that cannot be identified to its genus, it should be identified by the growth form underneath that point. Some colonies may have different growth forms in different areas. If this occurs, you should identify the growth form underneath each point that falls on the colony. Thus, identifications of points from an individual colony may differ. For example, in the image below, if the coral underneath the red marker cannot be identified to genus, it would be recorded as BR, while the blue marker would be recorded as ENC.

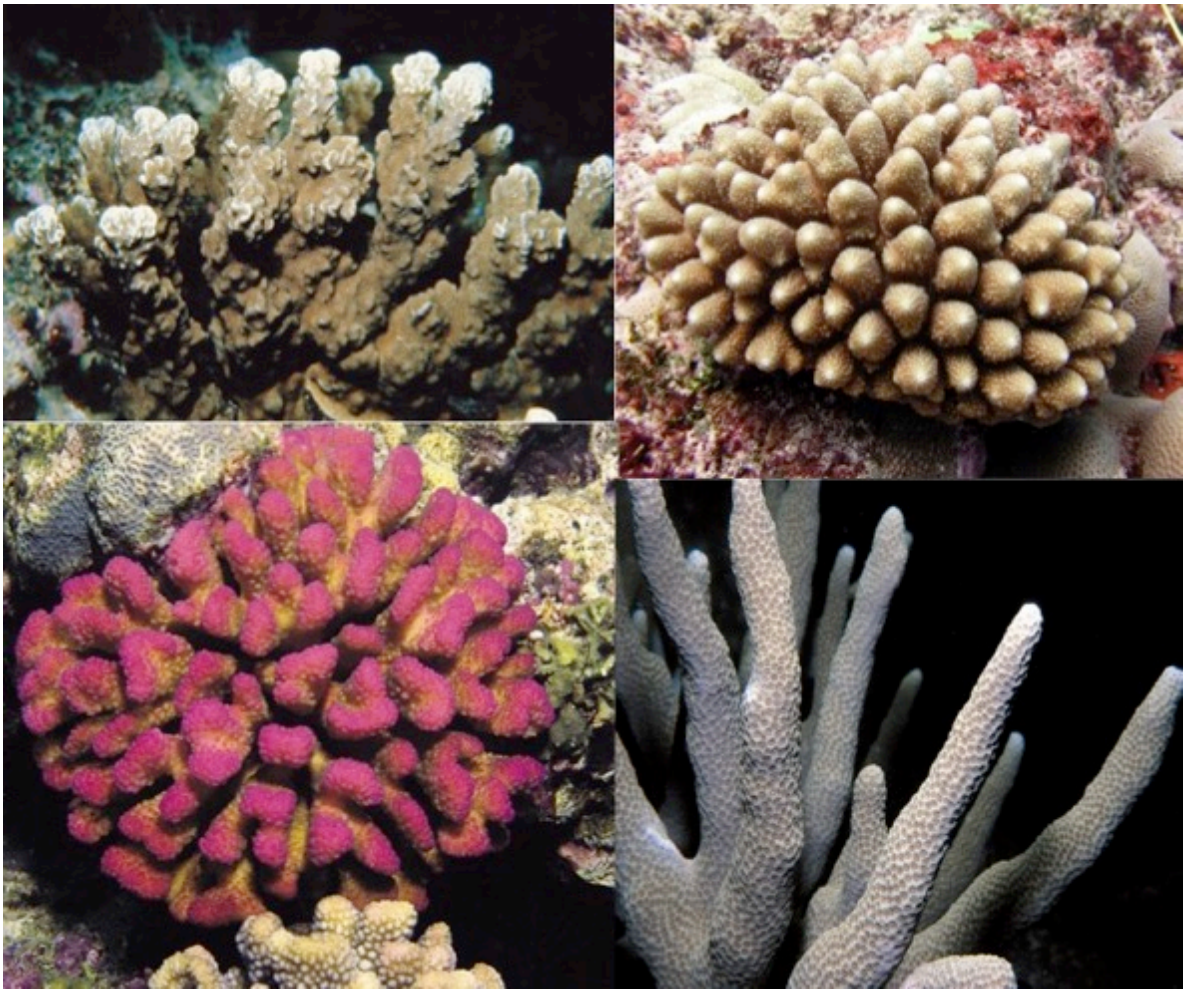
The codes given for categories in this section are used to identify them at the Tier 3b level, and are the same at the Tier 2 level.



NOAA photos

Branching hard coral (BR)

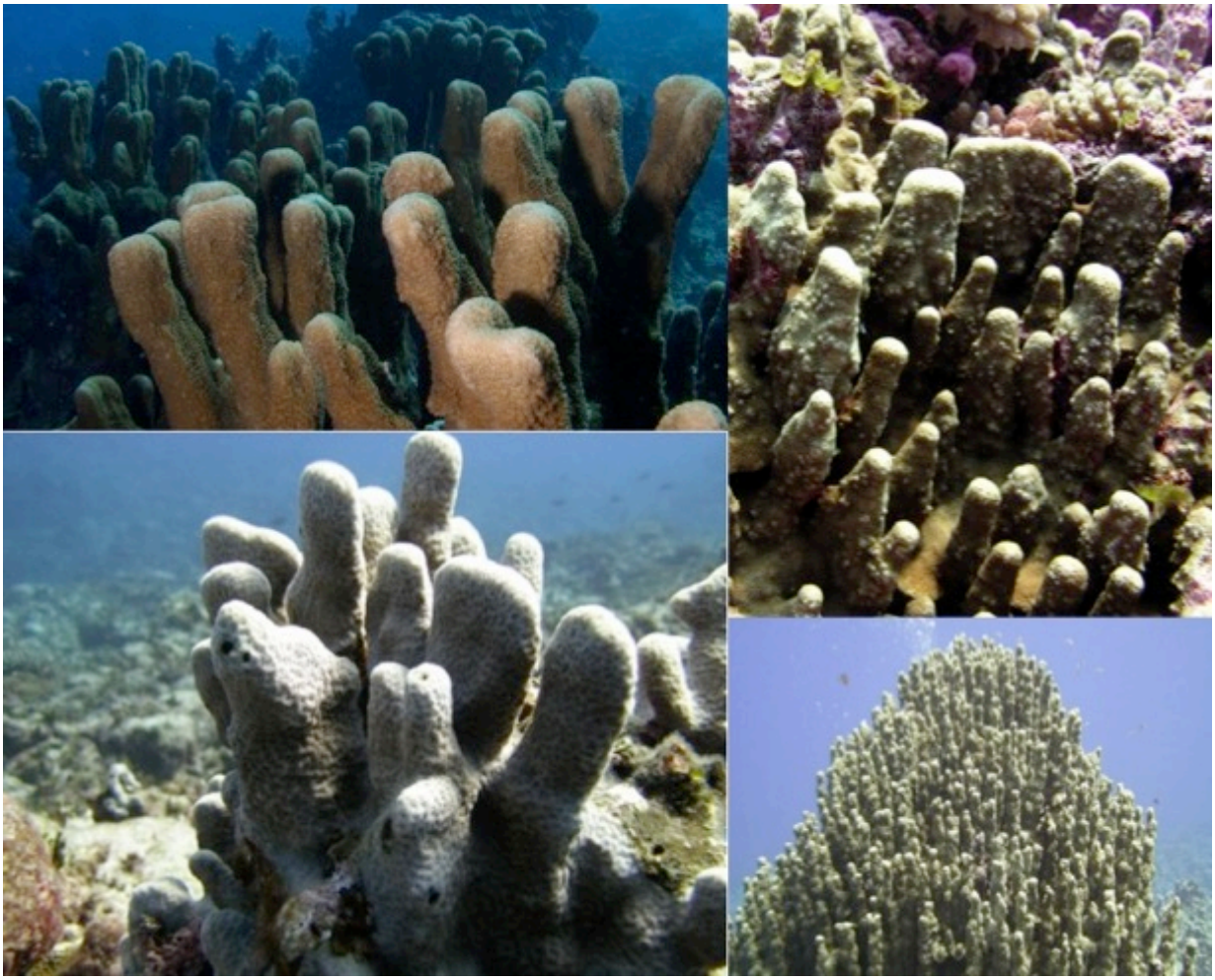
This group consists of corals that form large, arborescent (tree-like) colonies which exhibit elongated branched projections; corals with smaller, stubby and compact branches with finger-like (digitate) protrusions should also be classified as branching morphology.



guamreeflife.com; aims.gov.au

Columnar hard coral (COL)

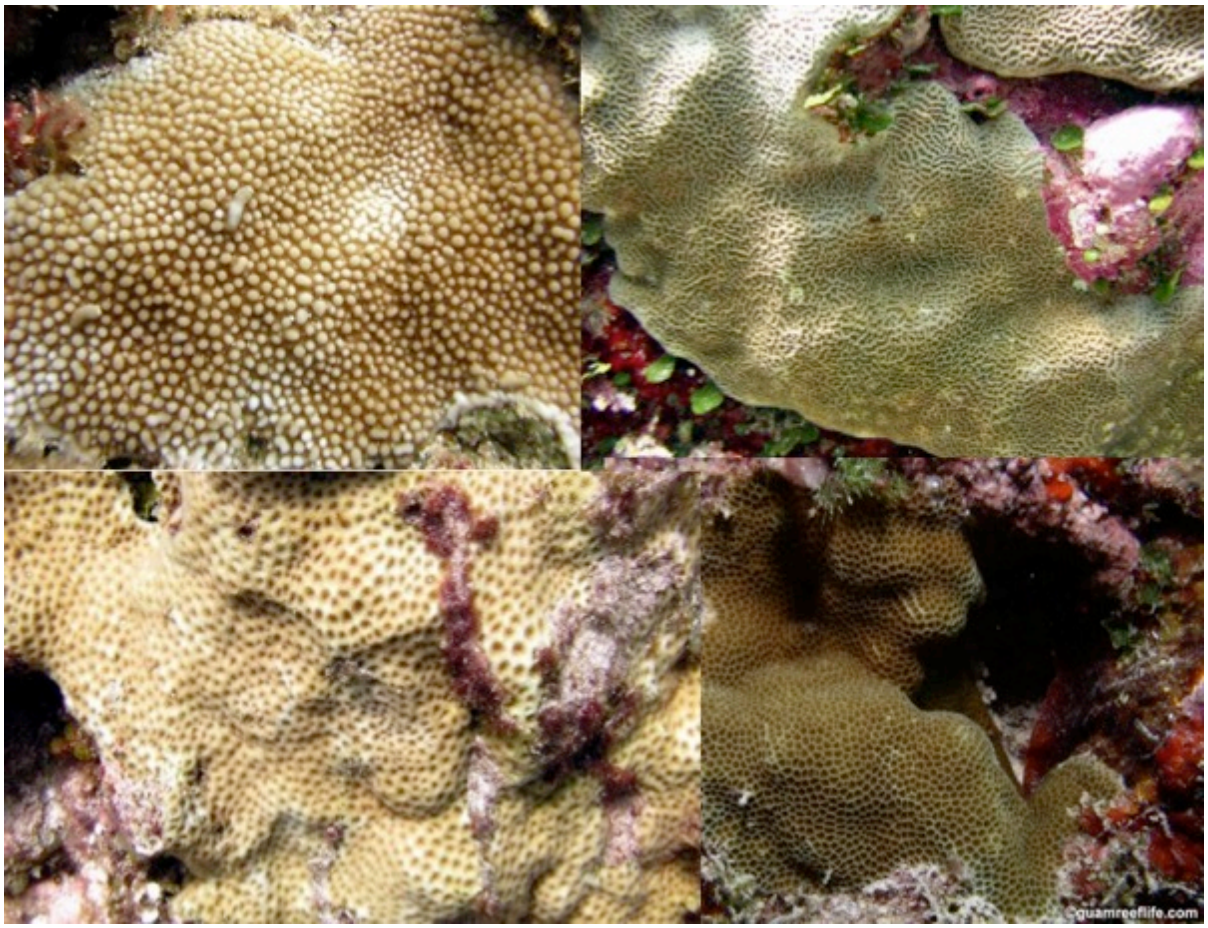
Some coral colonies, generally massive- and encrusting-looking, can exhibit club-like or column-like up-growths; these colonies should be classified as having a columnar morphology.



guamreeflife.com; aims.gov.au

Encrusting hard coral (ENC)

Coral colonies with encrusting morphology are those with flattened, thick or thin sheets/plates that adhere to and follow the contour of the substrate. Colony surfaces often range from smooth to rough, bumpy, knobby, or crinkled, with some specimens exhibiting raised colony edges, giving them a platy/foliose appearance.



guamreeflife.com

Foliose hard coral (FOL)

Coral colonies with foliose morphology include those that form flattened sheets or plates where a substantial portion of the colony is detached and elevated from the substrate. These corals often form shingle-like rows or tiers of overlapping plates, fused or convoluted whorls, vases, or leafy/lettuce-like stands. Note that growth forms used during classification of colonies in the field such as ‘plating’ and ‘laminar’, are not available in the classification scheme used for images. Therefore, plating and laminar colonies are included in the foliose category for BIA.

guamreeflife.com; aims.gov.au

Free-living hard coral (FREE)

Use the free-living morphology for coral colonies that live unattached from the substrate. This excludes broken-off colony branches or other products of fragmentation that are still alive. Free-living corals are conspicuous; most develop as flattened, dome-shaped disks, with a central mouth and apparent, radiating ridge-like structures. Includes the following genera: *Cycloseris, Diaseris, Halomitra, Herpolitha, Sandalolitha,* occasionally *Scolymia.*

guamreeflife.com

Massive hard coral (MASS)

Massive corals are those characterized by forming raised mounds or rounded heads with hemispherical to sub-hemispherical morphologies. It is important to note that massive does not necessarily describe the *size* of the colony, it is a description of the *growth form.* This growth form may also be referred to as ‘mounding.’ Large colonies are distinct and boulder-like; small ones have more of a dome or cushion-shape silhouette. It is not unusual for massive colonies to exhibit a bumpy or knobby surface, but for the most part all possess a solid, thick shape. *guamreeflife.com; aims.gov.au*

IV.A.2 SOFT CORAL

The codes given for categories in this section are used to identify soft corals at the Tier 3b level and are the same at the Tier 2 level.

Octocorals (OCTO)

Refers to gorgonian corals, sea fans, sea whips, sea pens, and other members of Subclass Alcyonaria (octocorals), except blue coral *Heliopora coerulea* (Order Helioporacea), which is classified as 'HCOE' and maps to the Coral group in Tier 1. All members of this classification category produce skeletal elements made of protein and calcium carbonate that give the colony sufficient soft support and the flexibility to sway with the ocean waves and currents. Common genera include *Cladiella, Lobophytum, Sarcothelia* and *Sinularia.*

guamreeflife.com; aims.gov.au; NOAA photos

Unclassified soft coral (USC)

These corals resemble gorgonians, forming tree-like colonies. They possess a hard axial protein skeleton and non-retractable polyps; this group includes black coral and wire coral (Order Antipatharia).

isprambiente.gov.it; NOAA photos

IV.A.3. INVERTEBRATE

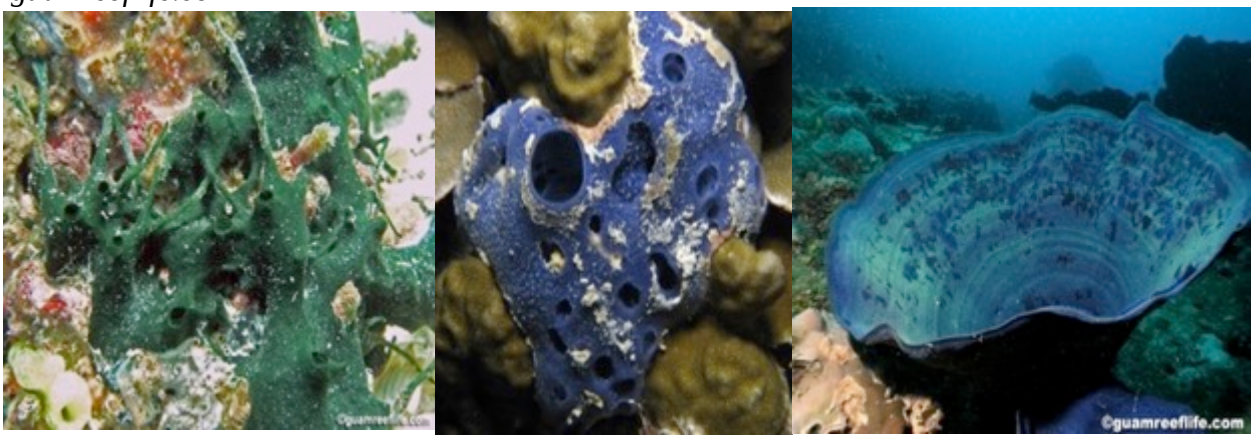
This Tier 1 group includes organisms from very different phyla, including Porifera (sponges), Cnidaria (anemones, corallimorphs, zoanthids), Mollusca (giant clams, other bivalves), Bryozoa/Ectoprocta (bryozoans), and Chordata (tunicates). The categories are arranged taxonomically according to these groups. However,
these relationships are not reflected in the system of Tiers used in BIA. The codes given for categories in this section are used to identify them at the Tier 3b level, and are the same at the Tier 2 level.

IV.A.3.A. PORIFERA

Sponge (SP)

Sponges (Phylum Porifera) have numerous species and growth morphologies, many of which can be confused with other benthic organisms. Sponges have porous tissue for filter feeding and many have large openings through which expelled water flows (excurrent openings). To help identify sponges, zoom-in on the photograph and examine the surrounding tissue. In general, sponges are more colorful than tunicates are "rougher" around the edges due to a lack of a "tunic" and being composed of spicules. Most sponges, unlike tunicates, are not able to close their excurrent openings. Sponges can also protrude/extend upwards off the benthos from their encrusting state, whereas tunicates tend to grow along the contours of the substrate underneath them.

guamreeflife.com



IV.A.3.B. CNIDARIA

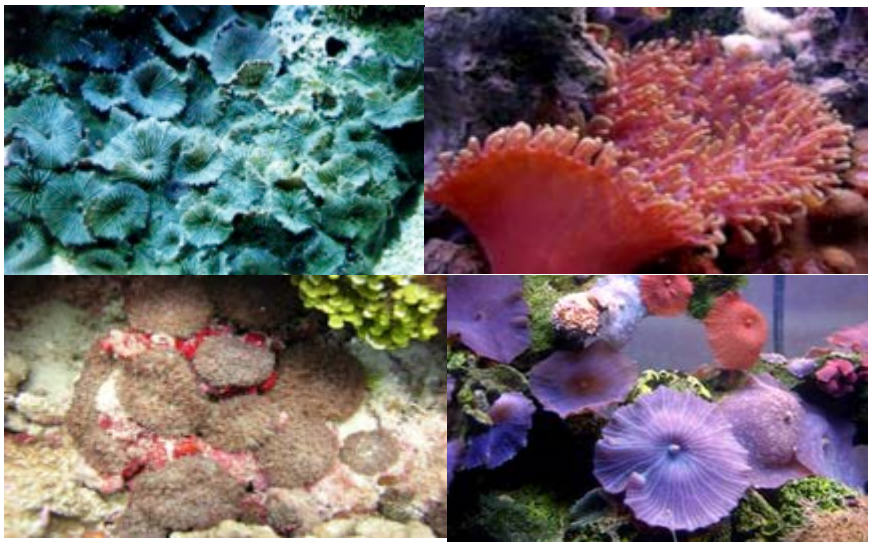
Anemone (AMNE)

Anemones include members of Order Actinaria (anemones) and Order Ceriantharia (tube-dwelling anemones).

A.Petrusek; reefcorner.com; uniprot.org

Corallimorph (CMOR)

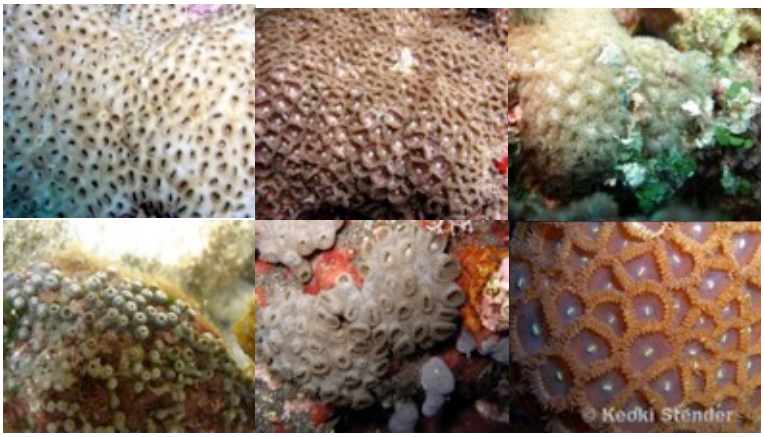
Corallimorphs (Order Corallimorpharia) are anemone-like animals that are found either solitary or in colonies. Their tentacles are generally much shorter than those of true anemones. They can be invasive and at this stage resemble a fuzzy carpet.



midlandsmarinelighting.com; akwarium.gdynia.pl; garf.org

Zoanthids (ZO)

Zoanthids (Order Zoanthidea) are colonial anemone-like animals having smooth, flat, broad oral disks with tentacles that radiate outward from their margins. Tentacles are found in two nearby rows and are always found in a multiple of six. The polyp's mouth has a ciliated groove at one or both ends. Zoanthids are connected by runners (called stolons) and they lack the hard skeletons of scleractinian corals. The following genera are included in this group: *Palythoa*, *Protopalythoa*, *Zoanthus*.

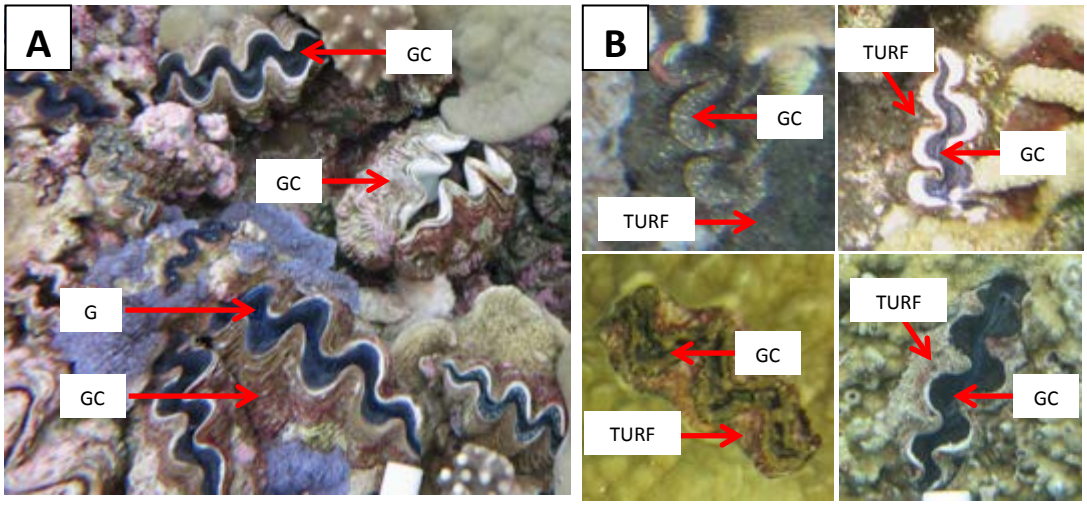


guamreeflife.com; marinelifephotography.com; NOAA photos

IV.A.3.C. MOLLUSCA

Giant clam (GC)

Giant clams may have shells that are drab in color and/or colonized by algae or other sessile organisms, but the mantle can be colorful and can grow from 0.25 m to more than 1 m in diameter. Giant clams with completely exposed shells (Figure A) should be classified as "GC", regardless of whether the point falls on the mantle or the algae-covered shell. If the giant clams are buried, classify only as "GC" if the point falls on the mantle (Figure B). For all other bivalves (clams, oysters, and mussels) in Class Bivalvia, use the Bivalve category (BI).



NOAA photos

Bivalve (BI)

Clams, oysters, and mussels are common examples of bivalves (Class Bivalvia). Giant clams (Family Tridacnidae) are a special case and have their own classification category (GC). For all other bivalves, use this category.

NOAA photos; guamreeflife.com

IV.A.3.D. BRYOZOA/ECOPROCTA

Bryozoan (BRY)

These colonial animals are early colonizers of bare surfaces on coral reefs. Most attach to solid surfaces but some live in sand. Each "member" lives in a zooid, or house, and has lophophores which are "tentacles" that extend out of the house to filter feed. The lophophores are ciliated and very "regular" in appearance. However, unless the image is clear, it will be hard to detect the lophophores and use them to distinguish between a tunicate or sponge. Individual zooids attach to other neighboring zooids forming bushy, branching, fanlike, or encrusting colonies that may be rigid or flexible. Most bryozoans have a lace-like appearance and can be confused with algae or sponges. However, unlike sponges and tunicates, you will not see incurrent and excurrent openings. This is because the lophophores in bryozoans are used for feeding. In general, bryozoans will not appear smooth like a tunicate. and their upright structure will appear to be "flower" and "plant"- like.

guamreeflife.com

IV.A.3.E. CHORDATA

Tunicate (TUN)

Tunicates (Class Ascidiacea) are made up of numerous species and growth morphologies, many of which can be confused with other benthic organisms. They can grow as solitary individuals or in colonies. Their soft body is surrounded by a thick test, or tunic, often transparent or translucent and varying in consistency from gelatinous to leathery. In general, if the organism has multiple holes (which are the individual incurrent siphons of the zooid) with a few larger holes (the shared excurrent siphons) spread out, it is probably a tunicate. Tunicates can close their siphons rather quickly, whereas sponges are for the most part unable to close their siphons

at all. Thus, if some of the openings of the sessile organism appear to be closed in the photograph, it is likely a tunicate. One final generalization is that tunicates tend to grow with the contours of the substrate, whereas sponges can grow upwards from the encrusting state.

guamreeflife.com; NOAA photos

IV.A.3.F. Other or Unidentifiable Sessile Invertebrates

Unclassified sessile invertebrate (UI)

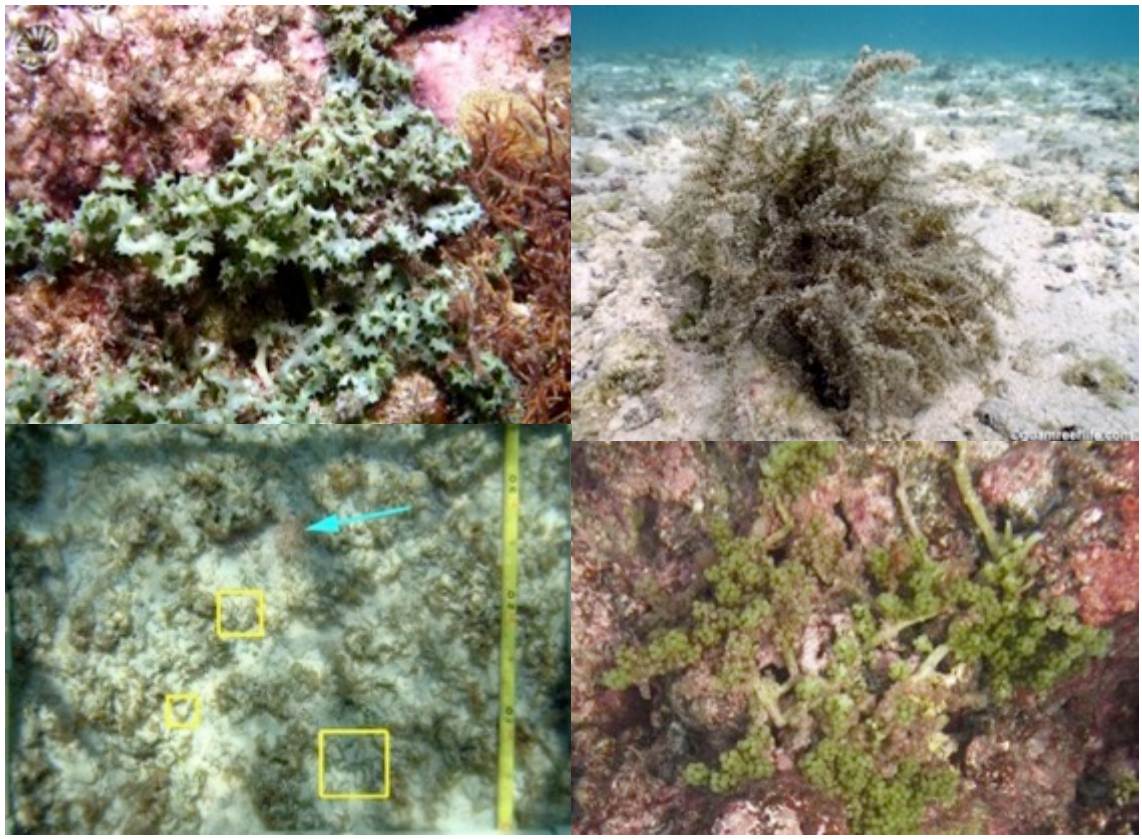
This category refers to sessile invertebrates that do not fall within one of the other categories, or should be used in situations when a sessile invertebrate cannot be distinguished, for example, differentiating between an encrusting sponge or tunicate.
NOAA photos

IV.A.4. Macroalgae

Upright macroalgae (UPMA)

As is the case with corals, it is preferable to identify algae to genus if possible. Broader categories (e.g. green, brown, red, encrusting macroalgae) are also available if the genus cannot be determined with confidence or if the correct genus is not included in the Labelset. If it is not possible to identify algae to one of these groups, it should be assigned to upright macroalgae. All of the Tier 3b categories under section IV.A.4 collapse to UPMA at the Tier 2 level, which is equivalent to Macroalgae at the Tier 1 level. The algae categories are presented here as "Fleshy" (e.g. green, brown, red) and "Other" forms because that is how they will likely be considered when identifying substrate during analysis.

Note that although Crustose Coralline Algae (CCA) is taxonomically red algae, the associated categories are classified differently because of their unique ecological role. CCA remains separate from UPMA and Macroalgae at higher tiers.



guamreeflife.com; NOAA photos

IV.A.4.A. FLESHY MACROALGAE

IV.A.4.A.I. DIVISION CHLOROPHYTA

Green macroalgae (GRMA)

This category is used for green upright macroalgae (Chlorophytes) that cannot be identified to genus. The typical color of plants in this category, resulting from the dominant chlorophyll pigments, is some shade of apple or grass green, although certain species may appear yellow-green or blackish-green due to the presence of carotenoid pigments or high concentrations of chlorophyll.

Tier 2 group mapping: Upright macroalgae (UPMA)

guamreeflife.com

***Avrainvillea* spp. (AVSP)**

This category contains spongy, blade-like green macroalgae, which are generally fan-shaped and rare. Recorded species are: *A. lacerate*, *A. amadelpha*, which is invasive in Hawai‘i and forms dense aggregations that trap sediment.

Tier 2 group mapping: Upright macroalgae (UPMA)

guamreeflife.com

***Caulerpa* spp. (CAUL)**

These macroalgae are typically bright green and havehorizontal creeping stolon with upright fronds of various forms. They are uncommon. Recorded species are: *C. arenicola, C. filicoides, C. microphysa, C. nummularia, C. racemosa, C. reyesii, C. serrulata, C. sertularoides, C. urvilleana, C. verticillata, C. webbiana. C. filicoides* forms dense mats in some areas (e.g. Lana‘i, Hawai‘i) that can overgrow and smother coral.

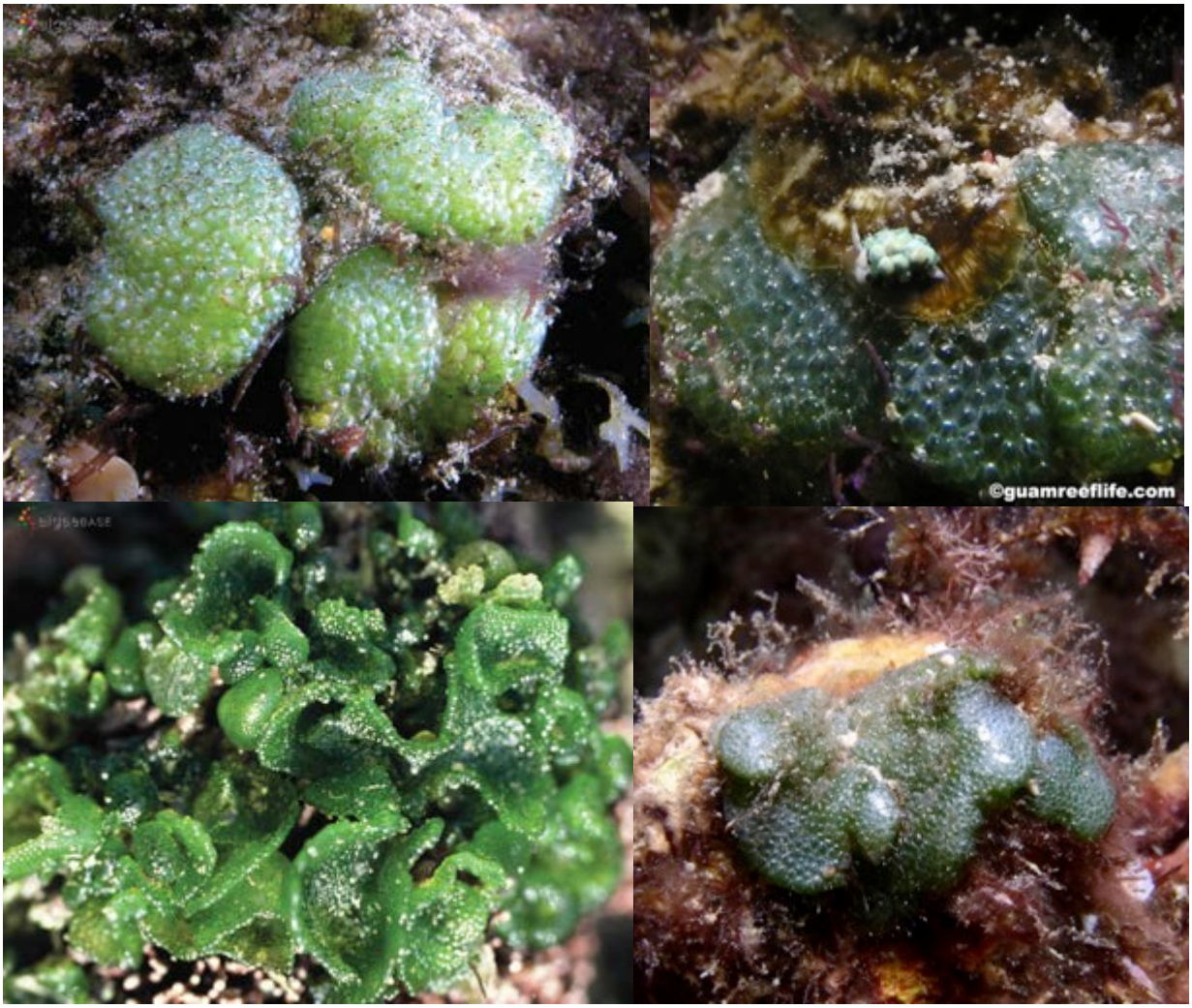
Tier 2 group mapping: Upright macroalgae (UPMA)

guamreeflife.com

***Dictyosphaeria* spp. (DICT)**

These macroalgae have a firm and tough texture consisting of visible large bubble-shaped cells. They grow close to the substrate. Forms vary from cup-like and hollow to closed and solid and are usually green to grey in color. They are common. Recorded species are: *D. cavernosa* and *D. versluysii*.

Tier 2 group mapping: Upright macroalgae (UPMA)



guamreeflife.com

***Halimeda* spp. (HAL)**

These are green alga with segmented, calcified branches. Plants can be erect or sprawling and are commonly found. Recorded species are: *H. distorta*, *H. gracilis*, *H. minima*, *H. opuntia*, and *H. tuna*.

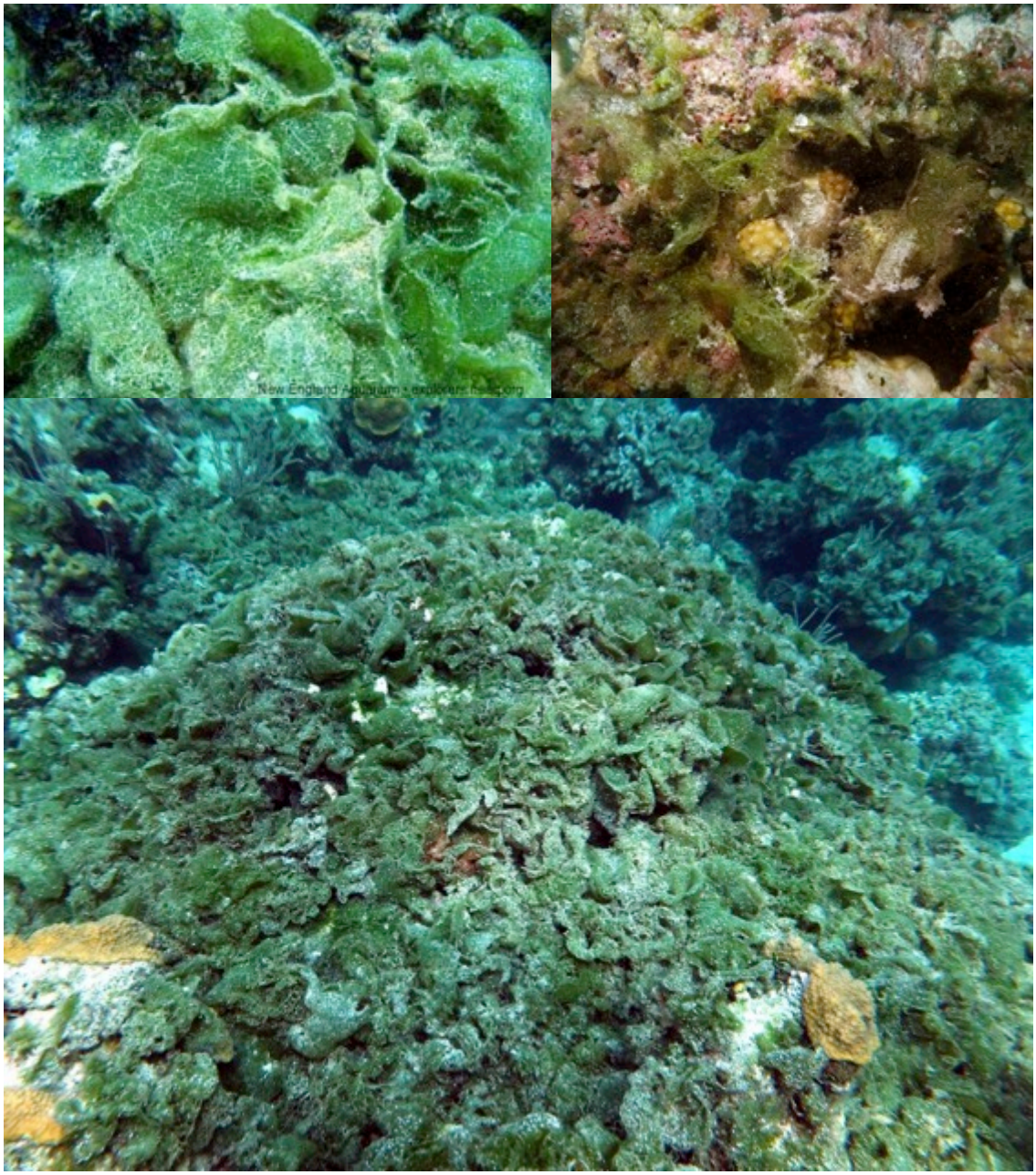
Tier 2 group mapping: Halimeda (HALI)

guamreeflife.com

***Microdictyon* spp. (MICR)**

These are green alga with flattened fronds. Primary filaments have several lateral branches that attach to other nearby filaments forming a net-like structure. They are relatively common in some areas like Swains Island. Common species: *M. setchellianum* and *M. umbilicatum.*

Tier 2 group mapping: Upright macroalgae (UPMA)



zonkil.gmu.edu; explorers.neaq.org

***Neomeris* spp. (NEOM)**

These green alga appear “wormlike”, erect, usually growing in groups; white because of heavy calcification. They are netlike, forming template through which branches protrude. Individual plants may be bright green at apices when young, with conspicuous hairs protruding in annular rows. Common species are: *N. annulata, N. vanbosseae.*

Tier 2 group mapping: Upright macroalgae (UPMA)

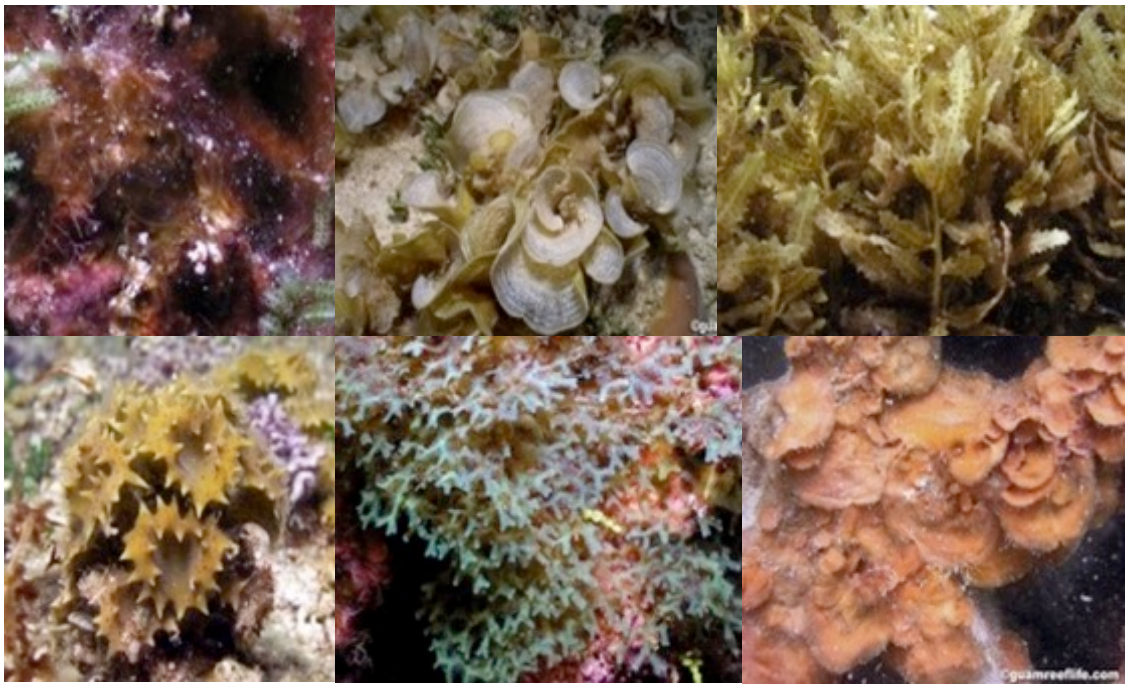
guamreeflife.com

IV.A.4.A.II. DIVISION OCHROPHYTA

Brown macroalgae (BRMA)

This category is used for brown upright macroalgae (Class Phaeophytes) that cannot be identified to genus. The colors of brown algae (predominantly due to the brown accessory pigment fucoxanthin) cover a spectrum from pale beige to yellow-brown to almost black. In tropical seas, they range in size from microscopic filaments to several meters in length.

Tier 2 group mapping: Upright macroalgae (UPMA)

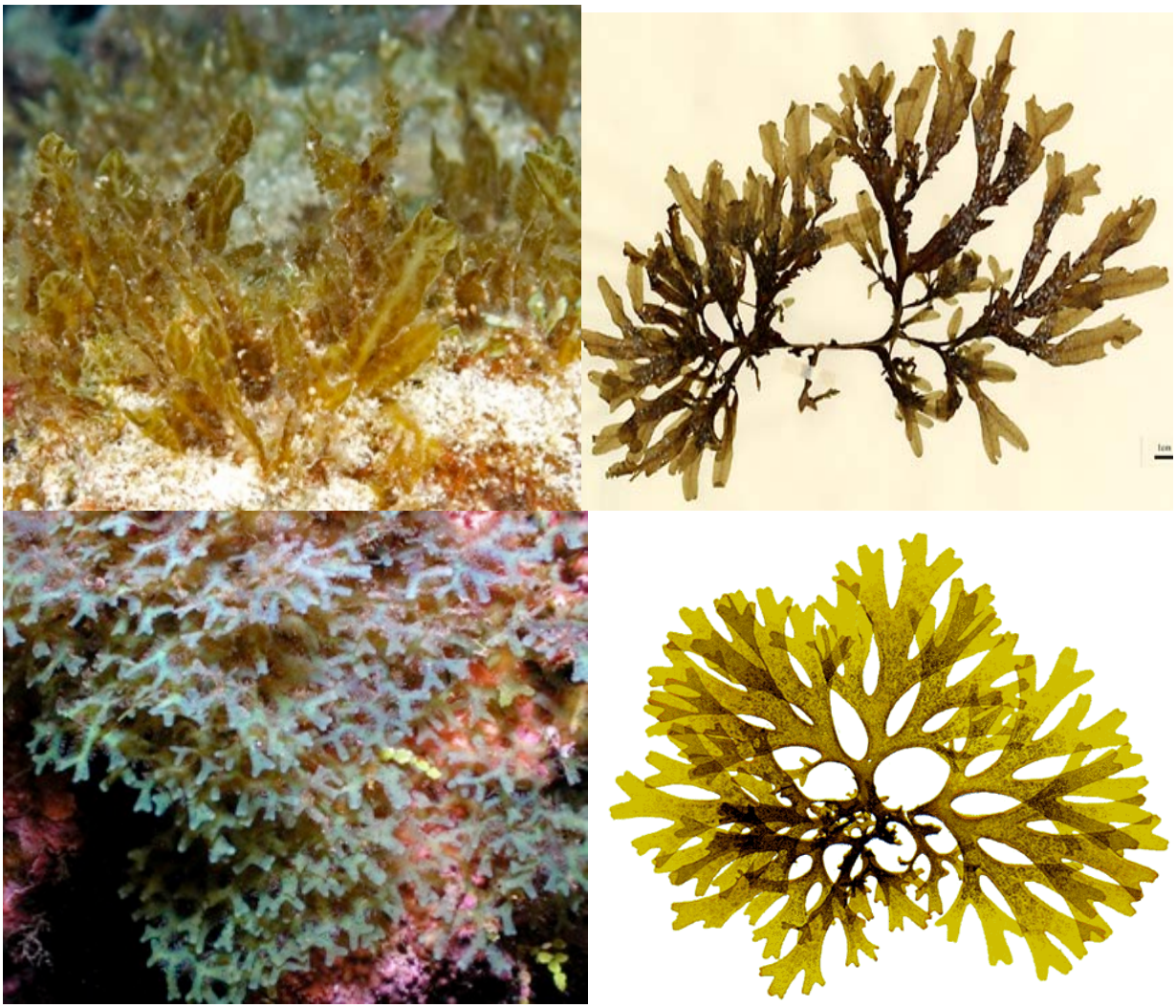


guamreeflife.com

***Dictyopteris and Dictyota* spp. (DICO)**

Dictyota and *Dictyopteris* species are brown macroalgae that have flattened, divided thalli. In *Dictyota*, branch tips form a Y-shape and do not have a midrib. *Dictyopteris* have a prominent midrib and thin lateral wings, and the branches are generally uniform. It is often difficult to confidently distinguish *Dictyopteris* from *Dictyota* in images from photoquadrats. Thus, both genera are assigned to the same category.

Tier 2 group mapping: Upright macroalgae (UPMA)



guamreeflife.com; biol.tsukuba.ac.jp; waikikiaquarium.org

***Padina* spp. (PADI)**

This is brown alga with a fan-shaped thallus with leading edge that is typically inrolled. It often appears striped in coloration and is uncommon. The most common species: *P. jonesii*

Tier 2 group mapping: Upright macroalgae (UPMA)

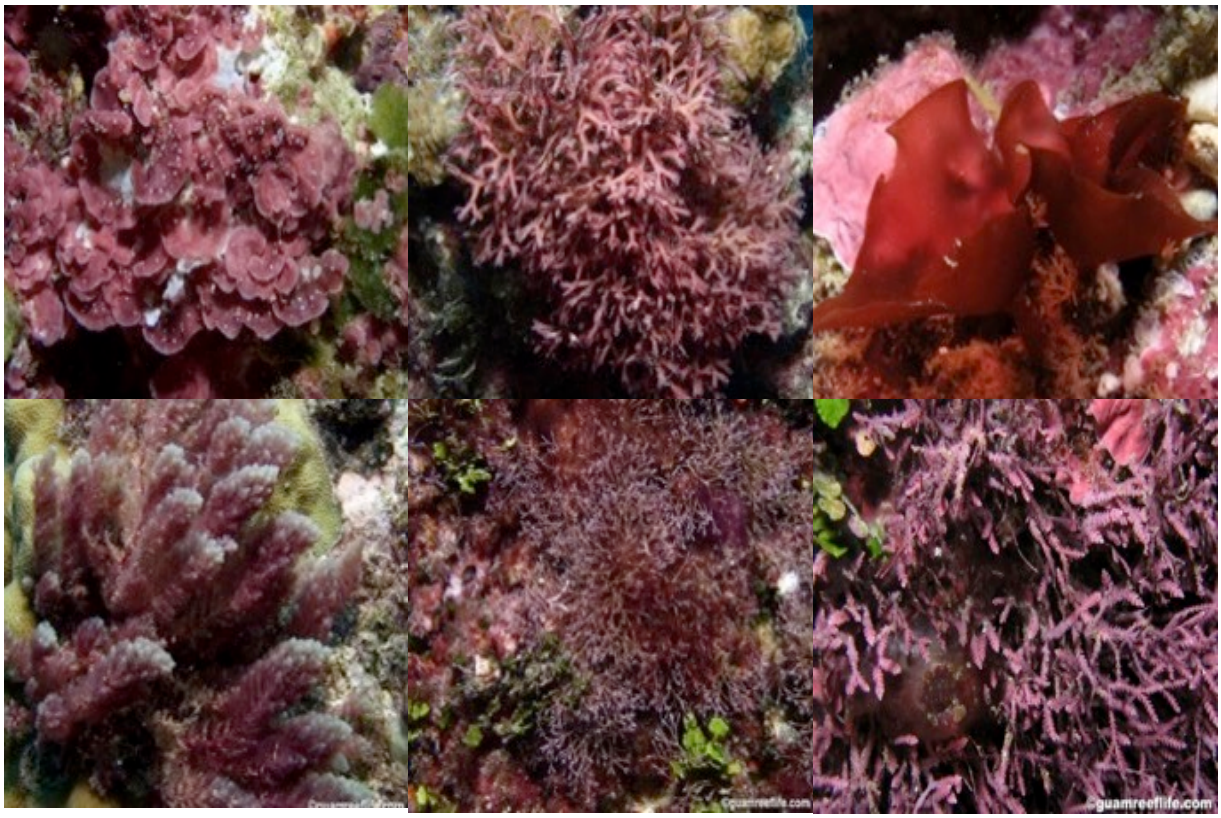
guamreeflife.com

IV.A.4.A.III. DIVISION RHODOPHYTA

Red macroalgae (RDMA)

This category is used for red upright macroalgae that cannot be identified to genus. Rhodophytes contain the pigment phycoerythrin; this pigment reflects red light and absorbs blue light. Because blue light penetrates water to a greater depth than light of longer wavelengths, these pigments allow red algae to photosynthesize and live at somewhat greater depths than most other algae. Some rhodophytes have very little phycoerythrin (especially in shallower or very clear waters), and may appear green or bluish from the chlorophyll and other pigments present in them.

Tier 2 group mapping: Upright macroalgae (UPMA)

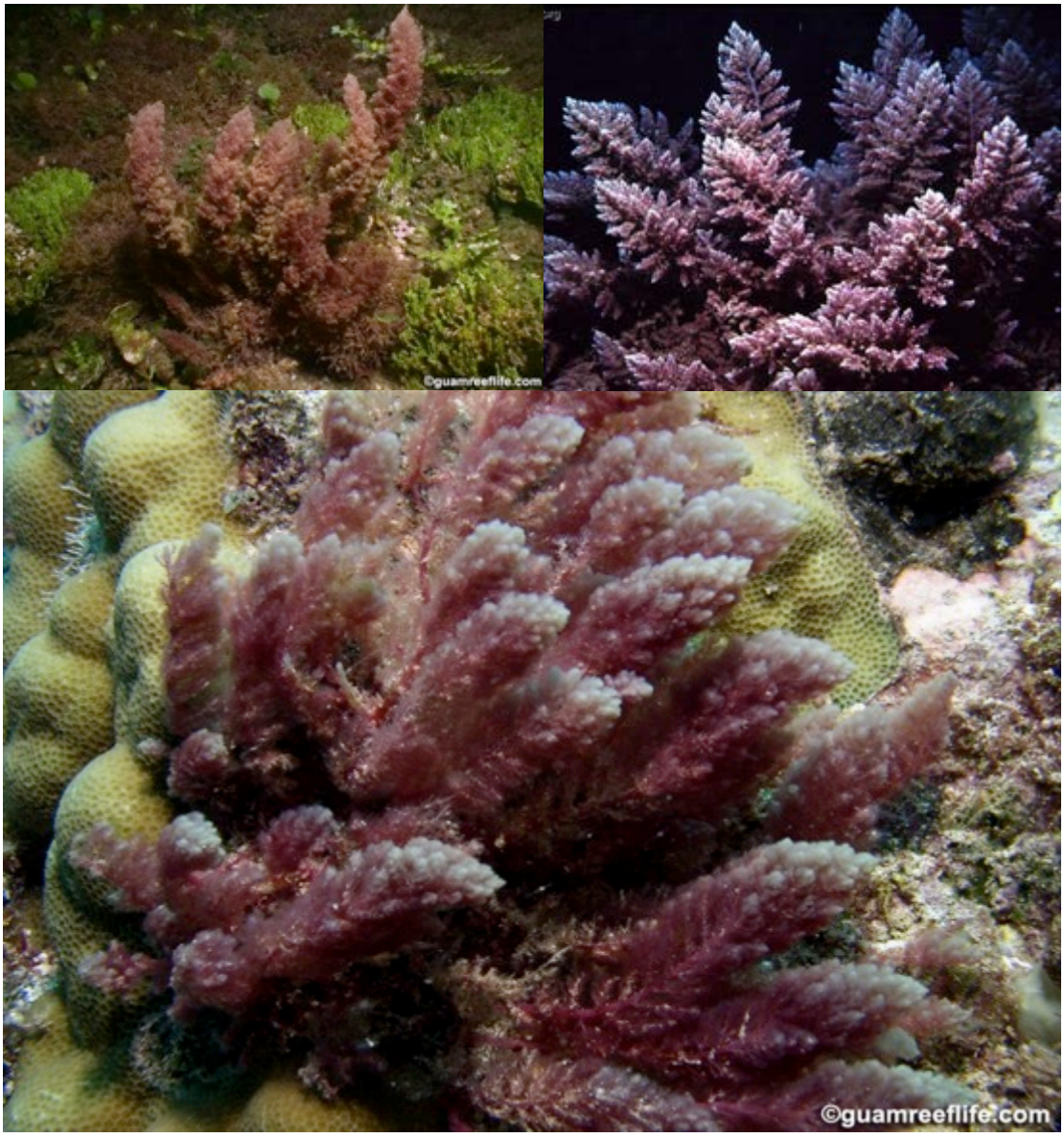


guamreeflife.com

***Asparagopsis* spp. (ASPP)**

These are red macroalgae with creeping stolons. Upright axes are fluffy and pink to gray in color. Ultimate branches are fine and taper to filaments just a few cells long. They are uncommon. Recorded species: *A. taxiformis.*

Tier 2 group mapping: Upright macroalgae (UPMA)



guamreeflife.com

IV.A.4.B. OTHER MACROALGAE GROUPS

IV.A.4.B.I. BLUE-GREEN MACROALGA (BGMA)

Blue-green algae, also known as Cyanophytes or cyanobacteria are photosynthetic and essentially aquatic prokaryotic organisms closely related to bacteria. They often form deep purple to black filamentous tufts or mats that may stretch for multiple centimeters in length, and therefore look different from turf algae. They may also form mucilaginous masses that are white or pale yellow in color.

Tier 2 group mapping: Blue-green macroalgae (BGMA)

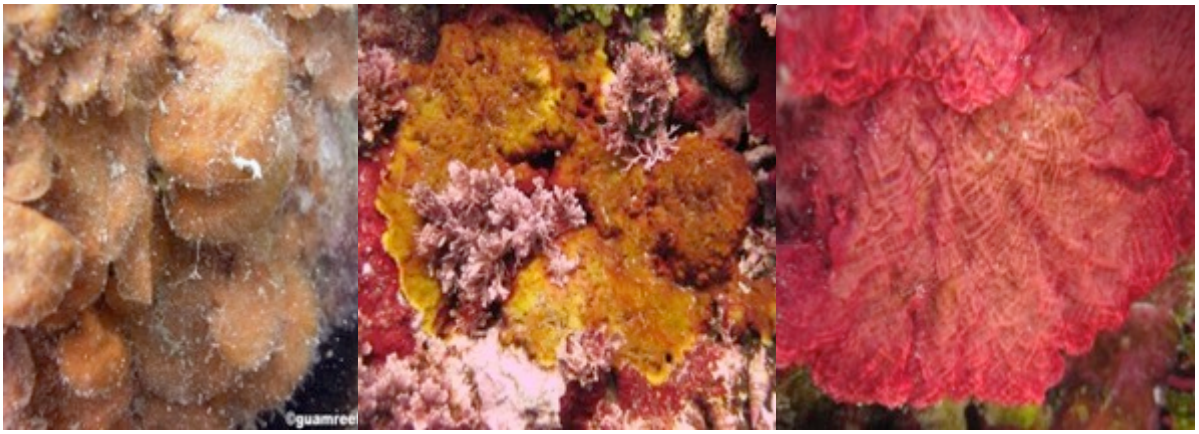
guamreeflife.com

IV.A.4.B.II. ENCRUSTING MACROALGAE

Encrusting macroalgae (EMA)

The general category, 'Encrusting Macroalgae' should be used if a more precise identification cannot be made. EMA can be either completely attached to the substrate, or it is equally likely to be attached at one margin and lifting off the substrate in a blade- like form. This blade can either be uncalcified like the brown EMA *Lobophora* spp. or calcified like red *Peyssonnelia* spp. If encrusting macro algae are calcified, they are calcified on the undersurfaces of the blade and this process can often indicate direction of growth by forming subtle growth rings that are visible through the blade (CCA do not have these ridge/rings form).

Tier 2 group mapping: Encrusting macroalgae (EMA)



guamreeflife.com

***Lobophora* spp. (LOBO)**

This is encrusting brown alga with thin, fan-shaped blades encrusting the substrate, often overlapping in a shingle-like pattern, and it comes inshades of green-brown to tan to brown. It grows in most reef environments, encrusting great areas of shaded, rocky substrates. It is especially abundant on undercut wall faces along deep drop-offs. Blades' surfaces are often covered with sediment and encrusted with epiphytes. Thecommon species: *L. variegata.*

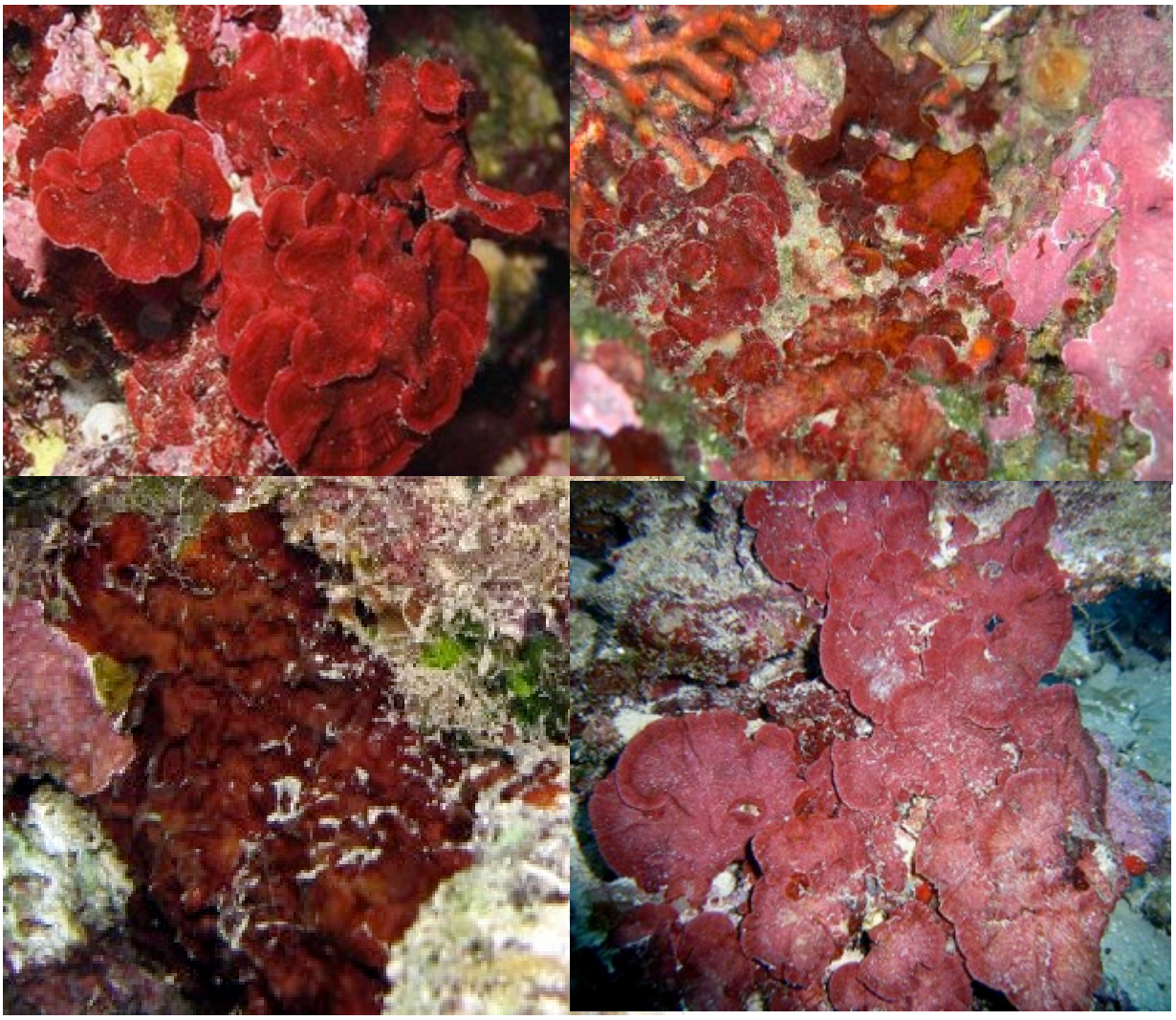
Tier 2 group mapping: Encrusting macroalgae (EMA)

guamreeflife.com; Magruder and Hunt

***Peyssonnelia* spp. (PESP)**

Plants are crust-like, mostly prostrate, relatively thin, composed of erect filaments arising from distinct basal layer, frequently calcified across its ventral surface. Surface is smooth and varies from scarlet, dark rose, wine red, to maroon in color.

Tier 2 group mapping: Encrusting macroalgae (EMA)



guamreeflife.com; university.uog.edu

IV.A.4.B.III. SEAGRASS (SG)

Seagrasses are flowering plants from one of four plant families (Posidoniaceae, Zosteraceae, Hydrocharitaceae, or Cymodoceaceae), which grow in marine, fully-saline environments.

Tier 2 group mapping: Seagrass (SG)

guamreeflife.com; M.Heckman

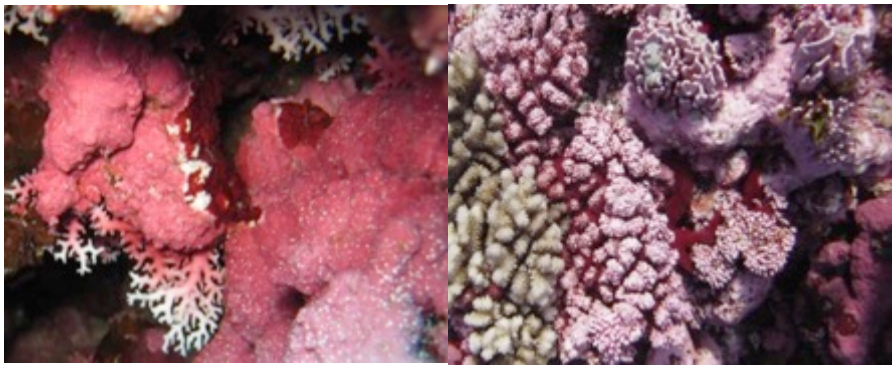
IV.A.5. CRUSTOSE CORALLINE ALGAE

Crustose coralline algae (CCA) is a type of calcified encrusting red macroalgae. It is classified separately from other red algae due to its importance as carbonate producer and reef builder. Commonly grows in patches on hard substrates, forming hard pink/lavender patches. The two Tier 3b categories defined here are maintained at Tier 2, and this category collapse to CCA in Tier 1.

Crustose coralline algae on hard substrate (CCAH)

Hard substrates range from pavement flats to basalt formations to bare carbonate (i.e. coral skeleton) structures. The pink and lighter red substrate in the images below is CCA; the darker, burgundy red is EMA (likely *Peysonnelia* sp.) in the image on the left and BGMA in the image on the right.

Tier 2 group mapping: Crustose Coralline Algae (CCAH)

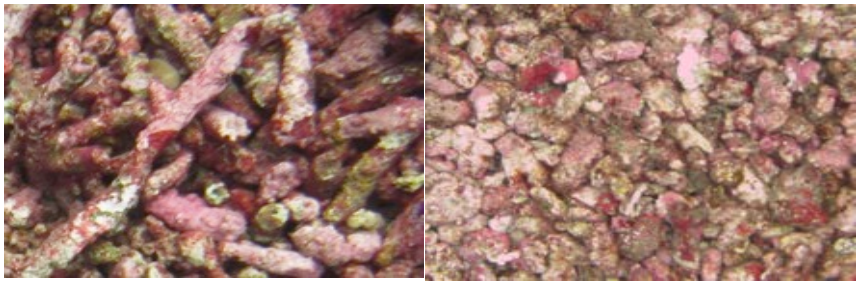


NOAA photos

Crustose coralline algae on rubble substrate (CCAR)

CCAR commonly grows on rubble, which is defined as hard fragments (e.g. rocks, pebbles, pieces of dead coral) typically gravel (>5 mm) to cobble (baseball) size with finer and coarser sediments mixed in patches. The pink and lighter red substrate in the images below is CCA; the darker, burgundy red is EMA (likely *Peysonnelia* sp.).

Tier 2 group mapping: Crustose Coralline Algae (CCAR)



NOAA photos

IV.A.6. TURF ALGAE

Four categories collapse to Turf at Tier 1. They retain their Tier 3b identities at Tier 2, however.

Turf growing on hard substrate (TURFH)

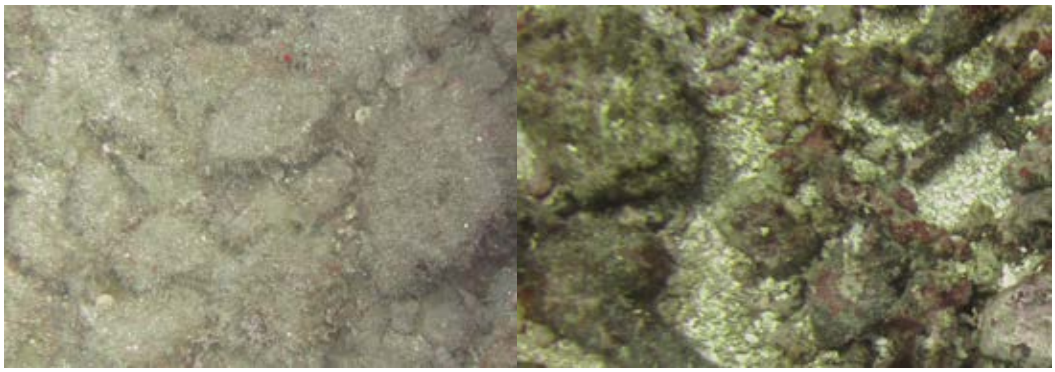
Turf algae often appear as fuzzy carpets growing across hard substrates. Hard substrates range from pavement flats to basalt formations to bare carbonate (i.e. coral skeleton) structures. Note that turf algae tends to trap a fine layer of sediment; this still constitutes a turf covered surface and should not be classified as Sand/Fine.
Tier 2 group mapping: Turf growing on hard substrate (TURFH)

NOAA photos

Turf growing on rubble substrate (TURFR)

Turf algae often cover rubble, giving the fragments a fuzzy appearance. Rubble is defined as hard fragments (e.g. rocks, pebbles, pieces of dead coral), typically gravel (> 5 mm) to cobble (baseball) size with finer and coarser sediments mixed in.

Tier 2 group mapping: Turf growing on rubble substrate (TURFR)



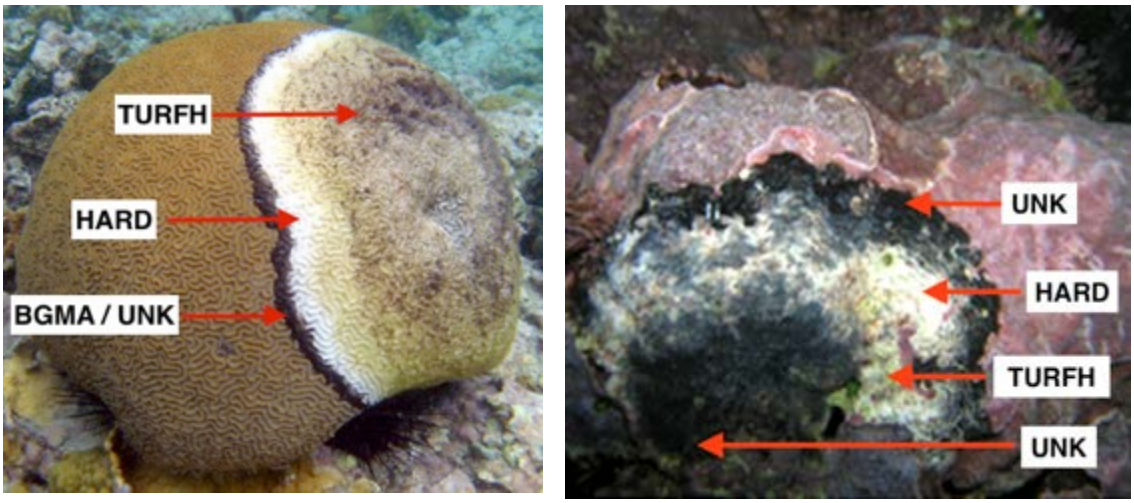
NOAA photos

Hard substrate (HARD)

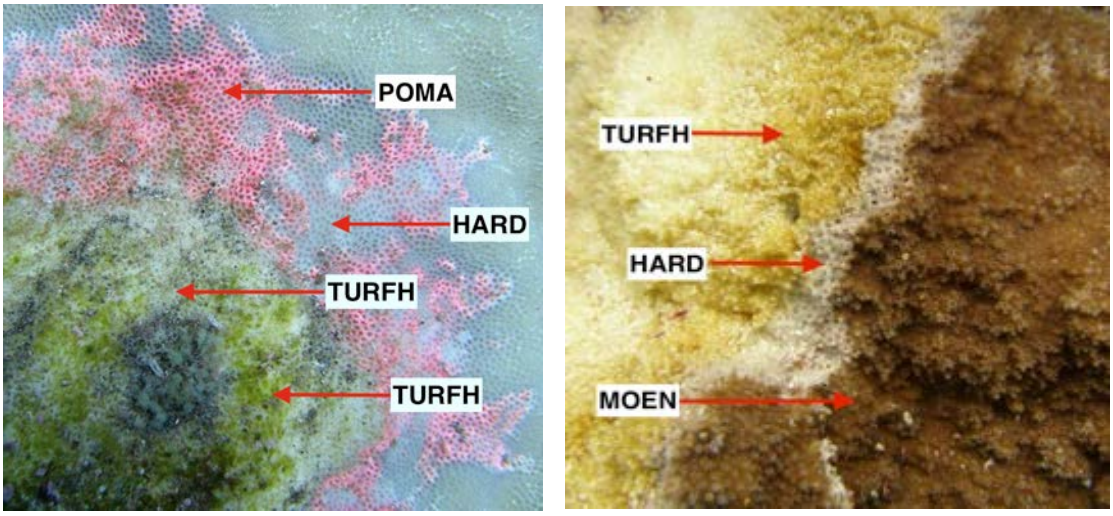
Hard surfaces are colonized by microscopic turf algae within days of being placed in the water, meaning that nearly all hard substrates are covered by turf algae even though these small organisms might not be visible in a photograph. Therefore, most hard bottoms will be classified as TURFH. Substrates classified as HARD are limited to cleanly scoured pavement flats, basalt formations, and bare carbonate structures (i.e. from freshly-dead coral skeleton or dead CCA).

NOAA photos

The following serves as a guideline for cases in which a disease or predation pattern is visible on corals and CCA.If the point falls directly on the active disease band (if present), the area underneath the point should be classified as the appropriate causative agent (e.g. blue green macroalgae in Black Band Disease), but only if the analyst is certain of the nature of the disease, otherwise, the point should be classified as UNK.I If the point falls on the stark-white/recently-dead area, this area should be classified as HARD. If the point falls on the algae-covered skeleton/old-dead area, this area should be classified as TURFH.



NOAA photos; clarku.edu



NOAA photos

Rubble substrate (RUB)

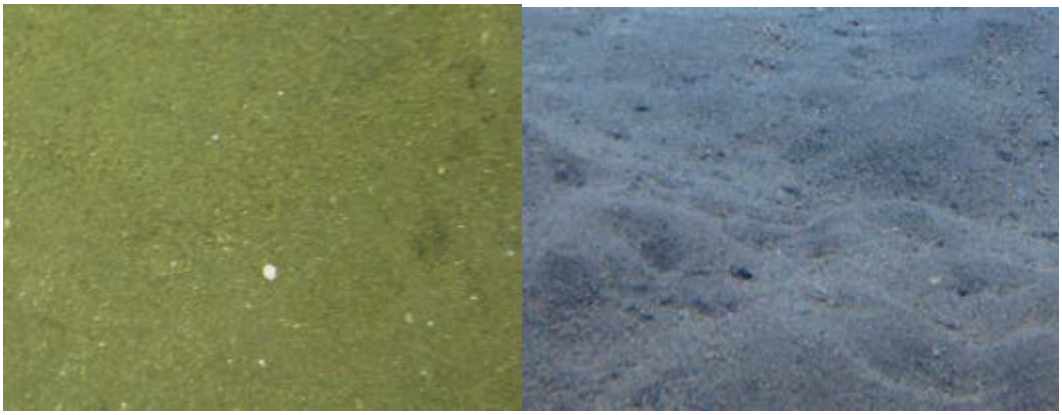
Hard surfaces are colonized by turf algae within days of being placed in the water. All rubble, which is defined as hard fragments (e.g. rocks, pebbles, pieces of dead coral), typically gravel (> 5 mm) to cobble (baseball) size with finer and coarser sediments mixed in, are covered by turf algae even though these small organisms might not be visible in a photograph. Therefore, most rubble will be classified as TURFR. Rubble that is in an area where it is constantly scoured (e.g. due to wave action) would be classified as RUB.

NOAA photos; youwarke.files.wordpress.com

IV.A.7. SEDIMENT

Fine substrate (FINE)

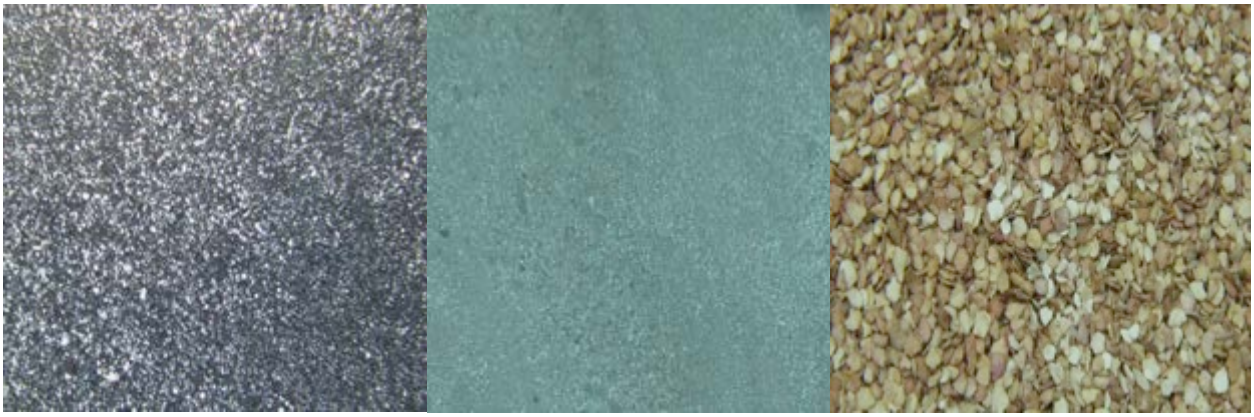
Using CREP Mapping Team's classification definition, fine sediment is defined as sediment with a grain size of < 1/16 mm. A thin dusting of fine sediment over a turf-covered surface is not sufficient to be called FINE habitat. Although it can be difficult to judge from a planar photograph, substrate is generally classified as FINE when it is >1 cm deep.



NOAA photos

Sand (SAND)

Sand is defined as sediment with a grain size between 1/16 mm and 5 mm. This can include silica sand, fine calcium carbonate sand, lava sand, and/or *Halimeda* spp. blade sand. A thin dusting of sand over a turf-covered surface is not sufficient to be called Sand habitat. Although it can be difficult to judge from a planar photograph, substrate is generally classified as SAND when it is > 1 cm deep.



NOAA photos; scripps.ucsd.edu

IV.A.8. MOBILE FAUNA

Mobile fauna (MOBF)

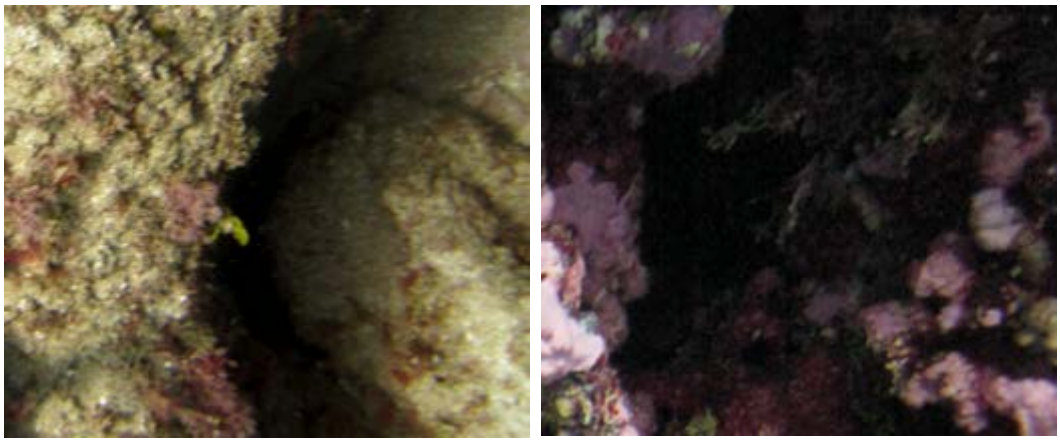
This category is appropriate to use for classification when the point falls on fauna that are not permanently affixed to a single location on the sea floor (e.g. sea cucumbers, seastars, sea urchins, fish, marine mammals, etc). Effort should be made to discern the benthic classification under the point; if that is not possible, this category should be used.

guamreeflife.com

IV.A.9. UNCLASSIFIED

Shadow (SHAD)

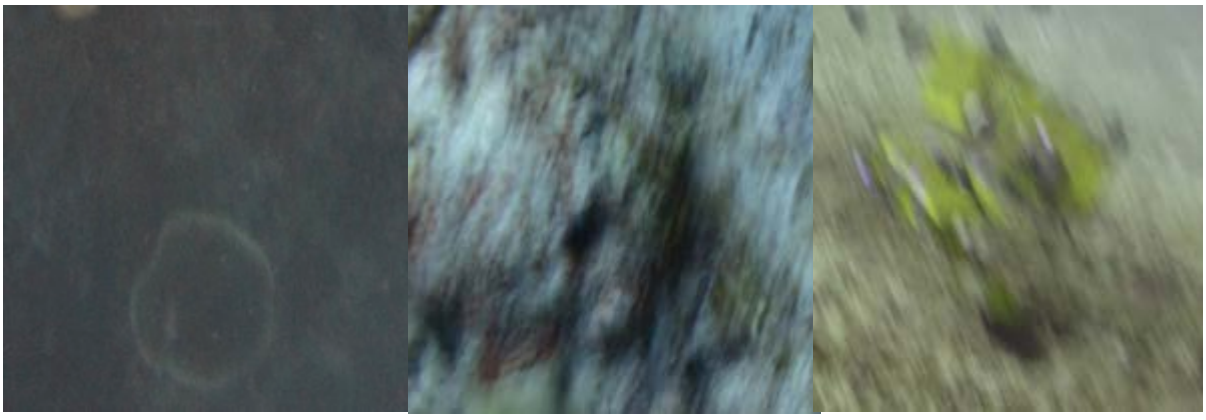
This category is appropriate when the point falls on a shadow cast by natural or anthropogenic features that prevent organism classification.



NOAA photos

Unclassified/Unknown (UNK)

This category is appropriate when the point falls on an area that is obscured or blurry and/or the substrate cannot be identified with confidence.



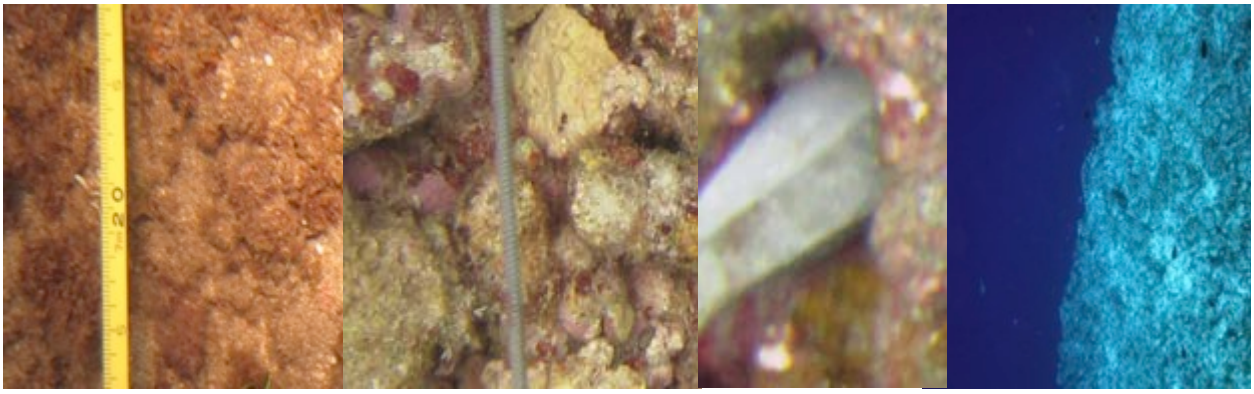
NOAA photos

IV.A.10. TAPE/WAND

The two categories in this group maintain their separate identities at Tier 2, but collapse to one category at Tier 1. Since they are artificial and not part of the substrate, they are removed from the results prior to analysis.

Tape (TAPE)

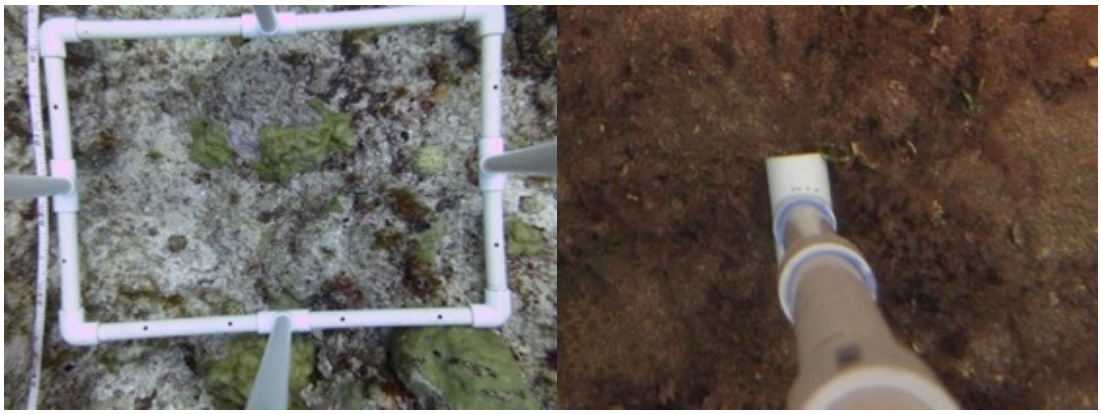
This category is appropriate when the point falls on the transect tape/line or tape hardware. It may also be used in the rare occasion that the point falls on the water column.



NOAA photos

Wand (WAND)

This category is appropriate when the point falls on the photoquadrat frame/spacing wand or photoquadrat hardware



NOAA photos

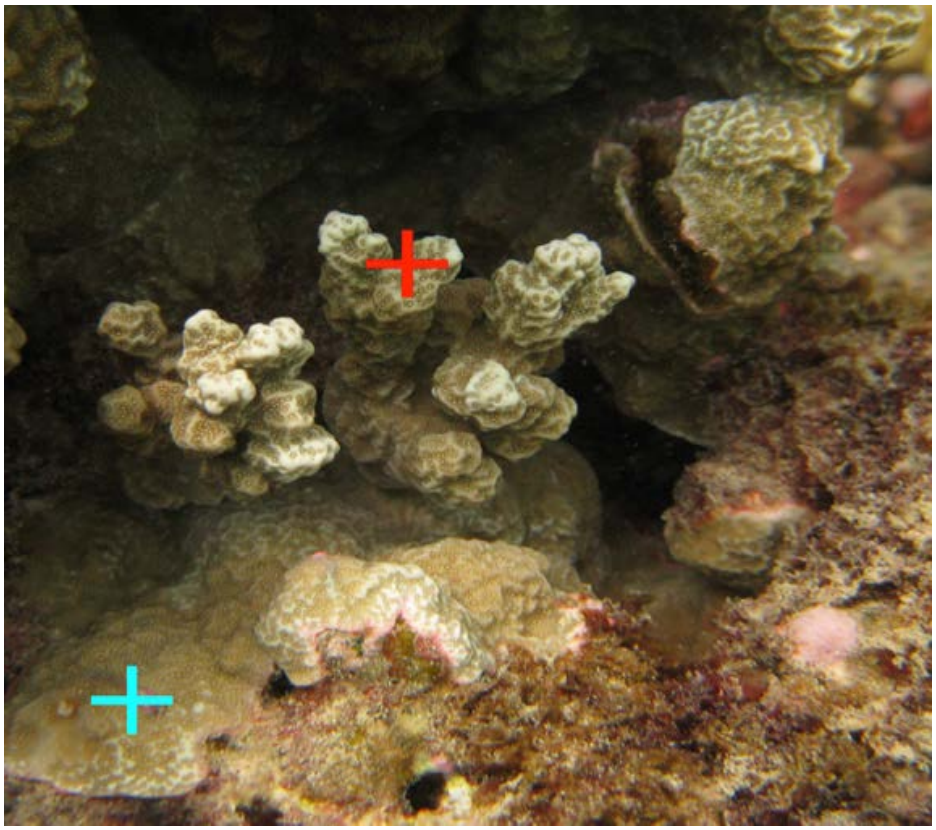
IV.B. BENTHIC IMAGE ANALYSIS – CLASSIFICATION GUIDE (TIER 2) FOR TOWED-DIVER SURVEY (TDS) IMAGES

Image quality can greatly influence how much detail can be extracted during images analysis. Thus, images collected from towed-diver surveys that were taken at sub-optimal conditions are analyzed at the functional group level or to a less detailed classification tier that can be identified with confidence.

IV.B.1. CORAL FUNCTIONAL GROUPS

If a point falls on a coral colony that has different growth forms in different areas, identify the growth form underneath each point that falls on the colony. Thus, identifications of points from an individual colony may differ. For example, in the image below, the coral underneath the red marker would be recorded as BR, while the coral underneath the blue marker would be recorded as ENC.

The codes given for categories in this section are used for Tier 2 identification at the Tier 2 level. The Tier 1 group mapping is given for each functional group

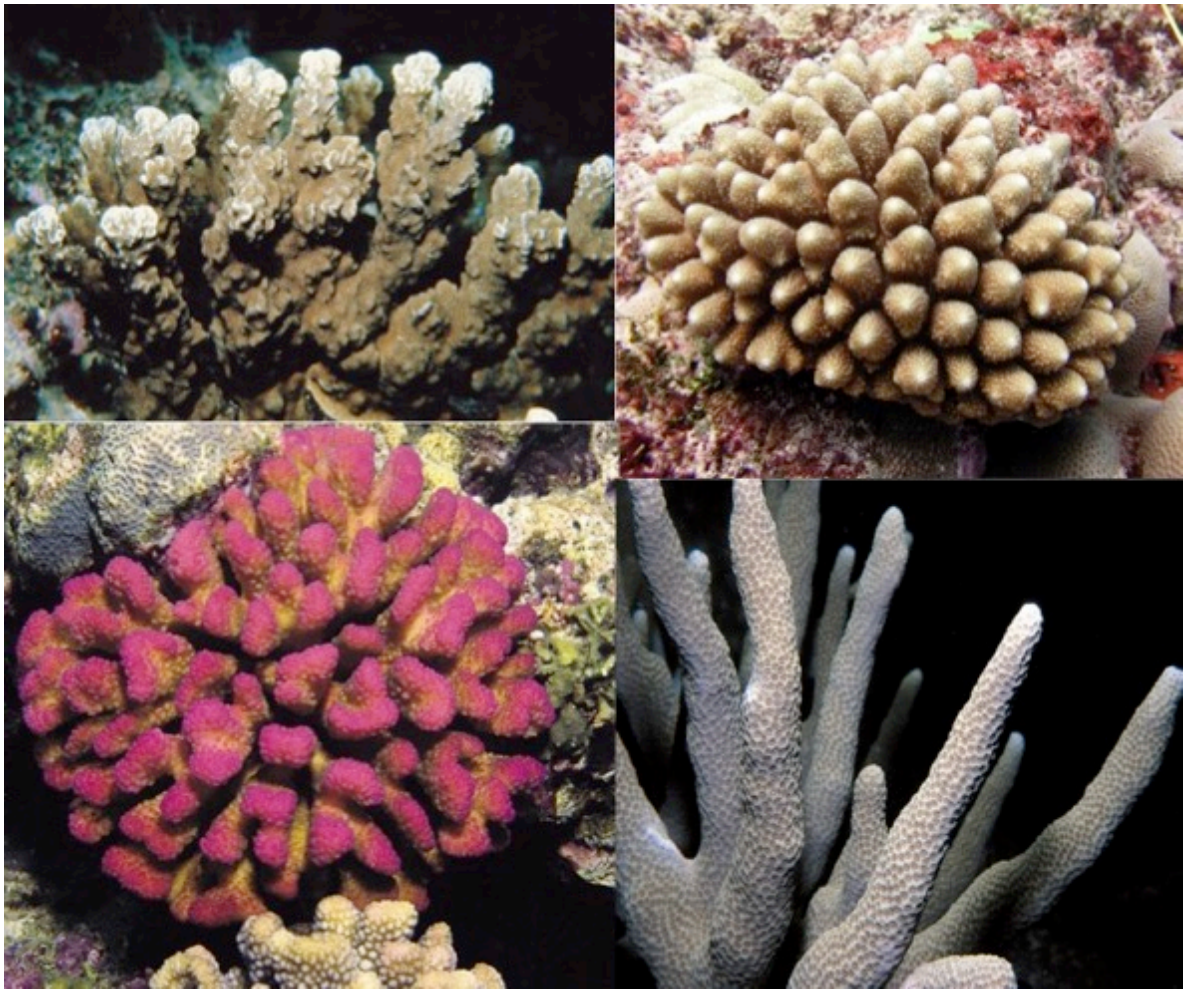


NOAA photos

Branching hard coral (BR)

Corals forming large, arborescent (tree-like) colonies exhibiting elongated branched projections, and corals with smaller, stubby and compact branches with finger-like (digitate) protrusions should be classified as branching morphology.

Tier 1 group mapping: Coral

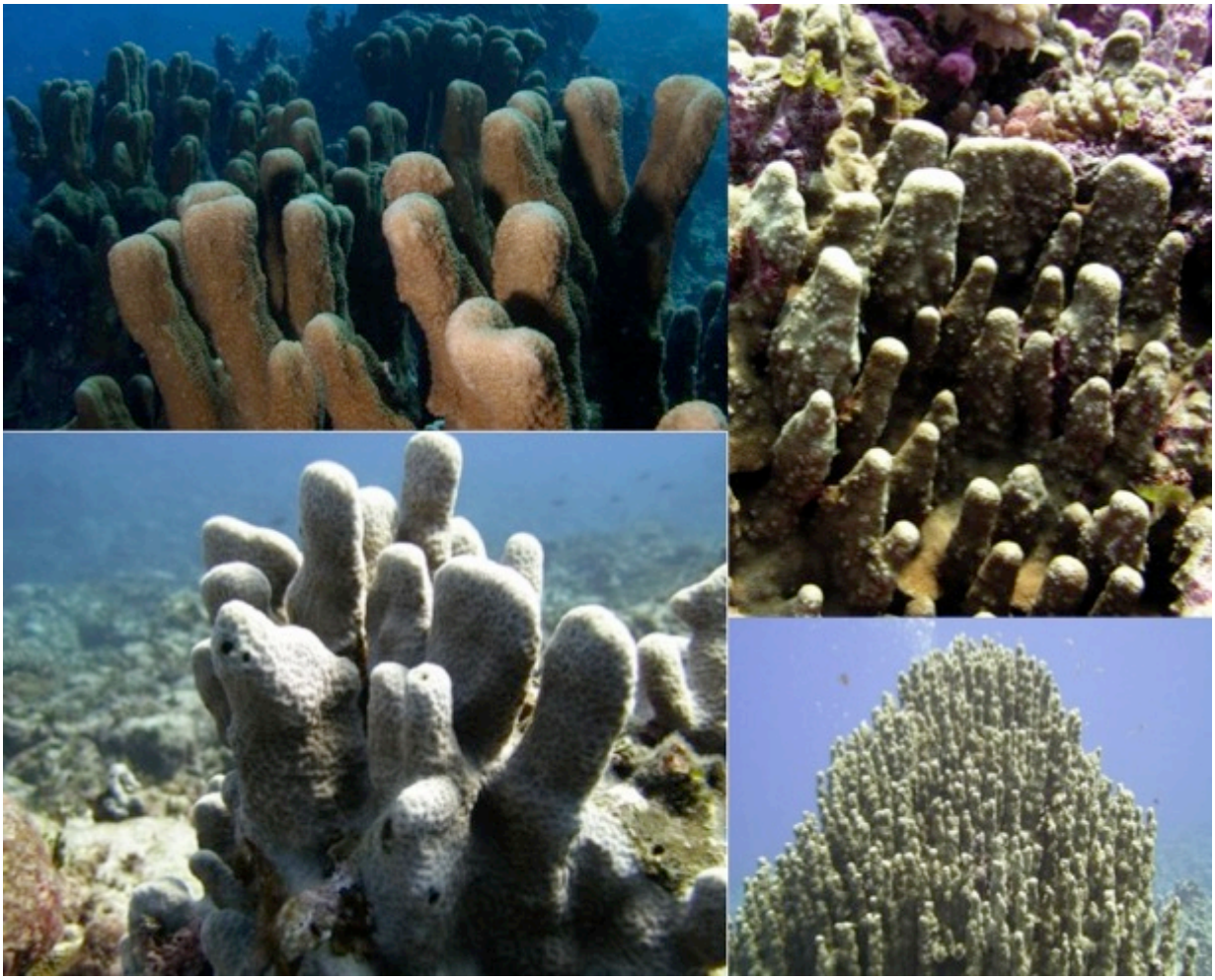


guamreeflife.com; aims.gov.au

Columnar hard coral (COL)

Some coral colonies, generally massive- and encrusting-looking, can exhibit club-like or column-like up-growths; these colonies should be classified as having a columnar morphology.

Tier 1 group mapping: Coral

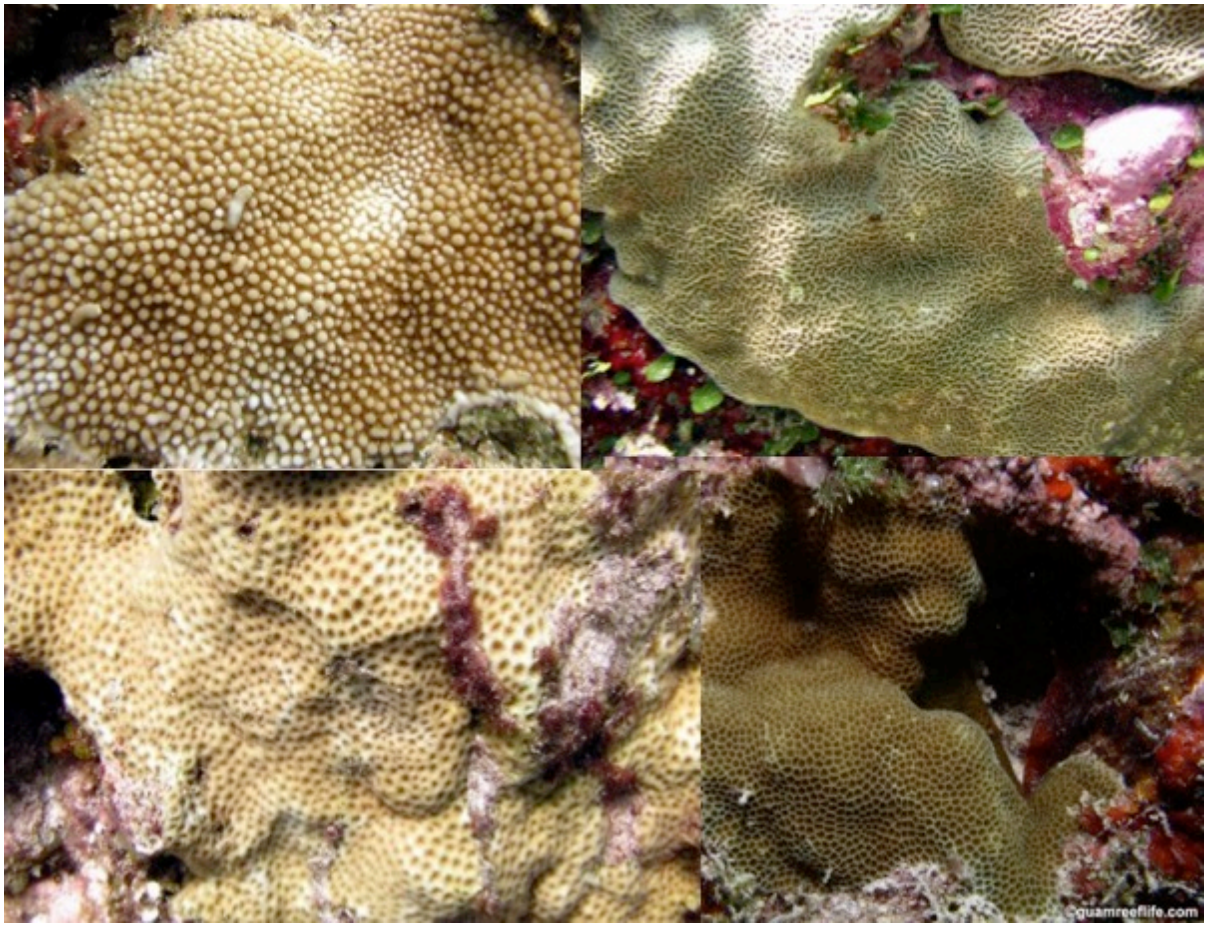


guamreeflife.com; aims.gov.au

Encrusting hard coral (ENC)

Coral colonies with encrusting morphology are those with flattened, thick or thin sheets/plates that adhere to and follow the contour of the substrate. Colony surfaces often range from smooth to rough, bumpy, knobby, or crinkled, with some specimens exhibiting raised colony edges, giving colonies a platy/foliose appearance.

Tier 1 group mapping: Coral



guamreeflife.com

Foliose hard coral (FOL)

Coral colonies with foliose morphology include those that form flattened sheets or plates, where a substantial portion of the colony is detached and elevated from the substrate. These corals often form shingle-like rows or tiers of overlapping plates, fused or convoluted whorls, vases, or leafy/lettuce-like stands. Note that growth forms used during classification of colonies in the field, such as ‘plating’ and ‘laminar’, are not available in the classification scheme used for images. Therefore, plating and laminar colonies are included in the foliose category for BIA.

Tier 1 group mapping: Coral

guamreeflife.com; aims.gov.au

Free-living hard coral (FREE)

Use the free-living morphology for coral colonies that live unattached from the substrate. This excludes broken-off colony branches or other products of fragmentation that are still alive. Free-living corals are conspicuous; most develop as flattened, dome-shaped disks, with a central mouth and apparent, radiating ridge-like structures. Includes the following genera: *Cycloseris, Diaseris, Halomitra, Herpolitha, Sandalolitha,* occasionally *Scolymia.*

Tier 1 group mapping: Coral

guamreeflife.com

Massive hard coral (MASS)

Massive corals are those characterized by forming raised mounds or rounded heads with hemispherical to sub-hemispherical morphologies. It is important to note that massive does not necessarily describe the *size* of the colony, it is a description of the *growth form.* This growth form may also be referred to as 'mounding.' Large colonies are distinct and boulder-like; small ones have more of a dome or cushion-shape silhouette. It is not unusual for massive colonies to exhibit a bumpy or knobby surface, but for the most part all possess a solid, thick shape.

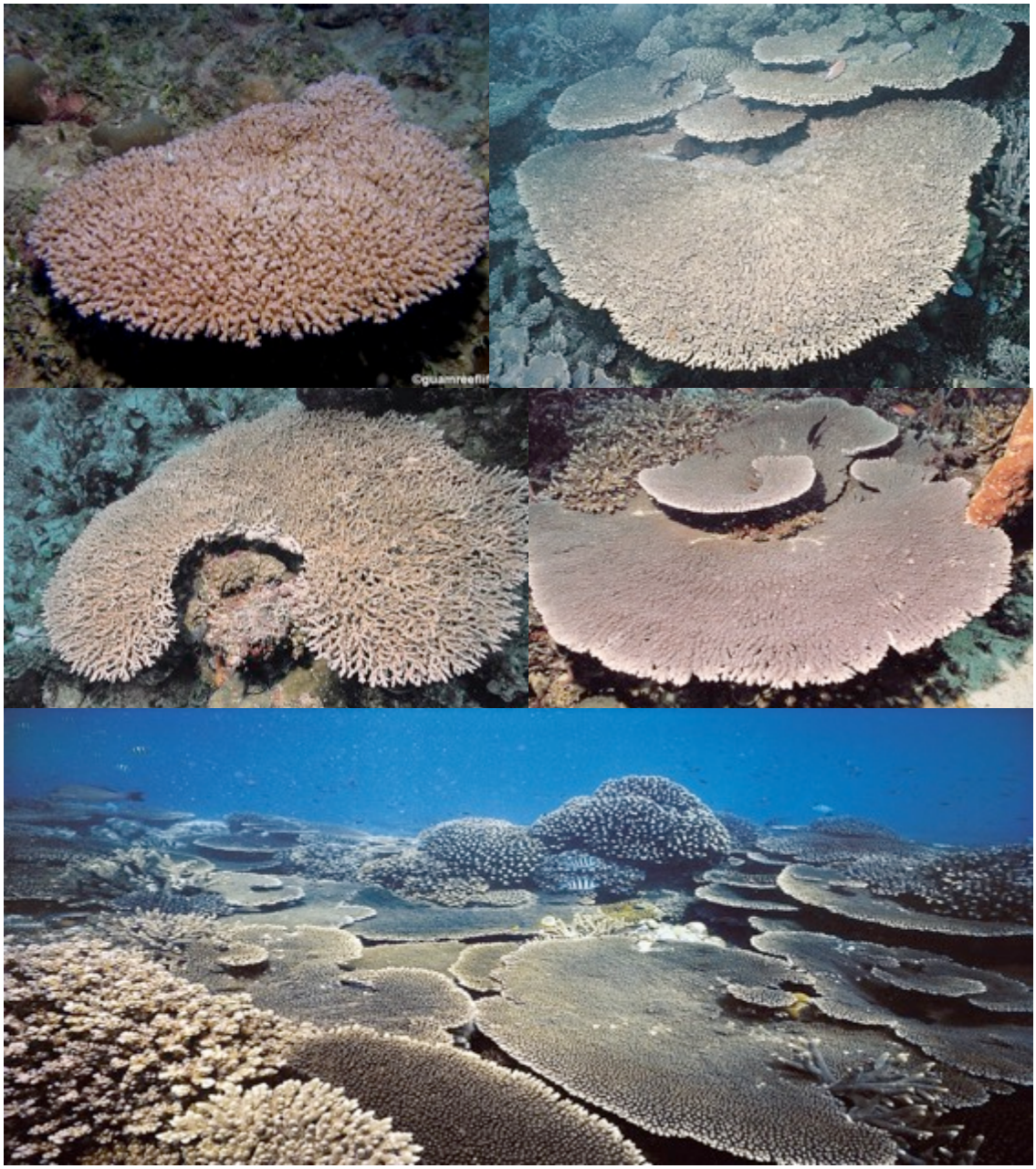
Tier 1 group mapping: Coral

guamreeflife.com; aims.gov.au

Tabulate hard coral (TAB)

Coral colonies with tabulate growth morphology are those that have the appearance of a table or bench, supported on a short, stout base that is attached to the substrate. The horizontal plate or plates have numerous fused and interlocking branches, forming a roughly circular or oblong plate sometimes up to 2 m in diameter.

Tier 1 group mapping: Coral



guamreeflife.com; aims.gov.au

Non-scleractinian hard coral (NS)

This classification category is to be used for other groups of non-scleractinian corals with hard skeletons, including fire corals (Family Milleporidae), blue coral (Order Helioporacea, e.g. *Heliopora coerulea*), and Stylasterid hydrocorals (Family Stylasteridae), regardless of growth form.

Blue corals, *Heliopora coerulea* (the only species in the genus), generally appears blue (hence the name), greenish, or tan, and colonies can be arborescent (tree-like), plate-like, encrusting, or form columns. Polyps have tentacles that give the colony a feathery appearance when extended.

Milleporids, or fire corals, are common on reefs (outside of the Hawaiian Archipelago) and have diverse growth morphologies, including sub-massive, branching, encrusting, and foliose. Colony coloration ranges from cream to tan or maroon. Although encrusting colonies may have a wrinkled and furrowed appearance, fire corals have a relatively smooth surface appearance that lacks the intricate surface texture and architecture that is evident in Scleractinians (true hard corals).

Stylasterid hydrocorals, commonly called lace corals, include 2 genera: *Distichopora* and *Stylaster* spp. They are often brightly-colored and can be found along walls, under overhangs, and in caves. Members of both genera branch in 1 plane.

IV.B.2. SOFT CORAL

Octocorals (OCTO)

Octocorals refers to gorgonian corals, sea fans, sea whips, sea pens, and other members of Subclass Alcyonaria (octocorals), except blue coral *Heliopora coerulea* (Order Helioporacea), which is classified as 'HCOE' and maps to the Coral group in Tier 1. All members of this classification category produce skeletal elements made of protein and calcium carbonate that give the colony sufficient soft support and the flexibility to sway with the ocean waves and currents. Common genera include *Cladiella, Lobophytum, Sarcothelia* and *Sinularia.*

guamreeflife.com; aims.gov.au; NOAA photos

Unclassified soft coral (USC)

These corals resemble gorgonians, forming tree-like colonies. They possess a hard axial protein skeleton and non-retractable polyps; includes black coral and wire coral (Order Antipatharia).

isprambiente.gov.it; NOAA photos

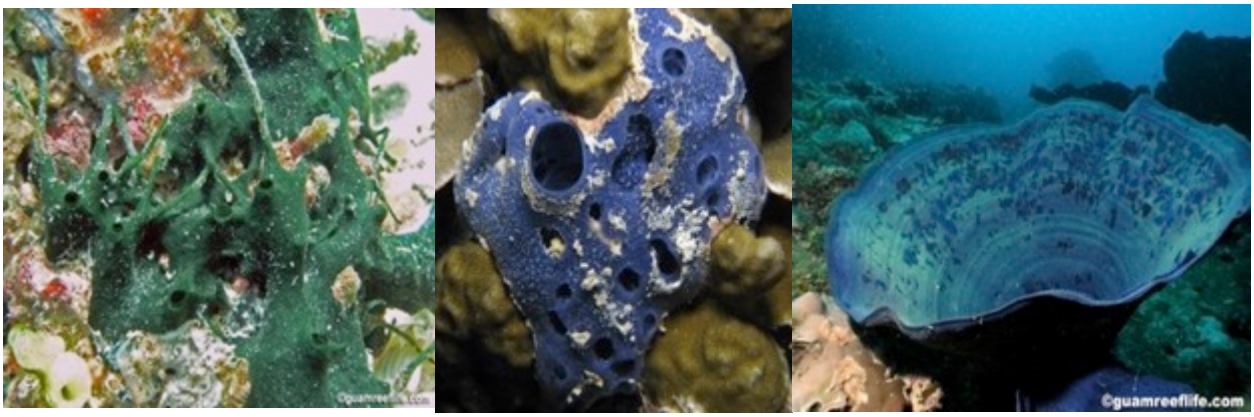
IV.B.3. INVERTEBRATE

This Tier 1 group includes organisms from very different phyla, including Porifera (sponges), Cnidaria (anemones, corallimorphs, zoanthids), Mollusca (giant clams, other bivalves), Bryozoa/Ectoprocta (bryozoans), and Chordata (tunicates). The categories are arranged taxonomically according to these groups. However, these relationships are not reflected in the system of Tiers used in BIA. The codes given for categories in this section are used to identify them at the Tier 2 level.

IV.B.3.A. PORIFERA

Sponge (SP)

Sponges (Phylum Porifera) have numerous species and growth morphologies, many of which can be confused with other benthic organisms. Sponges have porous tissue for filter feeding, and many have large openings through which expelled water flows (excurrent openings). To help identify sponges, zoom-in on the photograph and examine the surrounding tissue. In general, sponges are more colorful than tunicates and are "rougher" around the edges due to a lack of a "tunic" and being composed of spicules. Most sponges, unlike tunicates, are not able to close their excurrent openings. Sponges can also protrude/extend upwards off the benthos from their encrusting state, whereas tunicates tend to grow along the contours of the substrate underneath them.



guamreeflife.com

IV.B.3.B. CNIDARIA

Anemone (AMNE)

Anemones include members of Order Actinaria (anemones) and Order Ceriantharia (tube-dwelling anemones).

A.Petrusek; reefcorner.com; uniprot.org

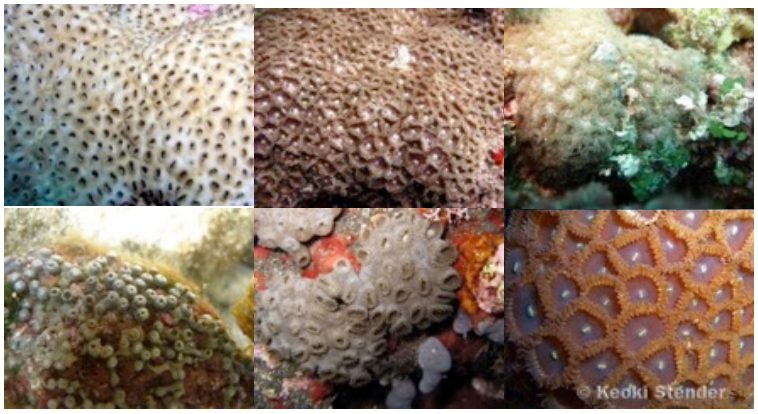
Corallimorph (CMOR)

Corallimorphs (Order Corallimorpharia) are anemone-like animals that are found either solitary or in colonies. Their tentacles are generally much shorter than those of true anemones. They can be invasive and at this stage resemble a fuzzy carpet.

midlandsmarinelighting.com; akwarium.gdynia.pl; garf.org

Zoanthids (ZO)

Zoanthids (Order Zoanthidea) are colonial anemone-like animals with smooth, flat, broad oral disks with tentacles that radiate outward from their margins. Tentacles are found in two nearby rows, and are always grouped in multiples of six. The polyp's mouth has a ciliated groove at one or both ends of the mouth. Zoanthids are connected by runners (called stolons), and they lack the hard skeletons of scleractinian corals. The following genera are included in this group: *Palythoa*, *Protopalythoa*, *Zoanthus*.

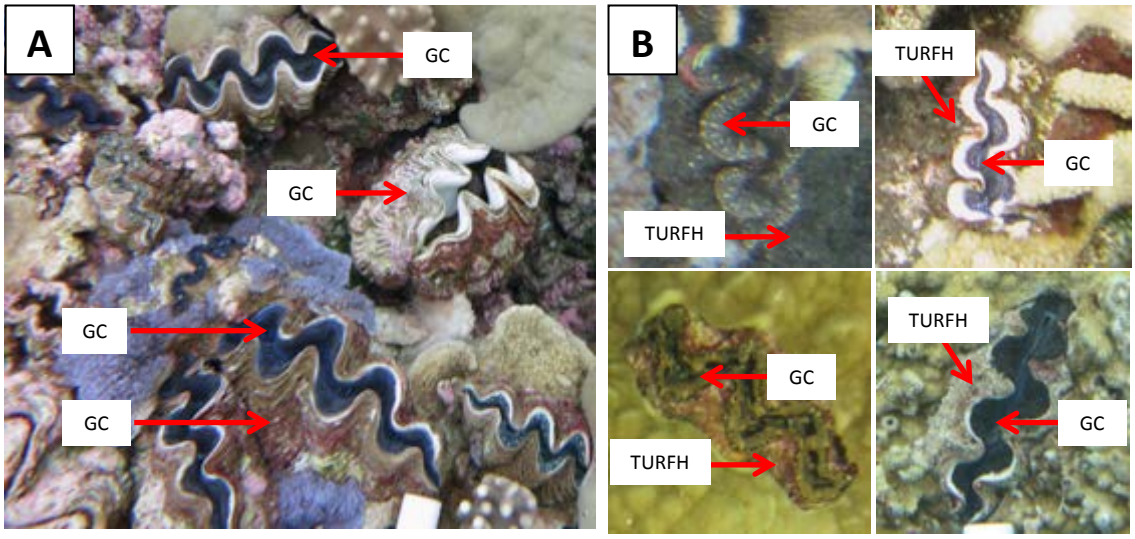


guamreeflife.com; marinelifephotography.com; NOAA photos

IV.B.3.C. MOLLUSCA

Giant clam (GC)

Giant clams may have shells that are drab in color and/or colonized by algae or other sessile organisms, but the mantle can be colorful and can grow from 0.25 m to more than 1 m in diameter. Giant clams with completely exposed shells (Figure A) should be classified as "GC", regardless of whether the point falls on the mantle or the algae-covered shell. If the giant clams are buried, classify only as "GC" if the point falls on the mantle (Figure B). For all other bivalves (clams, oysters, and mussels) in Class Bivalvia, use the Bivalve category (BI).



NOAA photos

Bivalve (BI)

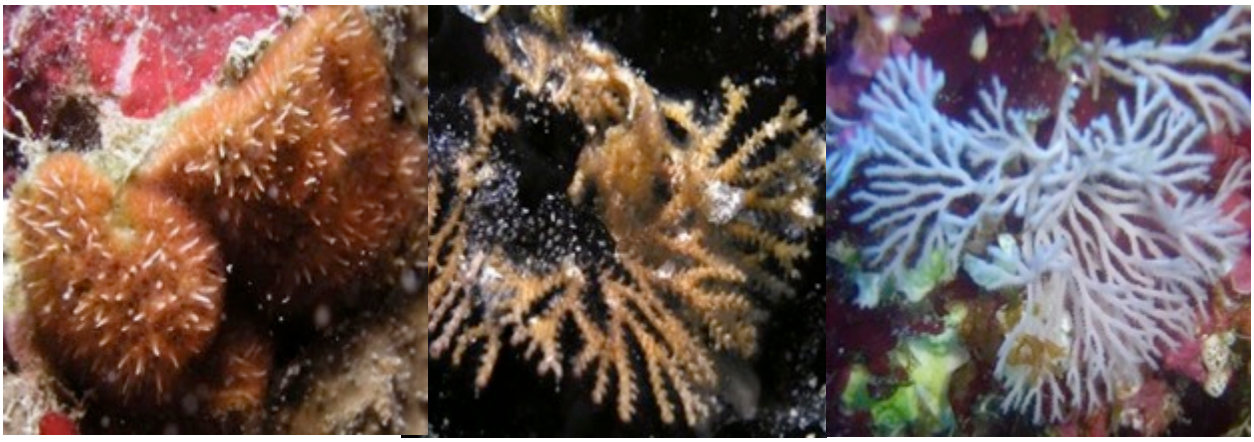
Clams, oysters, and mussels are common examples of bivalves (Class Bivalvia). Giant clams (Family Tridacnidae) are a special case, and have their own classification category (GC). For all other bivalves, use this category.

NOAA photos; guamreeflife.com

IV.B.3.D. BRYOZOA/ECOPROCTA

Bryozoan (BRY)

These colonial animals are early colonizers of bare surfaces on coral reefs. Most attach to solid surfaces but some live in sand. Each "member" lives in a zooid, or house, and has lophophores which are "tentacles" that extend out of the house to filter feed. The lophophores are ciliated and very "regular" in appearance. However, unless the image is clear, it will be hard to detect the lophophores and use them to distinguish between a tunicate or sponge. The individual zoids join to one another forming bushy, branching, fanlike, or encrusting colonies that may be rigid or flexible. Most bryozoans have a lace-like appearance and can be confused with algae or sponges. However, unlike sponges and tunicates, you will not see incurrent and excurrent openings. This is because the lophophores in bryozoans are used for feeding. In general, bryozoans will not appear smooth like a tunicate and their upright structure will appear to be "flower" and "plant"- like.



guamreeflife.com

IV.B.3.E. CHORDATA

Tunicate (TUN)

Tunicates (Class Ascidiacea) have numerous species and growth morphologies, many of which can be confused with other benthic organisms. They can grow as solitary individuals or in colonies. Their soft body is surrounded by a thick test, or tunic, often transparent or translucent and varying in consistency from gelatinous to leathery. In general, if the organism has multiple holes (which are the individual incurrent siphons of the zooid) with a few larger holes (the shared excurrent siphons) spread out, it is probably a tunicate. Tunicates are able to close their siphons rather quickly, whereas sponges are for the most part unable. Thus, if some of the openings of the sessile organism appear to be closed in the photograph, it is likely a tunicate. One final generalization is that tunicates tend to grow with the contours of the substrate whereas sponges can grow upwards from the encrusting state.

guamreeflife.com; NOAA photos

IV.B.3.F. OTHER OR UNIDENTIFIABLE SESSILE INVERTEBRATES

Unclassified sessile invertebrate (UI)

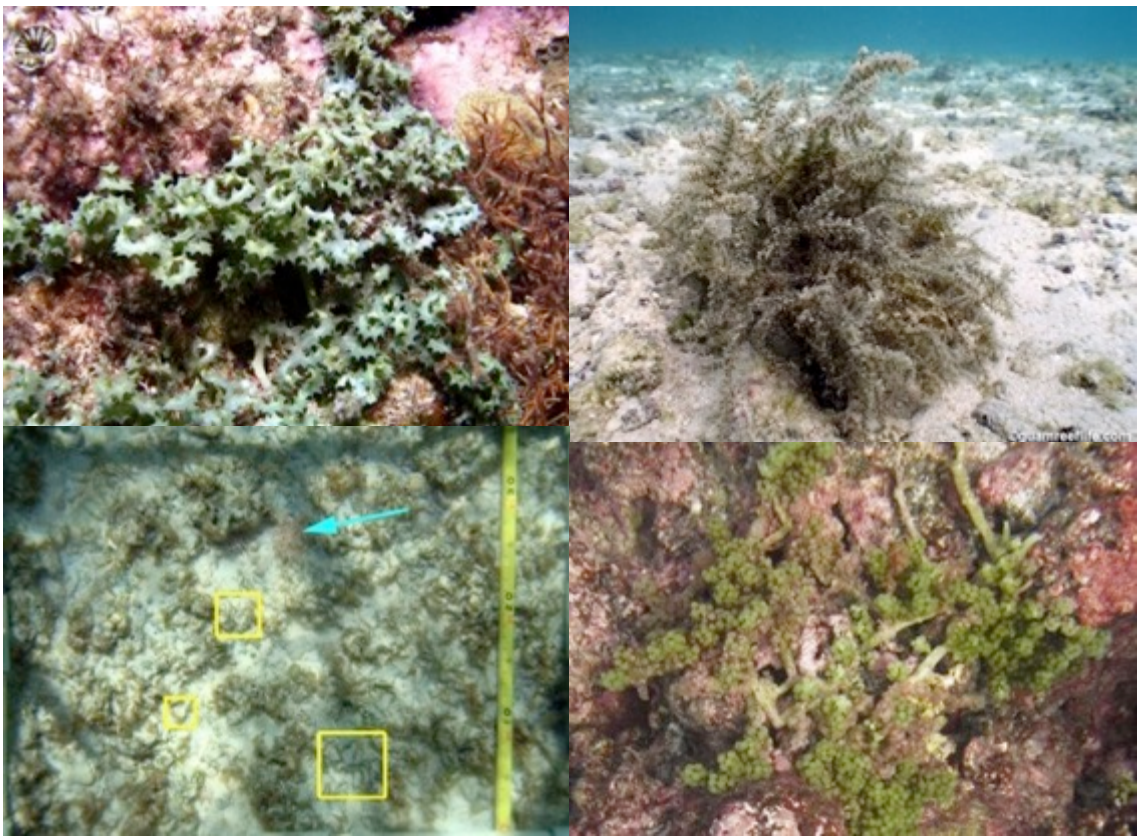
This category refers to sessile invertebrates that do not fall within one of the other categories, or in situations when a sessile invertebrate cannot be distinguished, for example, in differentiating between an encrusting sponge or tunicate.

NOAA photos

IV.B.4. MACROALGAE

Upright macroalgae

Macroalgae that do not form crusts adherent to rubble or the substrate should be termed as upright. Upright macroalgae (UPMA) at the Tier 2 level are equivalent to Macroalgae at the Tier 1 level. Note that although Crustose Coralline Algae (CCA) is taxonomically red algae, the associated categories are classified differently because of their unique ecological role. They remain separate from UPMA/ Macroalgae at Tier 1.



guamreeflife.com; NOAA photos

***Halimeda* spp. (HAL)**

Green alga with segmented, calcified branches. Plants can be erect or sprawling. Commonly found. Recorded species: *H. distorta*, *H. gracilis*, *H. minima*, *H. opuntia*, and *H. tuna.*

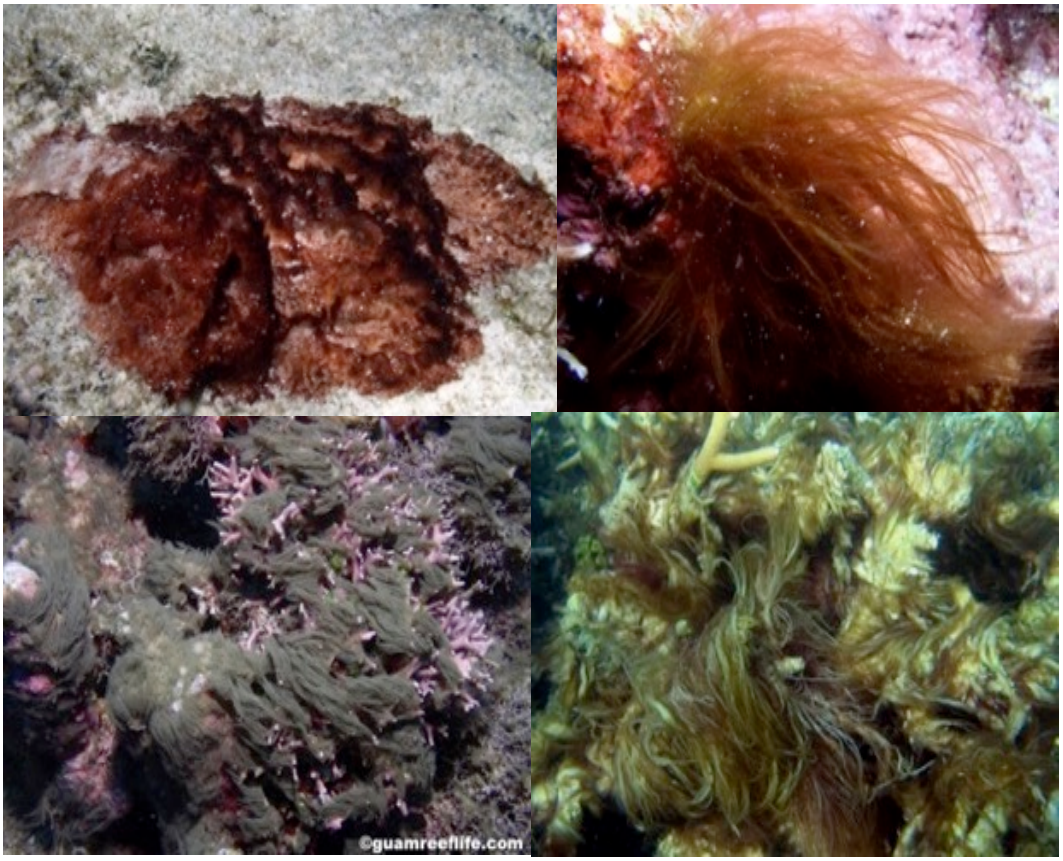
Tier 1 group mapping: Macroalgae

guamreeflife.com

Blue-green macroalga (BGMA)

"Blue-green algae", also known as Cyanophytes or cyanobacteria, are photosynthetic and essentially aquatic prokaryotic organisms closely related to bacteria. They often form deep purple to black filamentous tufts or mats that may stretch for multiple centimeters in length, and therefore look different from turf algae. They may also form mucilaginous masses that are white or pale yellow in color.

Tier 1 group mapping: Macroalgae

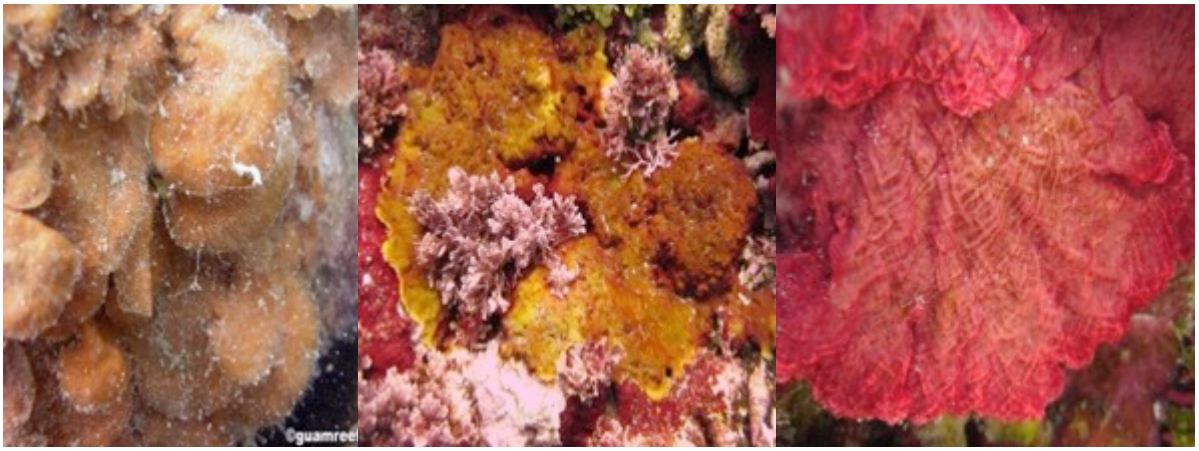


guamreeflife.com

Encrusting macroalgae (EMA)

Encrusting Macroalgae can be either completely attached to the substrate, attached at one margin and lifting off the substrate in a blade-like form. This blade can either be uncalcified like the brown EMA *Lobophora* spp. or calcified like red *Peyssonnelia* spp. If encrusting macro algae are calcified, it is on the undersurfaces of the blade, and this process can often indicate direction of growth by forming subtle growth rings that are visible through the blade (CCA do not have these ridge/rings form).

Tier 1 group mapping: Macroalgae



guamreeflife.com

Seagrass (SG)

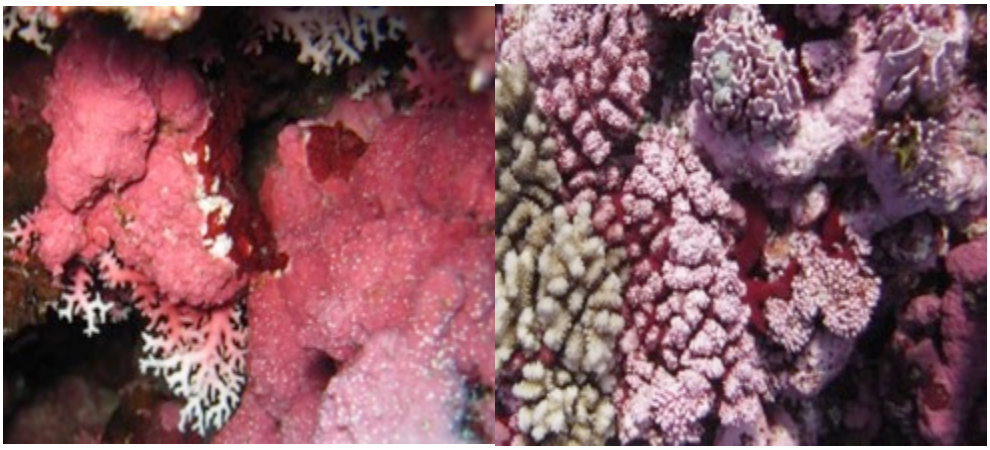
Seagrasses are flowering plants from one of four plant families (Posidoniaceae, Zosteraceae, Hydrocharitaceae, or Cymodoceaceae), which grow in marine, fully-saline environments.

Tier 1 group mapping: Macroalgae

guamreeflife.com; M.Heckman

Crustose coralline algae on hard substrate (CCAH)

Hard substrates range from pavement flats to basalt formation to bare carbonate (i.e. coral skeleton) structures. The pink and lighter red substrate in the images below is CCA; the darker, burgundy red is EMA (likely *Peysonnelia* sp.) in the image on the left and BGMA in the image on the right.
Tier 1 group mapping: Macroalgae

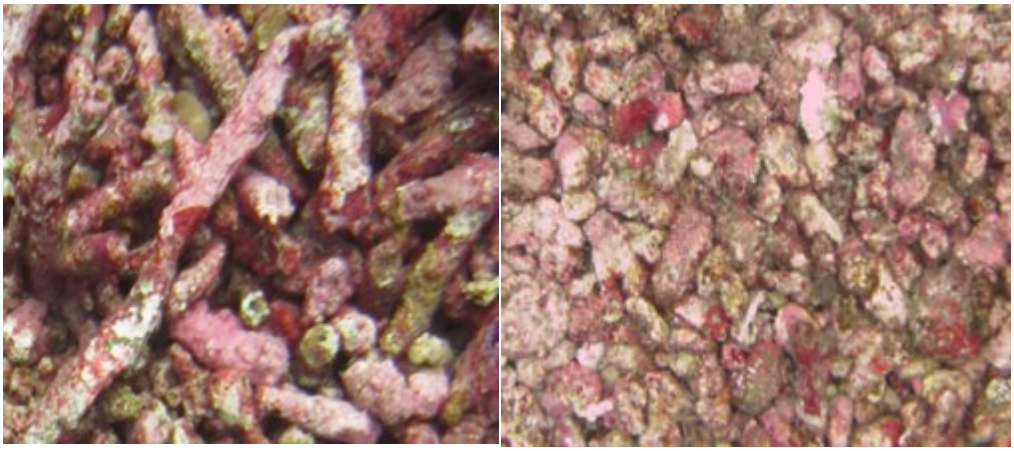


NOAA photos

Crustose coralline algae on rubble substrate (CCAR)

CCAR commonly grows on rubble, which is defined as hard fragments (e.g. rocks, pebbles, pieces of dead coral), typically gravel (>5 mm) to cobble (baseball) size with finer and coarser sediments mixed in patches. The pink and lighter red substrate in the images below is CCA; the darker, burgundy red is EMA (likely *Peysonnelia* sp.).

Tier 1 group mapping: Macroalgae



NOAA photos

IV.B.5. TURF ALGAE

Turf growing on hard substrate (TURFH)

Turf algae often appear as fuzzy carpets growing across hard substrates. Hard substrates range from pavement flats to basalt formation to bare carbonate (i.e. coral skeleton) structures. Note that turf algae tend to trap a fine layer of sediment; this still constitutes a turf covered surface and should not be classified as Sand/Fine.

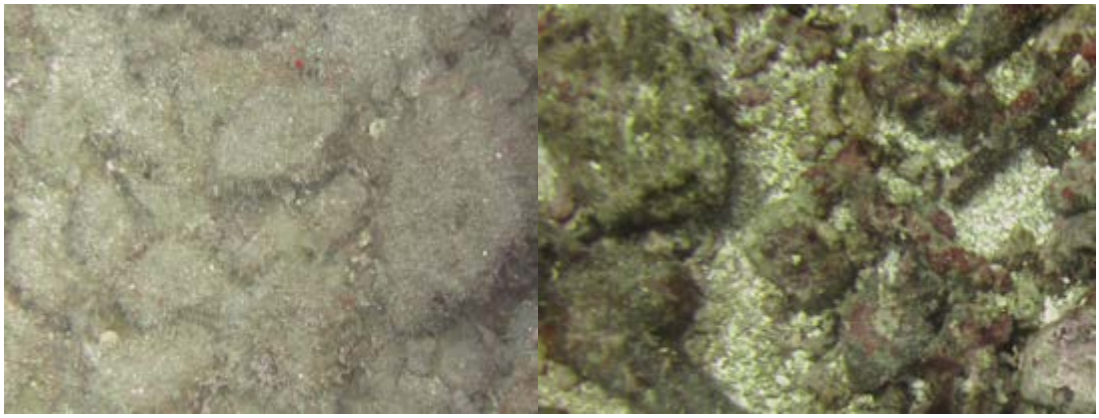
Tier 1 group mapping: Turf

NOAA photos

Turf growing on rubble substrate (TURFR)

Turf algae often cover rubble, giving the fragments a fuzzy appearance. Rubble is defined as hard fragments (e.g. rocks, pebbles, pieces of dead coral), typically gravel (> 5 mm) to cobble (baseball) size with finer and coarser sediments mixed in.

Tier 1 group mapping: Turf

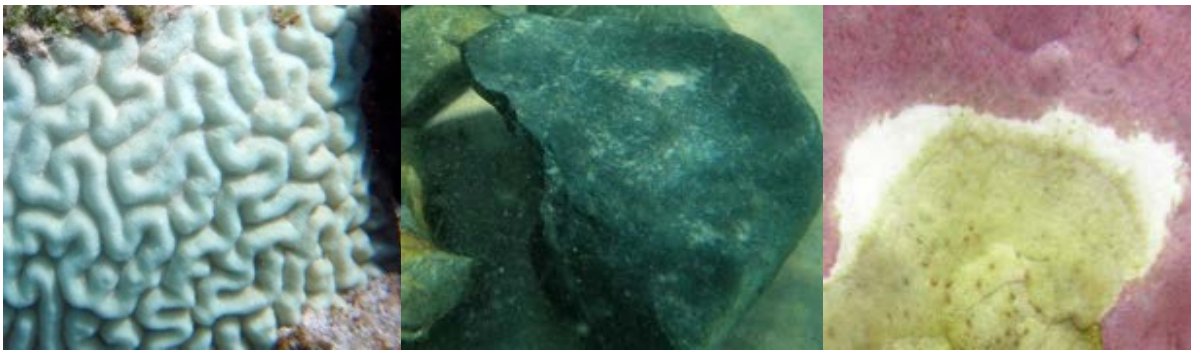


NOAA photos

Hard substrate (HARD)

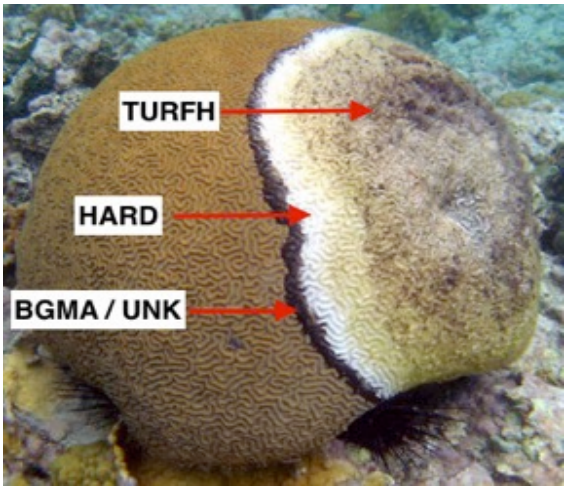
Hard surfaces are colonized by microscopic turf algae within days of being placed in the water, meaning that nearly all hard substrates are covered by turf algae even though these small organisms might not be visible in a photograph. Therefore, most hard bottom will be classified as TURFH. Substrates classified as HARD are limited to cleanly scoured pavement flats and basalt formations and bare carbonate structures (i.e. from freshly-dead coral skeleton or dead CCA).

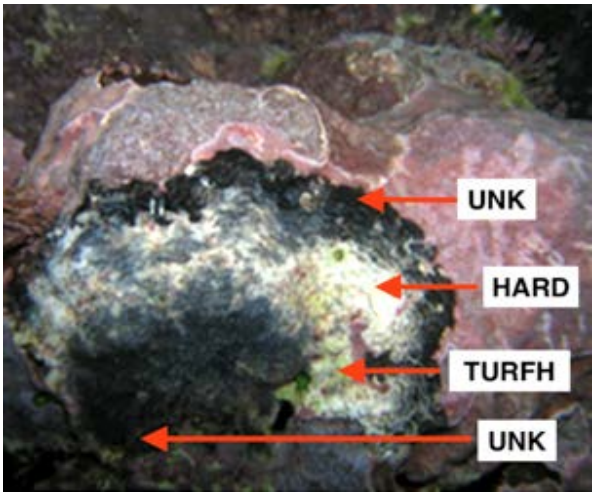
Tier 1 group mapping: Turf



NOAA photos

The following serves as a guideline in cases when a disease or predation is visible on corals and CCA: if the point falls directly on the active disease band (if present), the area underneath the point should be classified as the appropriate causative agent (e.g. blue green macroalgae in Black Band Disease), but only if the analyst is certain of the nature of the disease, otherwise, the point should be classified as UNK; if the point falls on the stark-white/recently-dead area, this area should be classified as HARD; if the point falls on the algae-covered skeleton/old-dead area, this area should be classified as TURFH.



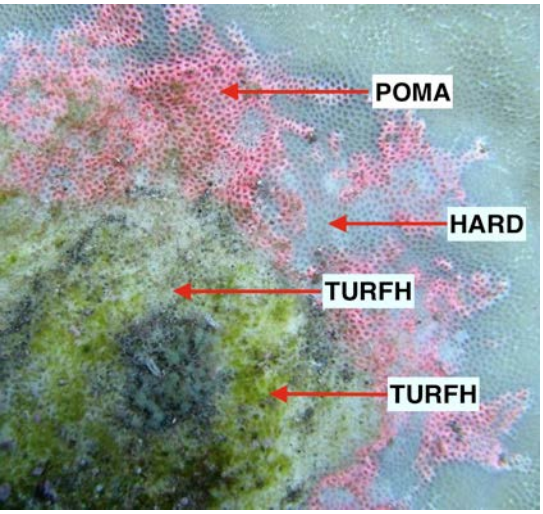


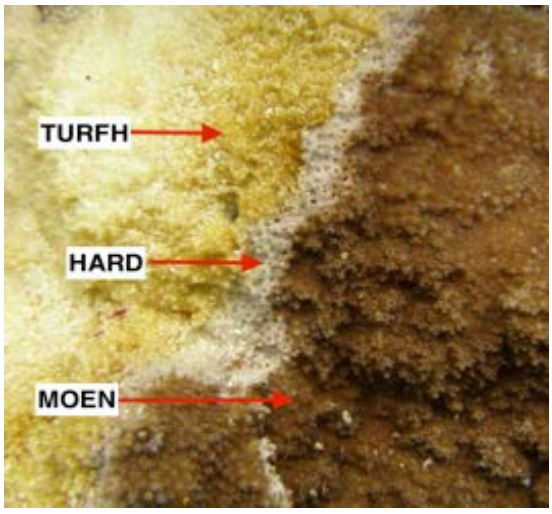
NOAA photos; clarku.edu

NOAA photos

Rubble substrate (RUB)

Hard surfaces are colonized by turf algae within days of being placed in the water. All rubble, which is defined as hard fragments (e.g. rocks, pebbles, pieces of dead coral), typically gravel (> 5 mm) to cobble (baseball) size with finer and coarser sediments mixed in, are covered by turf algae even though these small organisms might not be visible in a photograph. Therefore, most rubble will be classified as TURFR. Rubble that is in an area where it is constantly scoured (e.g. due to wave action) would be classified as RUB.





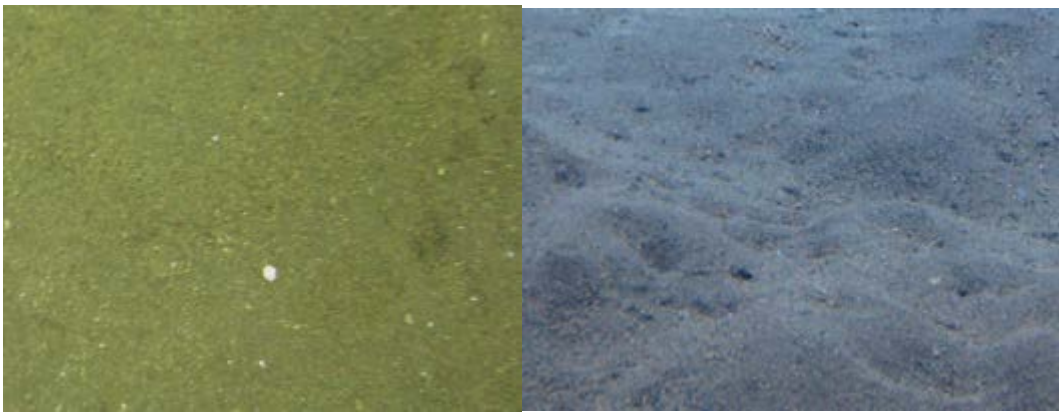
Tier 1 group mapping: Turf

NOAA photos; youwarke.files.wordpress.com

IV.B.6. SEDIMENT

Fine substrate (FINE)

Using CREP Mapping Team's classification definition, fine sediment is defined as sediment with a grain size of < 1/16 mm. A thin dusting of fine sediment over a turf-covered surface is not sufficient to be called FINE habitat. Although it can be difficult to judge from a planar photograph, substrate is generally classified as FINE when it is > 1-cm deep.



NOAA photos

Sand (SAND)

Sand is defined as sediment with a grain size between 1/16 mm and 5 mm. This can include silica sand, fine calcium carbonate sand, lava sand, and/or *Halimeda* spp. blade sand. A thin dusting of sand over a turf-covered surface is not sufficient to be called Sand habitat. Although it can be difficult to judge from a planar photograph, substrate is generally classified as SAND when it is > 1-cm deep.

NOAA photos; scripps.ucsd.edu

IV.B.7. MOBILE FAUNA

Mobile fauna (MOBF)

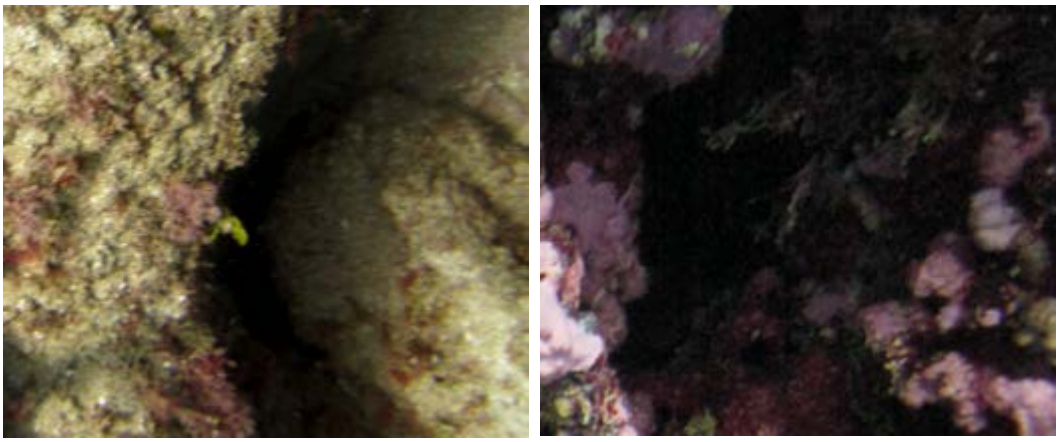
This category is appropriate when the point falls on fauna that are not permanently affixed to a single location on the sea floor (e.g. sea cucumbers, seastars, sea urchins, fish, marine mammals, etc). Effort should be made to discern what the benthic classification is under the point, if that is not possible, this category should be used.

guamreeflife.com

IV.B.8. UNCLASSIFIED

Shadow (SHAD)

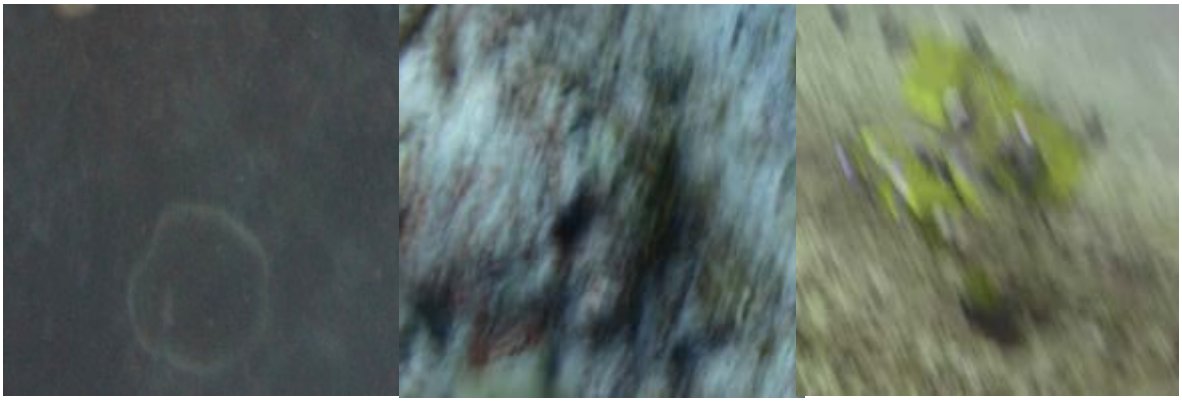
This category is appropriate when the point falls on a shadow cast by natural or anthropogenic features that prevents organism classification.



NOAA photos

Unclassified/Unknown (UNK)

This category is appropriate when the point falls on an area that is obscured or blurry and/ the substrate cannot be identified with confidence.



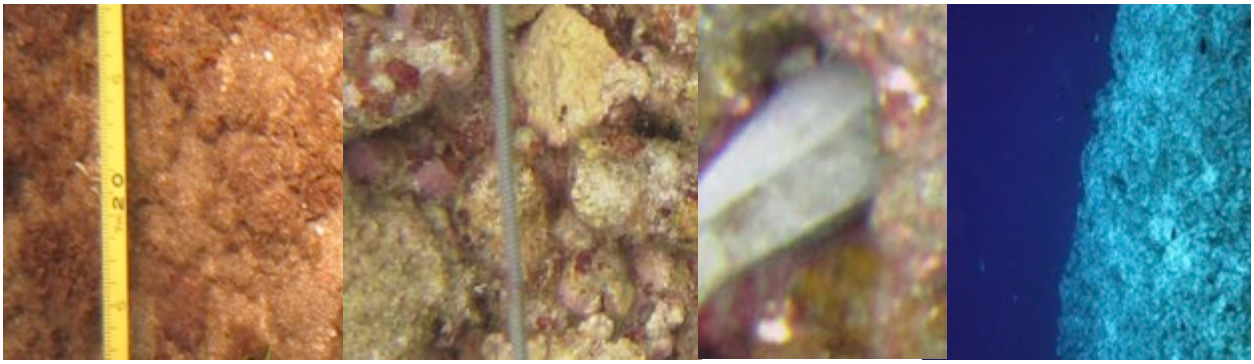
NOAA photos

IV.B.9. TAPE/WAND

The two categories in this group maintain their separate identities at Tier 2, but collapse to one category at Tier 1. Since they are artificial and not part of the substrate, they are removed from the results prior to analysis.

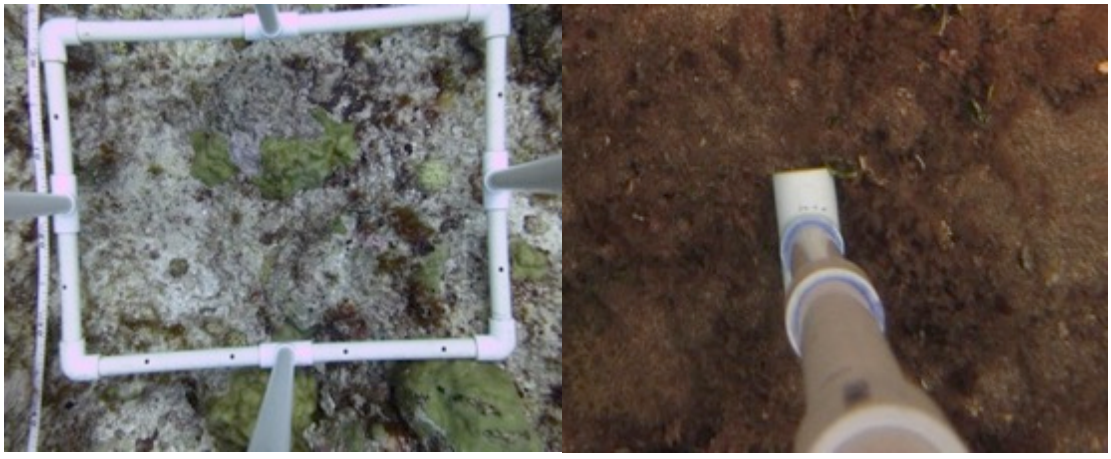
Tape (TAPE)

This category is appropriate when the point falls on the transect tape/line or tape hardware. **In the rare occasion that the point falls on the water column, this category should also be used.**
NOAA photos



Wand (WAND)

This category is appropriate when the point falls on the photoquadrat frame/spacing wand or photoquadrat hardware



NOAA photos

IV.C. BENTHIC CLASSIFICATION TIERS – MAPPING GUIDE

TAXON NAME	Genus/species Codes (TIER 3b)	Genus/species Codes (Tier 3)	Morphological Group Codes (TIER 2)	Functional Group Codes (TIER 1)
Branching hard coral	BR	BR	BR	CORAL
Columnar hard coral	COL	COL	COL	CORAL
Encrusting hard coral	ENC	ENC	ENC	CORAL
Foliose hard coral	FOL	FOL	FOL	CORAL
Free hard coral	FREE	FREE	FREE	CORAL
Massive hard coral	MASS	MASS	MASS	CORAL
Tabular hard coral	ACTA	ACTA	TA	CORAL
Non-scleractinian hard coral	MISP/HCOE/HYCO	NS	NS	CORAL
Acanthastrea spp	ACAS	ACAS	ENC	CORAL
Acropora abrotanoides	ACBR	ACBR	BR	CORAL
Acropora clathrata	ACTA	ACTA	TA	CORAL
Acropora cytherea	ACTA	ACTA	TA	CORAL
Acropora digitifera	ACBR	ACBR	BR	CORAL
Acropora humilis	ACBR	ACBR	BR	CORAL
Acropora hyacinthus	ACTA	ACTA	TA	CORAL
Acropora monticulosa	ACBR	ACBR	BR	CORAL
Acropora nasuta	ACBR	ACBR	BR	CORAL
Acropora nobilis	ACBR	ACBR	BR	CORAL
Acropora paniculata	ACTA	ACTA	TA	CORAL
Acropora samoensis	ACBR	ACBR	BR	CORAL
Acropora spp_branching	ACBR	ACBR	BR	CORAL
Acropora spp_tabulate	ACTA	ACTA	TA	CORAL
Acropora tenuis	ACBR	ACBR	BR	CORAL
Acropora valida	ACBR	ACBR	BR	CORAL
Alveopora spp.	GOAL	GOAL	ENC	CORAL
Astreopora spp.	ASSP	ASSP	ENC	CORAL
Barabattoia spp.	ENC	NEW	ENC	CORAL
Caulastrea spp.	ENC	NEW	ENC	CORAL
Cladopsammia spp.	ENC	ENC	ENC	CORAL
Coeloseris spp.	MASS	MASS	MASS	CORAL
Coscinaraea spp.	COSP	COSP	ENC	CORAL
Cycloseris spp.	FREE	FREE	FREE	CORAL
Cyphastrea spp.	CYPS	CYSP	ENC	CORAL
Diaseris spp.	FREE	FREE	FREE	CORAL
Diploastrea heliopora	DISP	MASS	MASS	CORAL
Distichopora spp.	HYCO	NS	NS	CORAL

TAXON NAME	Genus/species Codes (TIER 3b)	Genus/species Codes (Tier 3)	Morphological Group Codes (TIER 2)	Functional Group Codes (TIER 1)
Echinophyllia spp.	ECHL	ECHL	ENC	CORAL
Echinopora spp.	ECHP	ECHP	ENC	CORAL
Euphyllia spp.	EUSP	ENC	BR	CORAL
Favia spp.	FASP	FASP	MASS	CORAL
Favites spp.	FAVS	FAVS	MASS	CORAL
Fungia spp.	FUSP	FREE	FREE	CORAL
Galaxea spp.	GASP	GASP	ENC	CORAL
Gardineroseris spp.	MASS	MASS	MASS	CORAL
Goniastrea spp.	GONS	GONS	MASS	CORAL
Goniopora spp.	GOAL	GOAL	ENC	CORAL
Halomitra spp.	FREE	FREE	FREE	CORAL
Heliopora spp.	HCOE	NS	NS	CORAL
Herpolitha spp.	FREE	FREE	FREE	CORAL
Hydnophora spp.	HYSP	HYSP	MASS	CORAL
Isopora spp.	ISSP	ISSP	ENC	CORAL
Leptastrea spp.	LEPT	LEPT	ENC	CORAL
Leptoria spp.	LPHY	PLLE	MASS	CORAL
Leptoseris spp.	LESP	LESP	ENC	CORAL
Lobophyllia spp.	LOSY	LOSY	MASS	CORAL
Merulina spp.	MESP	FOL	FOL	CORAL
Millepora spp.	MISP	NS	NS	CORAL
Montastraea spp.	MONS	MASS	MASS	CORAL
Montipora aequituberculata	MOFO	MONE	FOL	CORAL
Montipora caliculata	MOEN	MOEN	ENC	CORAL
Montipora capitata	MOBR	MONE	BR	CORAL
Montipora capitata	MOEN	MONE	ENC	CORAL
Montipora capitata	MOFO	MONE	FOL	CORAL
Montipora flabellata	MOEN	MOEN	ENC	CORAL
Montipora foveolata	MOEN	MOEN	ENC	CORAL
Montipora incrassata	MOBR	MOEN	BR	CORAL
Montipora patula	MOEN	MOEN	ENC	CORAL
Montipora peltiformis	MOEN	MOEN	ENC	CORAL
Montipora spp_branching	MOBR	MONE	BR	CORAL
Montipora spp_encrusting	MOEN	MOEN	ENC	CORAL
Montipora spp_foliose	MOFO	NEW	FOL	CORAL
Montipora tuberculosa	MOEN	MOEN	ENC	CORAL
Montipora turgescens	MOEN	MOEN	ENC	CORAL
Montipora venosa	MOEN	MOEN	ENC	CORAL
Montipora verrilli	MOEN	MOEN	ENC	CORAL

TAXON NAME	Genus/species Codes (TIER 3b)	Genus/species Codes (Tier 3)	Morphological Group Codes (TIER 2)	Functional Group Codes (TIER 1)
Montipora verrucosa	MOEN	MOEN	ENC	CORAL
Mycedium spp.	ENC	ENC	ENC	CORAL
Oulophyllia spp.	OUSP	MASS	MASS	CORAL
Oxypora spp.	FOL	ENC	FOL	CORAL
Pachyseris spp.	PACS	FOL	FOL	CORAL
Paraclavarina spp.	BR	NEW	BR	CORAL
Pavona bipartita	PAMA	PAVS	MASS	CORAL
Pavona cactus	PAFO	PAVS	FOL	CORAL
Pavona chiriquiensis	PAEN	PAVS	ENC	CORAL
Pavona clavus	PAMA	PAVS	MASS	CORAL
Pavona decussata	PAFO	PAVS	FOL	CORAL
Pavona diffluens	PAEN	PAVS	ENC	CORAL
Pavona duerdeni	PAMA	PAVS	MASS	CORAL
Pavona explanulata	PAEN	PAVS	ENC	CORAL
Pavona explanulata	PAMA	PAVS	MASS	CORAL
Pavona frondifera	PAFO	PAVS	FOL	CORAL
Pavona maldivensis	PAEN	PAVS	ENC	CORAL
Pavona minuta	PAEN	PAVS	ENC	CORAL
Pavona spp_encrusting	PAEN	PAVS	ENC	CORAL
Pavona spp_foliose	PAFO	PAVS	FOL	CORAL
Pavona spp_massive	PAMA	PAVS	MASS	CORAL
Pavona varians	PAEN	PAVS	ENC	CORAL
Pavona venosa	PAMA	PAVS	MASS	CORAL
Pectinia spp.	FOL	NEW	FOL	CORAL
Platygyra spp.	PLSP	PLLE	MASS	CORAL
Plerogyra spp.	PLER	ENC	BR	CORAL
Plesiastrea spp.	ENC	MASS	ENC	CORAL
Pocillopora spp.	POCS	POCS	BR	CORAL
Podabacia spp.	FOL	FREE	FOL	CORAL
Porites annae	POBR	PONM	BR	CORAL
Porites arnoudi	POFO	POMA	FOL	CORAL
Porites arnoudi	POMA	POMA	MASS	CORAL
Porites australiensis	POMA	POMA	MASS	CORAL
Porites bernardi	POEN	POMA	ENC	CORAL
Porites brighami	POEN	POMA	ENC	CORAL
Porites compressa	POBR	PONM	BR	CORAL
Porites cylindrica	POBR	PONM	BR	CORAL
Porites densa	POMA	POMA	MASS	CORAL
Porites duerdeni	POBR	POMA	BR	CORAL
Porites evermanni	POMA	POMA	MASS	CORAL

TAXON NAME	Genus/species Codes (TIER 3b)	Genus/species Codes (Tier 3)	Morphological Group Codes (TIER 2)	Functional Group Codes (TIER 1)
Porites horizontalata	POBR	POMA	BR	CORAL
Porites horizontalata	POEN	POMA	ENC	CORAL
Porites horizontalata	POFO	POMA	FOL	CORAL
Porites lichen	POBR	POMA	BR	CORAL
Porites lichen	POEN	POMA	ENC	CORAL
Porites lobata	POEN	POMA	ENC	CORAL
Porites lobata	POMA	POMA	MASS	CORAL
Porites lutea	POEN	POMA	ENC	CORAL
Porites lutea	POMA	POMA	MASS	CORAL
Porites monticulosa	POBR	POMA	BR	CORAL
Porites monticulosa	POEN	POMA	ENC	CORAL
Porites monticulosa	POFO	POMA	FOL	CORAL
Porites murrayensis	POEN	POMA	ENC	CORAL
Porites murrayensis	POMA	POMA	MASS	CORAL
Porites rus	POBR	PONM	BR	CORAL
Porites rus	POEN	PONM	ENC	CORAL
Porites rus	POFO	PONM	FOL	CORAL
Porites solida	POEN	POMA	ENC	CORAL
Porites solida	POMA	POMA	MASS	CORAL
Porites spp_branching	POBR	PONM	BR	CORAL
Porites spp_encrusting	POEN	PONM	ENC	CORAL
Porites spp_foliose	POFO	NEW	FOL	CORAL
Porites spp_massive	POMA	POMA	MASS	CORAL
Porites vaughani	POEN	POMA	ENC	CORAL
Psammocora spp.	PSSP	PSSP	ENC	CORAL
Sandalolitha spp.	FREE	FREE	FREE	CORAL
Scapophyllia spp.	ENC	ENC	ENC	CORAL
Scolymia spp.	ENC	ENC	ENC	CORAL
Seriatopora spp.	BR	NEW	BR	CORAL
Stylaster spp.	HYCO	NS	NS	CORAL
Stylocoeniella spp.	ENC	ENC	ENC	CORAL
Stylophora spp.	STYS	STYS	BR	CORAL
Symphyllia spp.	SYSP	LOSY	MASS	CORAL
Tubastraea spp.	ENC	ENC	ENC	CORAL
Turbinaria spp.	TURS	TURS	FOL	CORAL
Black coral - Antipatharia	USC	USC	USC	SC
Cladiella spp.	OCTO	OCTO	OCTO	SC
Dendronephthya spp.	OCTO	OCTO	OCTO	SC
Lobophytum spp.	OCTO	OCTO	OCTO	SC
Octocoral	OCTO	OCTO	OCTO	SC

TAXON NAME	Genus/species Codes (TIER 3b)	Genus/species Codes (Tier 3)	Morphological Group Codes (TIER 2)	Functional Group Codes (TIER 1)
Pachyclavularia spp.	OCTO	OCTO	OCTO	SC
Sarcophyton spp.	OCTO	OCTO	OCTO	SC
Sinularia spp.	OCTO	OCTO	OCTO	SC
Soft Coral	OCTO	OCTO	OCTO	SC
Stereonephthya spp	OCTO	OCTO	OCTO	SC
Unclassified soft coral	USC	USC	USC	SC
Wire coral - Antipatharia	USC	USC	USC	SC
Anemone	AMNE	AMNE	AMNE	INV
Bivalve	BI	BI	BI	INV
Bryozoan	BRY	BRY	BRY	INV
Corallimorph	CMOR	CMOR	CMOR	INV
Discosoma spp.	CMOR	CMOR	CMOR	INV
Giant clam	GC	GC	GC	INV
Palythoa spp.	ZO	ZO	ZO	INV
Protopalythoa spp.	ZO	ZO	ZO	INV
Rhodactis spp.	CMOR	OCTO	CMOR	INV
Sponge	SP	SP	SP	INV
Tunicate	TUN	TUN	TUN	INV
Unclassified sessile invertebrate	UI	UI	UI	INV
Zoanthus spp.	ZO	ZO	ZO	INV
Asparagopsis spp.	ASPP	ASPP	UPMA	MA
Avrainvillea spp.	AVSP	AVSP	UPMA	MA
Blue-green macroalga	BGMA	BGMA	BGMA	MA
Brown macroalgae	BRMA	UPMA	UPMA	MA
Caulerpa spp.	CAUL	CAUL	UPMA	MA
Dictyopteris spp.	DICO	DICO	UPMA	MA
Dictyosphaeria spp.	DICT	DICT	UPMA	MA
Dictyota spp.	DICO	DICO	UPMA	MA
Encrusting macroalgae	EMA	EMA	EMA	MA
Green macroalgae	GRMA	UPMA	UPMA	MA
Halimeda spp.	HALI	HALI	HALI	MA
Lobophora spp.	LOBO	LOBO	EMA	MA
Microdictyon spp.	MICR	MICR	UPMA	MA
Neomeris spp.	NEOM	NEOM	UPMA	MA
Padina spp.	PADI	PADI	UPMA	MA
Peyssonnelia spp.	PESP	PESP	EMA	MA
Red macroalgae	RDMA	UPMA	UPMA	MA
Seagrass	SG	SG	SG	MA
Upright macroalgae	UPMA	UPMA	UPMA	MA

TAXON NAME	Genus/species Codes (TIER 3b)	Genus/species Codes (Tier 3)	Morphological Group Codes (TIER 2)	Functional Group Codes (TIER 1)
CCA growing on hard substrate	CCAH	CCAH	CCAH	CCA
CCA growing on rubble	CCAR	CCAR	CCAR	CCA
Turf on growin hard substrate	TURFH	TURFH	TURFH	TURF
Turf growing on rubble	TURFR	TURFR	TURFR	TURF
Hard substrate	HARD	HARD	HARD	TURF
Rubble substrate	RUB	RUB	RUB	TURF
Fine sediment	FINE	FINE	FINE	SED
Sand	SAND	SAND	SAND	SED
Mobile fauna	MOBF	MOBF	MOBF	MOBF
Shadow	SHAD	SHAD	SHAD	UC
Unclassified benthos	UNK	UC	UNK	UC
Tape	TAPE	TAPE	TAPE	TW
Wand	WAND	WAND	WAND	TW

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