



ReefCloud Training Manual

Harnessing the best in AI and on-ground knowledge
to help secure a future for coral reefs

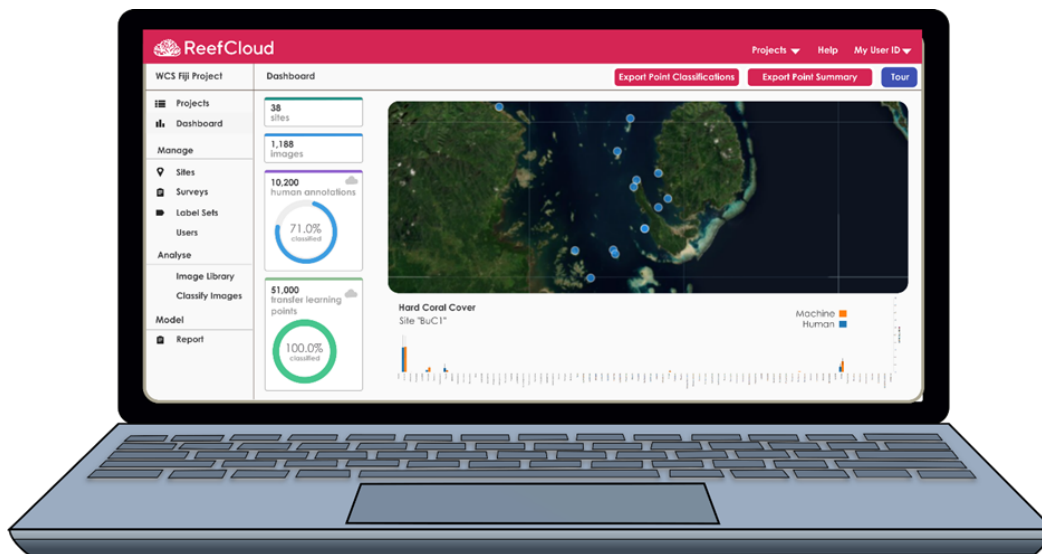
Welcome to ReefCloud

A quick introduction to the ReefCloud platform

The following set of training manuals are designed to support your use of [ReefCloud](#), a publicly accessible digital online platform for helping you and monitoring teams around the world store, analyse and share results from your coral reef photo monitoring activities.

ReefCloud is an [Australian Institute of Marine Science \(AIMS\)](#) led initiative, built by coral reef scientists for coral reef scientists. Digital technologies initially developed to support AIMS own long term monitoring activities on the Great Barrier Reef have been adapted with guidance and input of coral reef monitoring experts from across the Pacific.

Discovering shared challenges around storing, processing and analysing increasingly large amounts of benthic photo data helped us shape ReefCloud into a versatile and easy-to-use tool that has been trialed and tested by monitoring teams from government and academic research organisations to ranger groups, tourism operators and citizen scientists.



The resulting product, ReefCloud, is now free to use for everyone, and we hope the website and associated tools prove useful to your work.

Welcome! And don't hesitate to contact us at support@reefcloud.ai to speak to our team directly. We looking forward to helping you dive deeper into your data using ReefCloud.ai!

ReefCloud Background

To make informed decisions about the best way to manage coral reefs, scientists need to be able to accurately monitor their condition, gathering data about how they are being impacted by increasing pressures. As coral reefs experience increasingly severe levels of environmental stress, it is critical that monitoring remains accurate, compatible, and collaborative to support coral reef conservation.

ReefCloud is an open-access platform, designed to collate data quickly and efficiently from multiple sources to inform reef management decisions. Guided by end-users and using cutting-edge technology in data science and machine learning, ReefCloud will help to:

- Manage, archive, and share monitoring data;
- Fast-track the recording of changes to coral reef communities using automated technologies; and
- Collaborate and communicate widely on our understanding of where and how coral reefs are changing.

There are four simple steps to using ReefCloud, and we have compiled a suite of digital training resources to support users with each of these steps.



Get Started

Create your ReefCloud account
Set up a project
Add users to your team



Collect

Add surveys to your sites
Upload photos
Review your image library



Analyse

Annotate images
Train AI algorithm
Validate results



Explore

View your trends
Export results for analysis
Share with the world

Coral reefs and monitoring

Despite evolving technology to help us map and monitor the marine environment from above and below across bigger scales and in greater detail than ever before, climate change and other human drivers are forcing coral reefs to change at paces and scales that are making it harder and harder for us to track, let alone take meaningful action on.

For example, in the Pacific, where we are based, only a small proportion of our reefs - 4000 sites across 70,000km - are regularly monitored according to the [Global Coral Reef Monitoring Network](#).

Where they *are* monitored, that critical monitoring effort isn't always supplying information on to the people having to make decisions about how to protect and manage reefs. Barriers and delays in information flow from the rangers and field scientists to the managers and policy makers weakens the bridge between scientific findings and meaningful and timely conservation action.

We know what many of these barriers are, but can technology help us overcome them? If we can overcome these barriers in the Pacific, we can overcome them in the rest of the world too.

Our vision for inclusivity in monitoring

At the heart of ReefCloud is the role technology can play in overcoming common barriers to participation in coral reef monitoring. Expanding the network of marine scientists contributing data will help reduce key geographic gaps in monitoring and improve our global understanding of the health status.

Digital underwater photography for example is increasingly being adopted as a way of making observations. Digital photos revolutionise the way we record information about reefs, and advantages over pen and paper records, providing a standardised format and a permanent record that can be revisited.

As cameras have become more affordable, monitoring has become cheaper and more accessible – you don't need taxonomic expertise to collect information. And this means monitoring groups outside of academia and government research bodies, who's expertise hasn't always been included are able to contribute to global monitoring efforts. More inclusive monitoring approaches rely not just on technology to help us standardise the way we collect observations – from digital cameras under the water to remote sensing technologies above. But also needs data science and new technologies that can improve the way we analyse, store and share data with each other so we can directly compare and integrate knowledge.

To date, ReefCloud has been successfully piloted in Palau, Fiji, the Maldives, Vanuatu, and Australia, drawing on contributions of both images and advice from over 30 nations and territories across the world, and has been adopted by government research agencies, to citizen science groups to Indigenous communities.

A message from the ReefCloud founder

“Here at the Australian Institute of Marine Science, we’ve been monitoring coral reefs since the year I was born. Long term datasets on coral reefs help Australia do a better job of managing and protecting the reef, meaning Great Barrier Reef is one of the best managed reef systems on the planet. Not only have we had programs like Long Term Monitoring and Inshore monitoring program shaped our scientific understanding of reef processes, but we are proud that our standards and protocols and have been adopted by groups worldwide.

As a coral reef monitoring scientist, I’ve seen the way we collect the field data evolve over my career with a pen and paper to write down observations of what they saw – AIMS were among the first organisations to adopt digital underwater photography that’s becoming so popular now - meant we can now send divers with cameras instead. Those cameras can collect even more information, and we don’t have to rely on trained experts so can send bigger teams out. But despite this digital photography revolution, data science has failed to keep up with the analysis of this biological data into delivery to result in real world action.

My vision has been to harness latest technologies to help make the flow of data from the field to decision makers faster and more efficient.”



Dr Manuel Gonzalez-Rivero
ReefCloud Founder

Features overview

ReefCloud is an online data platform using cutting-edge artificial intelligence and advanced statistical models to automatically extract, analyse and synthesize data obtained from coral reef monitoring imagery.

Three innovations underpin how we support coral reef monitoring.



Cloud-based computing

Secure storage and management of photo data



Machine learning algorithms

Speed up analysis workflows with manual and AI coral tagging



Bayesian Modelling

Automated analysis, data synthesis and reporting

ReefCloud harnesses three technological innovations, that help 1) standardise, 2) speed up and 3) simplify the way we integrate and share coral reef monitoring data.

1. Cloud-based computing

Standardisation and storage in a global repository of coral reef photo data

Digital photo quadrats contain a wealth of detailed biological information. Storing, organising and managing this information in a standardised way is a critical first step in both securing the data and making it accessible and usable. The first thing ReefCloud offers is cloud-based computing that allows for the long-term safe storage, structured organisation and importantly ongoing management of data, in one safe and accessible online repository. As one of the planet's largest standardised repositories for coral reef photos, this not only safeguards the investment you made in collecting your field data, but means your photos contribute to this critical global permanent record of reef health.

ReefCloud also provides a platform that ensures that monitoring teams such as citizen scientists, local custodians and communities – who's data collection efforts aren't traditionally included in major government and global level science reporting due to the way it needs to be gathered and organized – are valued and included.

2. Artificial Intelligence

Speeding up analysis workflows

A level of taxonomic expertise and often a significant amount of time is required for analysing photo data, and this has been another barrier to information flow from reef to decision-maker. The second innovation of ReefCloud is the use of Artificial Intelligence (AI) to help speed up extraction of biological information from the photos you collected.

You may have heard of “Deep Learning”. It’s a form of AI that has permeated all aspects of the web, and can be found everywhere from your mobile phone to your home fridge. At ReefCloud we use this technique for learning how to identify corals in images. Lucky for us, users have donated millions of images of corals to help computers learn! And with your help we want to aggregate coral reef imagery from all over the world so we can have computers do the heavy lifting in tracking the health of coral reefs globally.

ReefCloud’s AI models have achieved 700 times improvement in the rate at which data can be extracted, analysed, and reported compared to manual efforts. Such efficiency gains, also mean potential of reallocation of funds through savings in terms of operational costs (77x cheaper (González-Rivero, Beijbom et al. 2020)) and human capacity (e.g., 16x reduction in people’s time invested in image analyses). Therefore, through automated approaches credible information is delivered to managers and decision makers in near real-time thereby negating the time-lag in reporting that is a consequence of traditional analytical methods.

3. Automated reporting

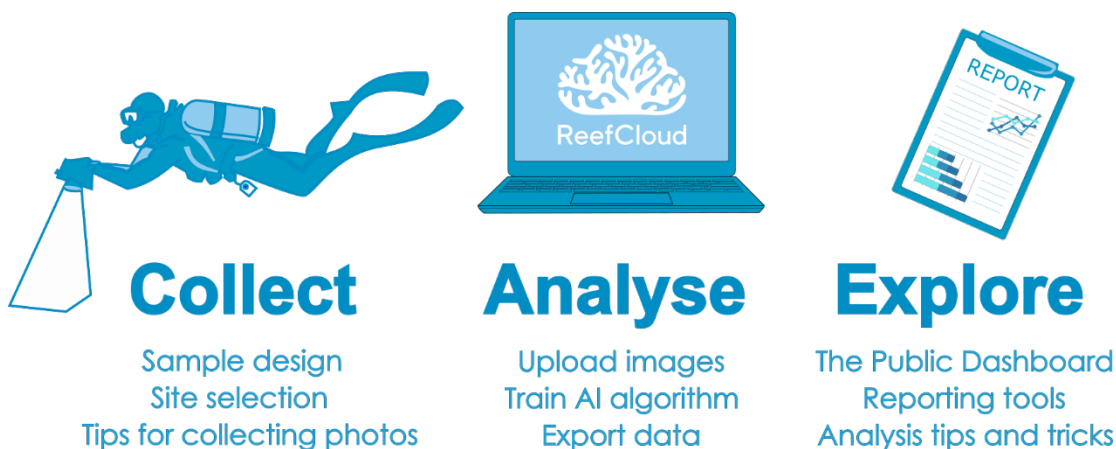
Simplifying the path from data to decision-making

ReefCloud’s final innovation is in the sophisticated statistical modelling techniques applied to the data, that allow biological information from across multiple individual projects and geographies to be integrated at a higher level it so can be displayed and accessed in a single standardised format in near real-time. Real-time data are delivered to the [ReefCloud Public Dashboard](#) for anyone to access.

Expanding ReefCloud to advance interoperability, integration, sharing, use and re-use of coral reef monitoring data to support local management decisions will also assist in the production of future [GCRMN Status of Coral Reefs of the World](#) reports, with faster dissemination of knowledge on reefs hopefully leading to faster response times and action to protect them.

ReefCloud manual outline

The ReefCloud manual is divided into three standalone sections. Each of these workbooks comes with accompanying videos and other resources, including presentations and online tools and links for further information and support. A suite of other resources and training materials are available online on our Resources Page.



Part 1. Collect Photos

Suggestions for sample design and tips for photo data collection for ReefCloud.

This first section of the manual (currently only available online) deals with collecting field data for use with ReefCloud. Monitoring teams may have pre-existing survey sites and an established sampling design. ReefCloud is designed to be flexible to work within the confines of your existing monitoring set up – if you are already conducting coral reef monitoring, we suggest you skip Part 1 unless you or your team are looking for advice on this.

Part 2. Analyse Data

A step-by-step walk through of the ReefCloud data portal for analysis of photo data




This section of the ReefCloud manual (included below) is intended as a standalone guide to the use of the ReefCloud platform – specifically from setting up an account, to uploading photos, extracting information from those photos with the support of AI and viewing your results. As well as being available here, it is also found under the 'Help' section on the website. Start here if you have monitoring photos and you're ready to go!

Part 3. Explore Results

This Reporting Toolkit (currently only available online) is available for users wanting to explore their data further and looking for support with reporting.

It is available [here](#).

If you get stuck using the manuals at any time, you may want to look at our online [FAQ pages](#), where we have compiled the answers to the most frequently asked questions on Machine Learning, Data Collection, ReefCloud Use and Troubleshooting.

| Manual section | Modules |
|---|--|
| <p>Part 1. Collect Photos</p>  <p>Collect</p> | <p>1.1. Sample design and site selection 1.2. Collecting photos <i>currently online only</i></p> |
| <p>Part 2. Analyse Data</p>  <p>Analyse</p> | <p>2.1. Getting started in ReefCloud 2.2. Uploading images 2.3. Analysing images / training AI 2.4. Export results</p> |
| <p>Part 3. Explore Results</p>  <p>Explore</p> | <p>3.1. Exploring my data 3.2. The Public Dashboard 3.3. Reporting toolkit <i>currently online only</i></p> |

Thank-You to our ReefCloud family!

The production and ongoing development of ReefCloud has been a huge collaborative effort! We acknowledge the teams around the world who have helped contribute to the development of ReefCloud, including funding partners to platform users who have provided feedback and guidance during its development.

We hope you find this guide easy to use. Please get in contact if you are interested in teaching others and we can supply you with our 'train-the-trainers' teaching pack.

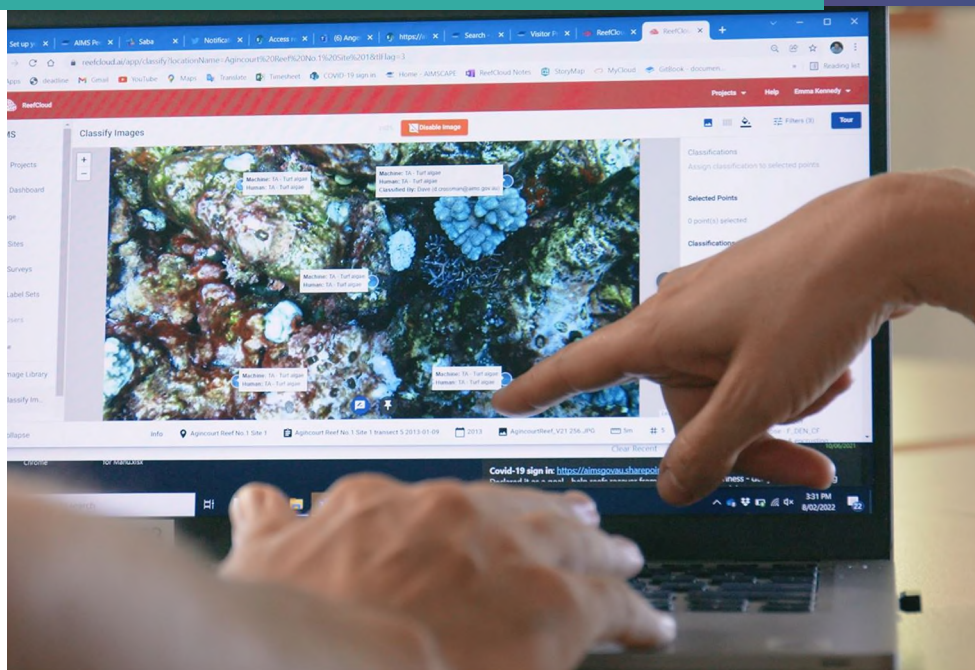
Table of Contents

| | |
|--|-----------|
| WELCOME TO REEF CLOUD..... | 1 |
| A quick introduction to the ReefCloud platform..... | 1 |
| REEFCLOUD BACKGROUND | 2 |
| Coral reefs and monitoring..... | 2 |
| Our vision for inclusivity in monitoring | 3 |
| FEATURES OVERVIEW..... | 5 |
| 1. Cloud-based computing..... | 5 |
| Standardisation and storage in a global repository of coral reef photo data..... | 5 |
| 2. Artificial Intelligence | 6 |
| Speeding up analysis workflows | 6 |
| 3. Automated reporting | 6 |
| Simplifying the path from data to decision-making | 6 |
| REEFCLOUD MANUAL OUTLINE | 7 |
| Part 1. Collect Photos | 7 |
| Suggestions for sample design and tips for photo data collection for ReefCloud..... | 7 |
| Part 2. Analyse Data | 7 |
| A step-by-step walk through of the ReefCloud data portal for analysis of photo data..... | 7 |
| Part 3. Explore Results | 7 |
| This Reporting Toolkit (currently only available online) is available for users wanting to explore their data further and looking for support with reporting. | 7 |
| THANK-YOU TO OUR REEF CLOUD FAMILY! | 8 |
| TABLE OF CONTENTS | 9 |
| REEFCLOUD USER MANUAL..... | 12 |
| PART 2: ANALYSING DATA IN REEF CLOUD..... | 13 |

| | |
|--|-----------|
| Sampling approaches, camera settings and tips for in-the-field collection of photographic data to be used in ReefCloud. | 13 |
| Features overview | 14 |
| MODULE 2.1. GET STARTED! | 16 |
| 2.1.1 Sign Up | 16 |
| 2.1.2 Set up your project | 16 |
| Creating a new Project..... | 17 |
| Step 1. Project Details..... | 17 |
| Step 2. Data capture method..... | 18 |
| Step 3. Setup AI model | 19 |
| Step 4. Data Permissions | 24 |
| 2.1.3 Add Users to your Project..... | 25 |
| MODULE 2.2. COLLECT YOUR DATA | 28 |
| 2.2.1 Configure your surveys | 28 |
| Sites..... | 28 |
| Surveys..... | 30 |
| 2.2.2 Upload Images..... | 33 |
| Upload images one survey at a time. | 33 |
| Bulk upload for multiple surveys. | 34 |
| 2.2.3 Review your images..... | 36 |
| MODULE 2.3. ANALYSE YOUR PHOTOS | 37 |
| 2.3.1 Train Automated Image Analysis | 37 |
| Manual image analysis for training..... | 37 |
| Additional tools to help you analyse images: | 37 |
| 2.3.2 Label set editing and mapping | 38 |
| Managing your label set | 38 |
| Label set mapping..... | 39 |
| 2.3.3 Validating AI results..... | 41 |
| Model Validation | 42 |
| Site Validation..... | 42 |
| MODULE 2.4. EXPLORE RESULTS | 44 |
| 2.4.1 View your project summary | 44 |

| | |
|-------------------------------------|-----------|
| 2.4.2 Export your data | 46 |
| 2.4.3 Public Dashboard | 46 |
| General Dashboard features..... | 46 |
| Benthic summary data..... | 47 |
| Environmental pressures..... | 51 |
| GLOSSARY | 55 |
| ReefCloud Data Portal | 55 |
| ReefCloud Public Dashboard | 55 |
| Project..... | 55 |
| Site | 55 |
| Survey | 55 |
| Human Annotatable Points..... | 55 |
| Transfer Learning Points | 56 |
| Model..... | 56 |

ReefCloud Manual Part 2



Part 2: Analysing data in ReefCloud

Sampling approaches, camera settings and tips for in-the-field collection of photographic data to be used in ReefCloud.

To make informed decisions about the best way to manage our precious coral reefs, we need to be able to accurately monitor their condition, gathering data about how they are being impacted by increasing pressures. As coral reefs experience environmental stress, it is critical that monitoring remains accurate, compatible, and collaborative to support coral reef conservation.

ReefCloud can help you:

- Manage, archive, and share monitoring data;
- Fast-track the recording of changes to coral reef communities using automated technologies; and
- Collaborate and communicate widely on our understanding of where and how coral reefs are changing.

To use ReefCloud you just need to follow 4 simple steps:



Get Started

Create your ReefCloud account
Set up a project
Add users to your team



Collect

Add surveys to your sites
Upload photos
Review your image library



Analyse

Annotate images
Train AI algorithm
Validate results



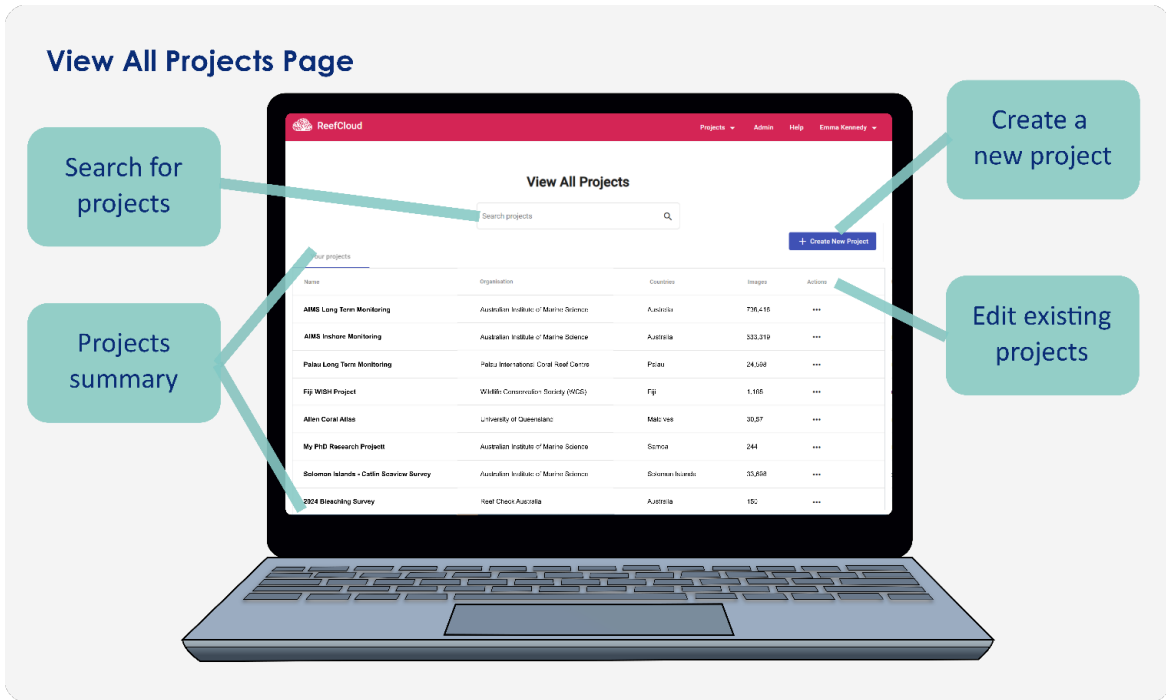
Explore

View your trends
Export results for analysis
Share with the world

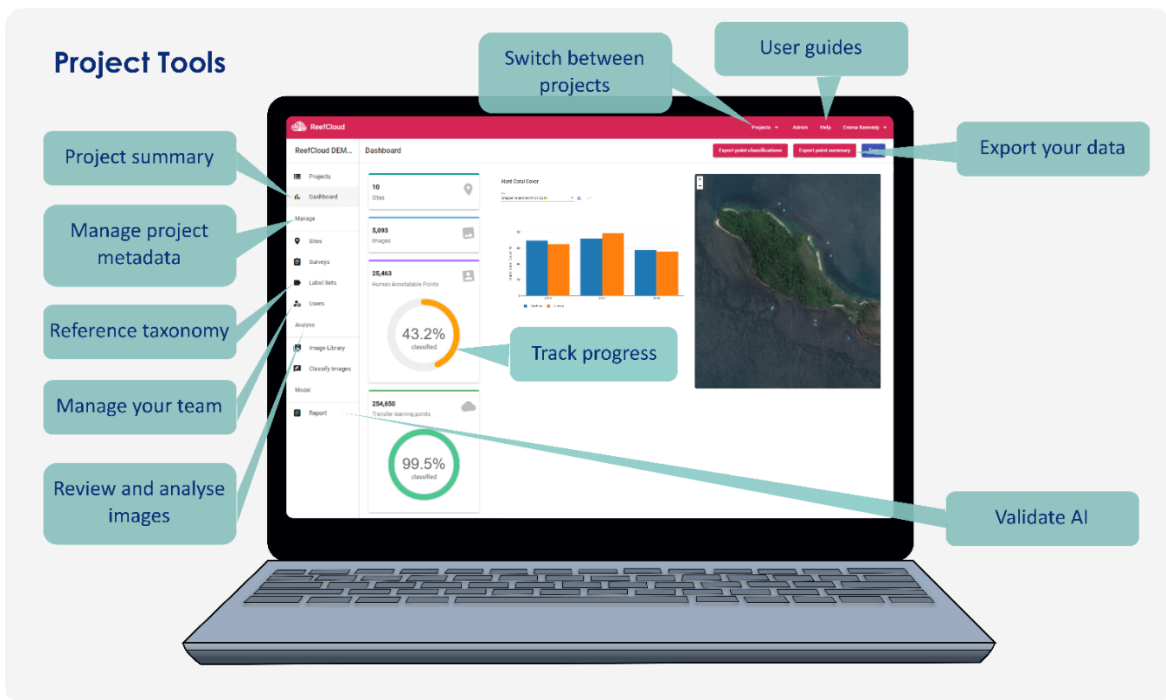
Hot tip!

ReefCloud is best supported for use in the Google Chrome browser and may not function as well in other internet browsers, such as Internet Explorer.

Features overview



The "View all Projects" page allows you to navigate through your projects and configure them.



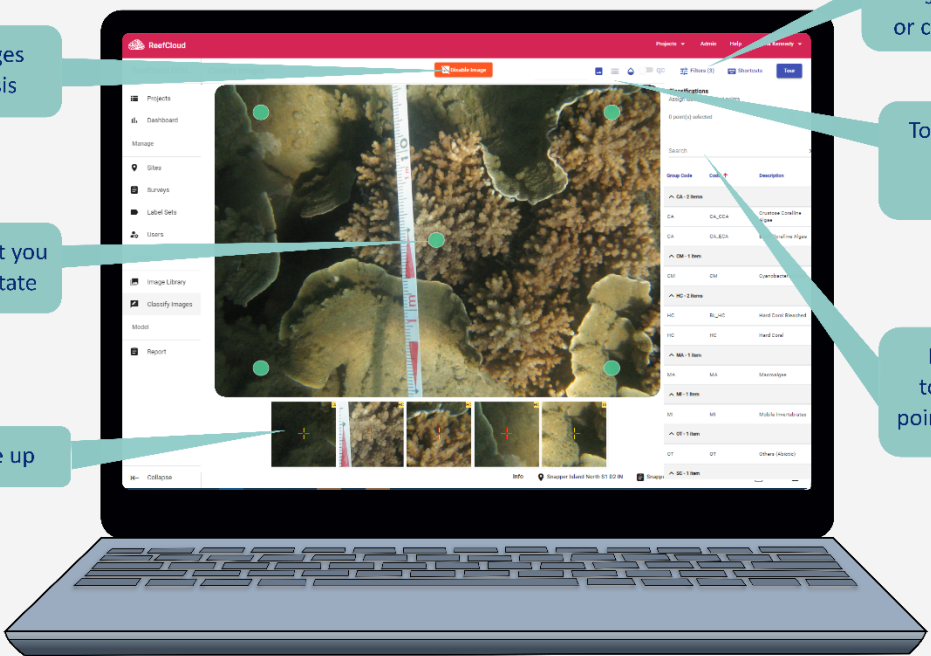
Within the Project Page, you can explore the results and work on your project

Image Analysis

Exclude images from analysis

Select the point you want to annotate

Points close up



Filter photos by site, date or classification

Toggle between image and point view

Find a label to assign to a point in the image

Classify Images allows you to annotate your coral reef photos to train the AI models for automated analysis

Module 2.1. Get Started!

Signing up, setting up your project and adding users

2.1.1 Sign Up

Sign up for an account at reefcloud.ai and click “**Login to Data Portal**”. If you already have an account, enter your username and password to sign in. Otherwise, click “**Sign up**” for a new account.

- Create a username, enter your name and e-mail.
- Create a password. Note your password must contain at least:
 - One lower case letter.
 - One upper case letter.
 - One special character
 - One number
- Eight (8) characters in total.

After signing up you will receive a confirmation email to verify your new account.

If you forget your password for ReefCloud, click the “Forgot your password?” prompt and enter your username. Please note that you can use your email address as the username; they are interchangeable. We will send a message to your registered email to reset your password.

2.1.2 Set up your project

Projects define your studies, monitoring programs or research projects. A **Project** consists of images (photo-quadrats) collected within a set of sites and surveyed once or over repeated periods, and associated annotations and data. **Projects** can be set up to include **Users** who can manage the project details (**Admin user**) or those who can view and analyse the data (**General user**).

You can use **Projects** to define data collected for different purposes (e.g., monitoring programs), define specific label-sets and methodology, share data among collaborators, summarise the results, export data in bulk, etc.



Sign up with a new account

Username

Name

Email

Password

- ✓ Password must contain a lower case letter
- ✗ Password must contain an upper case letter
- ✗ Password must contain a special character
- ✗ Password must contain a number
- ✗ Password must contain at least 8 characters

Sign up

Already have an account? Sign in

Creating a new Project

The screenshot shows the 'View All Projects' page in ReefCloud. At the top, there is a navigation bar with the ReefCloud logo, 'Projects', 'Help', and 'My User Account'. Below the navigation bar, the title 'View All Projects' is centered. A search bar with the placeholder text 'Search projects' and a magnifying glass icon is positioned below the title. To the right of the search bar is a blue button with a plus sign and the text '+ Create New Project'. Below these elements is a section titled 'Your projects' which contains a table with the following data:

| Name | Organisation | Countries | Images | Actions |
|----------------------------|--|-----------|---------|---------|
| AIMS Long Term Monitoring | Australian Institute of Marine Science | Australia | 736,416 | ... |
| AIMS Inshore Monitoring | Australian Institute of Marine Science | Australia | 333,319 | ... |
| Palau Long Term Monitoring | Palau International Coral Reef Centre | Palau | 24,598 | ... |
| Fiji WISH Project | Wildlife Conservation Society (WCS) | Fiji | 1,188 | ... |

Overview of the project page

Once you login into ReefCloud, a list of **Projects** that either you manage or are a member of is presented in the Projects table. From here you can navigate through your Projects or create a new one.

By clicking on the blue “**Create Project**” button you will be taken through a wizard that takes you step-by-step through a new project setup, which involves adding project details and choosing a labelset and point sampling method.

Step 1. Project Details.

Project Name and *Project Description* are required fields. Try and keep *Project Name* short and informative, as it may be viewable to other users. This can't be edited later, as it is the key that ties all your information together.

Project Description is intended to summarise the science behind your project, aims, and any other relevant background information. This will also be viewable by other users, even if your data remain private.

Organisations is an optional field and it is intended to register the different organisations affiliated to this Project. You can select as many organisations as needed from the list. Selecting an *Organisation* can make your project easier for collaborators to find. If you don't see your organisation listed, please email us so we can add you! We're working on an option to request new organisations to be added. *If you choose to make your project public, your Organisation may appear on the [ReefCloud Public Dashboard](#).*

Create New Project

1
2
3
4

Project Details
Data capture method
Setup AI Model
Data Permissions

Project details

A ReefCloud project will define your study, monitoring programs or research projects. A project consists of multiple sites which have been surveyed once or over repeated periods. Each survey or transect will include multiple images.

Project Name

The name of your project

0 / 128

Project Description

Briefly summarise the purpose of your project

Briefly summarise the science behind your project

Organisations (Optional)

Select your organisation/s

If you don't see your organisation, please email support@reefcloud.ai to be added

Global Region (Optional)

Select your region/s

If unsure [find your region here](#)

Countries

Country *

Cancel
Next

Four steps help you create a project

Global Region captures, at large scale, where the reefs you surveyed are located geographically. We provide a list of Coral Reef Regions defined by the World Resource Institute and you can refer to this link to identify your region or regions of interest. Coral and other benthic species vary regionally, and completing this field helps us to aggregate Projects based on reef biogeography, which can help improve machine learning algorithms for common use. Select all that apply.

Countries is a list to help us identify the domain, in terms of countries, in which your Project operates. Please select all that apply.

Step 2. Data capture method.

This second section of the Project setup captures metadata on your in-water sampling protocol - your image size, sampling method and the way you sampled across each site.

Sampling Protocol describes the sampling design used for image collection. Select all that apply.

-
- *Photo transects* represent images positioned along a straight line or following the contour of a natural feature on along the reef, while *Photo quadrats* are collections of discrete randomly placed images.
 - *Geo-referenced transects* are a special case when every image along a transect line is associated with its own unique set of spatial coordinates (latitude and longitude). Geo-referenced images can be obtained from technology platforms or using a towed GPS unit (see sampling protocols for details).
 - *BRUVS* stands for Baited Remote Underwater Video.

Data Collection Method refers to the technique used to collect the images within your project. Images can be collected diving, snorkeling or using remote sensing vehicles (e.g., Autonomous Robots (AUV), Towed Camera, etc). You can select Other and provide details if needed.

Field Of View is a rough estimate of the maximum width of reef area (in cm) captured within each image. Depending on your camera and survey technique, some scientists take photos very close to the reef, capturing 20-30 cm of reef per image, others might photograph a wider area. Providing a value here will help us estimate the footprint of your images to standardise the information we feed to the machine learning algorithm (AI). While in some cases this width is very standard (for example if you use an altimeter or tripod to keep the camera a fixed distance from the substrate) we understand that in other cases this value varies from image to image, and we may not know the exact value. So, we ask for an estimated value as a reference.

Step 3. Setup AI model

This next section of the Project setup requires you to define how the information will be extracted from the images by creating a label set (your classification scheme) and defining the number and distribution of points.

Choosing a Label Set

Data on the abundance and composition of the benthos are extracted from images by classifying the benthos below a collection of points overlaid on each image. This process is called image annotation and images can be annotated in ReefCloud based on pre-defined classification schemes (your reference taxonomy, referred to here as "Label sets") or by importing you own set of labels into a customised label set.

Defining your label set is an important part of setting up your Project. We suggest you import your own using the Upload Your Own function following the on-screen prompts, but you also have the option to use the default ReefCloud "T1", "T2" and "T3" label sets (see Appendix on Taxonomy for more details). [Editing your label set](#) is possible after setting up your project.

Uploading your own label set

New label sets need to be uploaded as a .csv file and must contain three elements: a Code, a Description and a Functional Group. Download the template to see how it should be set up.

- **Codes** represent a unique short identifier for each of the benthic components you want to include in your analysis.
- **Description** is a longer descriptor of each benthic component, for example a species name, to remind you what your label represents.
- **Functional Group** is a higher-level grouping for labels that will help make larger label sets easier to navigate in when you are working on annotations, and will aid visualisation of your data on the dashboard.

There is also an option to add a **Keyboard Shortcut Code** for each label. This will help you find labels quickly when annotating your photos.

What label set should I use?

Label sets are creatable and customisable for each project and can be as simple or complex as you need. For example, ReefCheck use 10 simple substrate categories to describe for community monitoring, while at Palau International Coral Reef Center we use over 120 labels, including many coral species names.

There is a trade off with the size and complexity of your label set. In general, we recommend users to try to go as in-depth as possible with taxonomy, as information can always be aggregated upwards, but to some extent the machine may learn faster on simpler label sets and this may reduce the number of manual annotations you need to make before the machine is performing well. Bear in mind with inclusions of species that the machine will only be able to identify species if you can confidently identify the species from the photo.

You may already have a label set that your project or organisation uses, for consistency. If you don't, consider following established labels such as the Collaborative and Automated Tools for Analysis of Marine Imagery codes (CATAMI classification), specifically designed to help standardise vocabulary across different studies.

Drop your .csv file, and add a Label Set Name and a Label Set Description - a short description of your labelset, perhaps including size or intended usage, and then save it to apply to your project.

Once your label set is created it becomes a foundational part of your Project, so take your time creating your label set, and check out our online FAQ if you get stuck.

Create New Project

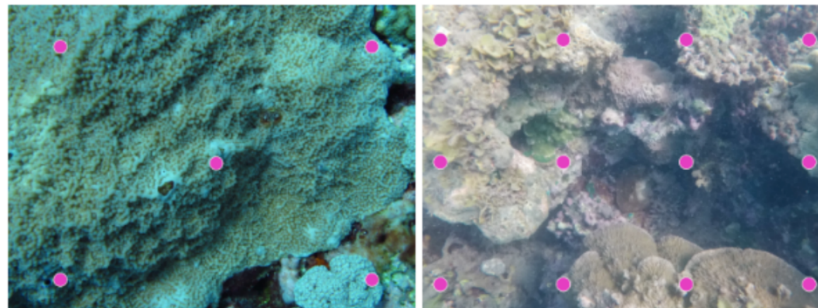


Select your label set

Define how the information will be extracted from the images by creating a label set. A label set is a classification scheme. Also define the number of points and the distribution of points you would like to annotate per image. The model will always annotate 50 points per image, including those you choose.

Select a template or upload your own

| Template | Upload Your Own |
|--|---|
| Name | Description |
| AIMS T1 - Essential labelset | Essential benthic reef labels for users beginning reef monitoring. Preview Select |
| AIMS T2 - General growth-form labelset | General growth-form based labels for users with familiarity with coral growth forms and other common reef taxa. Preview Select |
| AIMS T3 - Taxon-specific labelset | Taxon-specific labels for users with higher levels of taxonomic identification skills for corals and other reef benthic taxa at the genus-level. Preview Select |
| GBRMPA Eye on the Reef Benthos | Benthic categories of coral, macroalgae and benthos matching Eye on the Reef survey methods, with additional benthic categories. Preview Select |
| Mermaid | Marine Ecological Research Management Aid full benthic labelset Preview Select |
| ReefCheck Australia | ReefCheck Australia's standard line intercept benthic categories, adapted for photoquadrats in ReefCloud Preview Select |



Fixed: 5 points

Recommended if you have a larger sampling effort

Grid: 12 points - 4 x 3

Recommended for most photoquadrat datasets, including BRUVS stills

To set up your AI model, you first need to either upload your own reference taxonomy (label set) or choose one of the default options

Choosing a default labelset

ReefCloud also provides a range of default labelsets, corresponding to different levels of taxonomy with different intended purposes for different monitoring programs, with different levels of intended taxonomy. Once selected, you can modify these labels within your project - adding, removing or editing label descriptions - if you find you need to tailor it towards your specific monitoring objective.

The three default labelsets allow us to highlight specific taxonomic units which are important and have these labels defined within the ReefCloud guide for consistency. Please see our Taxonomy Guidelines for more details on the default label sets.

Create New Project

▲ ▲ 3 4
 Project Details Data capture method Setup AI Model Data Permissions

AIMS T1 - Essential labelset

Name: AIMS T1 - Essential labelset

Description: Essential benthic reef labels for users beginning reef monitoring.

Filter: _____

| Code | Description | Group Code | Keyboard Shortcut Code |
|--------|--------------------------|------------|------------------------|
| HC | Hard Coral | HC | |
| BL_HC | Hard Coral Bleached | HC | |
| SC | Soft Coral | SC | |
| MA | Macroalgae | MA | |
| TA | Turf Algae | TA | |
| CA_CCA | Crustose Coralline Algae | CA | |
| CA_ECA | Erect Coralline Algae | CA | |
| SP | Sponge | SP | |
| SI | Sessile Invertebrates | SI | |
| MI | Mobile Invertebrates | MI | |

Items per page: 10 1 - 10 of 17 |< < > >|

Close

Fixed: 5 points
 Recommended if you have a larger sampling effort

Grid: 12 points - 4 x 3
 Recommended for most photoquadrat datasets, including BRUVS stills

Example of the AIMS T1 default labelset, including the "Code", "Description" and "Group Code" fields

Defining your point sampling approach

Point count methodology, whereby the proportion of randomly overlain points intersecting an organism or substratum is used to estimate its coverage, is a common method for estimating the abundance of benthic organisms on coral reefs.

In ReefCloud, images in your project can be annotated using a different number (e.g., 5 – 50) and distribution of points (e.g., random, equidistant). Use this feature to dictate how many points appear on each photo, and whether they are arranged randomly across photos or in a fixed grid pattern (5-points in an X-shape, or 12 or 20 points in a grid).

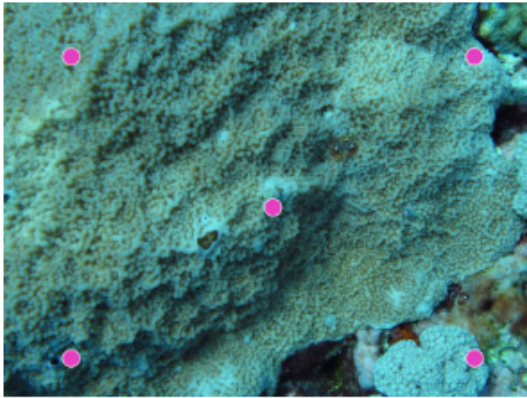
Carefully consider the distribution and number of points you select, since this step is part of defining your AI model and can't be changed later on.

How many points per image should I choose?

The optimum number of points is dependent on the number of images, but also on the spread of the images across the habitat you want to sample, and the size, abundance and spatial distribution of the target organisms (see Perkins et al 2016), and also your scientific question and what kind of information you're interested in capturing. Generally precision is improved with a larger number of images than more points per image.

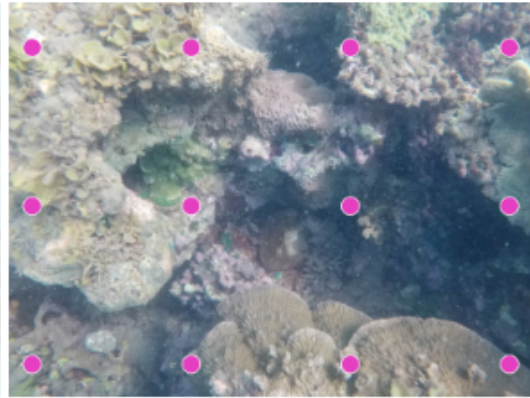
For broadscale monitoring, 5-10 points are generally considered adequate, especially where there are plenty of photos. Some research suggests where coral cover is lower a greater number of points are needed (5 points for >60% coral cover, 30 points for <30%). If your goal is to adequately capture all recognisable features within each image >60 points has been recommended (Perkins et al 2016). The complexity of your label set will also influence the number of recommended points.

Coming soon, you will be able to define a margin from the edge of the image to exclude points to be considered in this area, and the method used to generate these points.



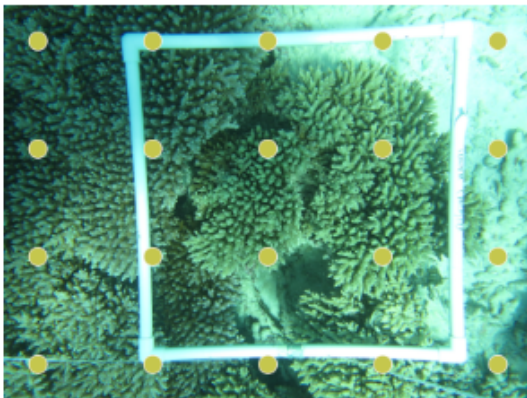
Fixed: 5 points

Recommended if you have a larger sampling effort



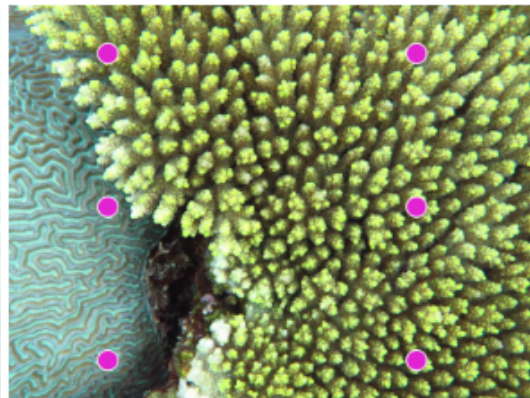
Grid: 12 points - 4 x 3

Recommended for most photoquadrat datasets, including BRUVS stills



Grid: 20 points - 5 x 4

Higher number of points per image are recommended for smaller datasets



Line Spaced Grid: 6 points - 2 x 3

Example of some typical points sampling configurations.

Step 4. Data Permissions

ReefCloud was developed around the principle of sharing and encourages users to make data available as much as possible. We do recognise that not all data can be made open access because of the nature of data, funding, etc.

This section allows users to define how they wish to share data from a project. You can select three categories of data sharing:

- **Private:** Your data will not be visible to other users of ReefCloud. Only the location of sites and contact information will be shared in the public dashboard to allow data to be discoverable and encourage collaboration. Please note that while the data will not be accessible by other users, two exceptions are made:

-
- Your image annotations will be used to improve the state of machine learning that will benefit the science community. This will be only visible to the ReefCloud developers.
 - The estimation of benthic cover from the images in this project using machine learning will be used to produce aggregated summaries on the state and trend of coral reef communities in your region. These aggregated summaries will be available to the public in a dashboard, but the data on specific locations will not be revealed, only the aggregated summaries (e.g., countrywide, Ocean region, etc).
 - **Visible only:** Your data will remain private and no other user, outside of your project users, will be able to access the data. However, the benthic cover estimated from the images in this project will be shown in a public dashboard across surveys and sites. We will also disclose the contact information from the project administrator in this dashboard in order to encourage collaboration across the science community.
 - **Fully Open access:** In this option, you grant ReefCloud a license to openly share the data with other ReefCloud users that request downloading all the data from this project. This data will be protected under a Non-commercial use Creative Commons license that requires users of this data to acknowledge its source.

Important Acknowledgement: Towards the end of this section, you will be asked to agree to an acknowledgement to state how your data will be used within ReefCloud. Please note that you can specify different formats for sharing your data among collaborators, from private to public access. In addition to the data sharing policies that you will manage, the ReefCloud team will be using your data (Images and Annotations) to help the team in the development of ReefCloud and the design of more powerful Machine Learning methods to assist the scientific community.

The team is keen to hear your thoughts about this point: support@reefcloud.ai.

2.1.3 Add Users to your Project

It's great to collaborate on Projects, and once you've completed your project set up you can begin to add your team members so you can work together.

Under the "Users" tab on the left-hand side of your Project Page, you can grant access to others and assign them permissions. Invite friends and collaborators by entering their email address. If they aren't yet signed up to ReefCloud, they'll receive an email invitation.

Grant access to this project by adding users and assigning access permissions. You can find them by email if they already have a ReefCloud account. If not, a new user account will be created and they will be notified by the email supplied.

Email Add User

| Email | Permission | Remove | Email Verified |
|-------------------------|------------|--------|----------------|
| me@myemailaddress.com | ADMIN | ✗ | ✓ |
| collaborator1@email.com | WRITE | ✗ | ✓ |
| collaborator2@email.com | WRITE | ✗ | ✓ |
| myboss@email.com | ADMIN | ✗ | ✓ |
| mystudent2@email.com | WRITE | ✗ | ✓ |
| mystudent@email.com | WRITE | ✗ | ✓ |
| our_funder@bigbucks.com | READ | ✗ | ✓ |

Three easy steps to adding users to your project: 1) go to the "Users" tab 2) enter collaborators email address 3) adjust permissions

There are three levels of permissions you can assign your collaborators:

- **Read** allows users to view the Project, and export the dataset.
- **Write** allows users to upload new data, help with annotations, and edit the details of sites and surveys. *Write users cannot delete sites or surveys, add new users or delete or edit label sets.*
- **Admin** gives full control of the Project. Only a user with full Admin rights can delete or add users, and access all ReefCloud functions.

When you create a Project, ReefCloud automatically assigns you as an *Admin* user, however, you can add more *Admin* or *Read/Write* users to that Project.

When adding new users, think carefully about who you are sharing your data with. It may be advisable to set up a data sharing agreement before adding users to your project outside of your organisation.

Manage Tonga Project users

Grant access to this project by adding users and assigning access permissions. You can find them by email if they already have a ReefCloud account. If not, a new user account will be created and they will be notified by the email supplied.

Email

| Email | Permission | Remove | Email Verified |
|-------------------------|------------|--------|----------------|
| me@myemailaddress.com | WRITE | ✗ | ✓ |
| collaborator1@email.com | WRITE | ✗ | ✓ |
| collaborator2@email.com | ADMIN | ✗ | ✓ |

Another way to modify user permissions or to add more is through the Projects Page, under "Actions" on right hand side

If you have multiple projects, another way to access the "Manage Users" feature is through the "View All Projects" page.

- Click on the "Admin" button on the top ribbon of the page. This will take you a page that list the project where you are an administrator.
- Click on the "Users" link for the Project you want to modify.
- To add any new user, enter the user email address and click "Add User". If the email address belongs to an already registered ReefCloud user, this will add them to your project. Otherwise, ReefCloud will send an email inviting them to join and will add them to the user list of your project.
- From this, you can also remove users or change their role by clicking on the Admin check box.

Module 2.2. Collect your data

2.2.1 Configure your surveys

When collecting images for surveys, it is important to record where, when, and how the data was collected (metadata). To help organise the data from surveys, ReefCloud considers three types of metadata: **Sites**, **Surveys** and **Sampling Units**.

Sites

Sites are the individual locations where data are collected during the fieldwork. They represent a single point in space and capture a collection of sampling units (e.g., transects, random images, etc). In monitoring projects, a **Site** is often a fixed location that is routinely sampled over time. In this case, each sample period represents a survey for a given site.

The image shows a mobile application interface for adding a new site. The form is titled "Add Site" and contains the following fields and options:

- Site Name***: A required text input field.
- Site Code**: A text input field.
- Position**: A section containing two required text input fields: **Latitude*** and **Longitude***.
- Reef**: A section containing several input fields:
 - Reef Name**: A text input field.
 - Reef zone**: A dropdown menu.
 - Reef type**: A dropdown menu.
 - Habitat**: A text input field.
 - Exposure Level**: A dropdown menu.
- At the bottom right, there are two buttons: **Cancel** and **Submit**.

Create new sites individually using the "Add Site" button and completing the fields in the pop-up box

When you add a new site, as well as a Site Name, Lat/Long and Depth (required) there are options to add additional information that may help you group your data for analysis later.

To create a site, follow these steps:

1. From the Projects window, select a project
2. Click on “Sites” from the left-hand ribbon menu. This will take you to the Sites page, listing your existing sites in the project and a map showing their location. As you populate your Sites with Surveys and Images, more information will appear in the table.
3. You can create a new individual site using the blue “Add Site” button at the top of the Sites page. This will bring up a pop-up window asking you to enter the following details:
 - a. **Site Name:** Customised name for your site. This must be unique. *If you choose to make your project public, your Site Name and location may appear on the [ReefCloud Public Dashboard](#).*
 - b. **Site Code** [Optional]: A short abbreviation of your Site name
 - c. **Latitude:** Latitude coordinates in decimal degrees. Note that we use WGS84 as the reference datum.
 - d. **Longitude:** Longitude coordinates in decimal degrees. Note that we use WGS84 as the reference datum.
 - e. **Reef Name** [Optional]: Sometimes multiple sites can be located across a single individual reef (e.g., Davis Reef). This field gives the option of capturing additional data to use in aggregating your results.
 - f. **Reef Zone** [Optional]: Describes the typical zones of a reef: back reef, crest, fore reef, and pinnacle.
 - g. **Reef type** [Optional]: Typical reef formations: atoll, barrier, fringing, lagoon, and patch.
 - h. **Habitat** [Optional]: free field to add more information for help aggregating data
 - i. **Exposure Level** [Optional]: How exposed is this site to the regular weather (routine conditions): Very Sheltered, Sheltered, Semi-sheltered, Exposed.
 - j. **Depth:** the average depth at which you collect the images. If you want to group multiple transects at different depths under the same Site GPS location (e.g., 5m transect, 10m transect and 12m transect all under "Site A"), you can put in a depth range here (e.g., 5-12m), and specify depths when you submit your transects as different surveys in the next step. Alternatively, you can submit each transect as a different site (e.g. Site Name = "Site A, 5m transect", "Site A, 10m transect").
 - k. **Country** [Optional]. This will be auto-populated from your Project Set Up, but you can change it.
 - l. **Country Region** [Optional]: Specific region within the country of the collection (e.g., Great Barrier Reef, Koror State, etc).

- m. **Local Region** [Optional]: Within the country region, is there another subregion? (e.g., Northern Great Barrier Reef).
- n. **Management** [Optional]: Management regime (e.g., Open/Close to fisheries, No public access, etc).

4. Alternatively, if you have many sites to create at once, you can use the blue “Import Sites” button from the Sites page. This will allow you to fill an Excel Spreadsheet template to create your sites, all at once! Download the Template Spreadsheet as a .csv and populate it with your data. The only fields that are mandatory are the "Site Name", "Latitude", "Longitude" and "Depth". Upload your completed file to autopopulate the sites table.

| | A | B | C | D | E | F | G | H | I | J | K | L | M |
|----|-------------------------------|---------------------|----------------|-----------|-----------|----------------|----------|-----------|-------|-----------|--------------------|--------------|------------|
| 1 | Site Name | Site Code | Reef Name | Reef Zone | Reef Type | Exposure level | Latitude | Longitude | Depth | Country | Country Region | Local Region | Management |
| 2 | Snapper Island South S1 D2 IN | Snapper Island Site | Snapper Island | | | | -16.2998 | 145.496 | 2 | Australia | Great Barrier Reef | Central | O |
| 3 | Snapper Island South S1 D5 IN | Snapper Island Site | Snapper Island | | | | -16.2999 | 145.496 | 5 | Australia | Great Barrier Reef | Central | O |
| 4 | Snapper Island North S1 D2 IN | Snapper Island Site | Snapper Island | | | | -16.2924 | 145.4969 | 2 | Australia | Great Barrier Reef | Central | O |
| 5 | Snapper Island North S1 D5 IN | Snapper Island Site | Snapper Island | | | | -16.2919 | 145.4965 | 5 | Australia | Great Barrier Reef | Central | O |
| 6 | Snapper Island South S2 D2 IN | Snapper Island Site | Snapper Island | | | | -16.3008 | 145.4994 | 2 | Australia | Great Barrier Reef | Central | O |
| 7 | Snapper Island South S2 D5 IN | Snapper Island Site | Snapper Island | | | | -16.3011 | 145.4994 | 5 | Australia | Great Barrier Reef | Central | O |
| 8 | Snapper Island North S2 D5 IN | Snapper Island Site | Snapper Island | | | | -16.2949 | 145.5004 | 5 | Australia | Great Barrier Reef | Central | O |
| 9 | Snapper Island North S2 D2 IN | Snapper Island Site | Snapper Island | | | | -16.2958 | 145.5006 | 2 | Australia | Great Barrier Reef | Central | O |
| 10 | Snapper Island North S3 D2 IN | Snapper Island Site | Snapper Island | | | | -16.3018 | 145.507 | 2 | Australia | Great Barrier Reef | Central | O |
| 11 | Snapper Island South S3 D2 IN | Snapper Island Site | Snapper Island | | | | -16.3021 | 145.502 | 2 | Australia | Great Barrier Reef | Central | O |
| 12 | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | | |

Example of how to populate the "Import Sites" template. Only the "Site Name", "Latitude", "Longitude" and "Depth" fields are mandatory

Surveys

Surveys capture the time when a site was surveyed. Most monitoring programs will have multiple Surveys per Site, representing repeated sampling over time (e.g., annual surveys). Some Projects are designed for a single survey to capture spatial patterns only. In that case, each Site will only have a one Survey and it is important to record when that survey happened.

Surveys can be created using the “Create Survey” button from the Survey page or by bulk upload from a template file, following the prompts from the blue "Bulk Import" button. When importing surveys in bulk, you can also import their associated images. See [Upload images](#) section for more details.

To create a new survey, follow these steps:

1. Click on “Surveys” tab from the left-hand ribbon menu. This will take you to the Surveys page, listing your all your surveys and associated metadata.
2. You can create a new individual survey using the blue “Create Survey” button at the top right of the Surveys page. This will bring up a pop-up window asking you to enter the following details:
 - **Survey Site:** Use the dropdown list to select the Site at which your Survey took place.
 - **Title:** Give your Survey a unique title that captures what the survey is sampling (in a way that is meaningful for you and your team): for example, you might put in the year

if it is an annual survey, e.g., Site A, 2024, add the transect number if there are multiple transects per site e.g., Site A, 2024, T1, and/or the depth if you have multiple survey depths per site e.g., Site A, 2024, 5m transect.

- **Depth** [Optional]: Add the depth (in meters) your survey was conducted at.


Create Survey

Survey Site*


Title*

Depth (m)

Transect No.

Start Date* 

Start Time
12:00 AM

Description 

Collection Method

Restricted
false

Cancel Submit

- **Date**: Select the survey date using the calendar. If you are using the Bulk Import function, the date should follow the format dd/mm/yyyy.

- **Description** [Optional]: Free field to add more notes about your survey: perhaps the weather, or any disruptions or interesting findings.
 - **Collection method** [Optional]: add from the dropdown list. This becomes useful if you have a mix of survey methods (e.g. some diving and some snorkelling surveys).
 - **Restricted**: in many circumstances, monitoring practitioners are happy for the bulk of their historic data to be shared but may want to keep recent survey data private until there's been a chance to analyse and explore results. This option allows you to restrict access to particular surveys while keeping the remainder of your project public. Click "true" if you'd like to keep this survey data private. For more information on privacy, see [Privacy and Data Sharing information](#) here.
3. Alternatively, if you have multiple surveys to upload, this can be done using the Bulk Import feature.

ReefCheck data import feature

[ReefCheck](#) is a non-profit organisation that has been training and organising teams of local volunteer citizen scientist divers to collect information on coral reef health since 1997. ReefCloud has teamed up with the ReefCheck Foundation's global network of reef surveyors to support inclusion of ReefCheck data. We've added a blue "ReefCheck Import" upload button on the top right of the Surveys page that allows submission of standard site description, invertebrate belt and substrate line intercept transect ReefCheck datasheets. Please only use this button if you are following the [ReefCheck EcoDiver Program](#) protocols. We are working on a way to share data back to ReefCheck's global database: until then please also submit datasheets online to ReefCheck.

Coming Soon!

Sampling Units are the smallest aggregation of data from your surveys and represent the minimum unit that captures the heterogeneity of your site. For example, a typical sampling unit is a transect which has multiple images and can vary in length, depending on the Project. Some Projects are set up to use a random number of images collected within a Site, which out smaller sampling units. In that case, the sampling unit is the site. In any case, it is important to capture the characteristics of a sampling unit (estimated size, whether they are permanently marked on the reef or rather a random collection, etc.

2.2.2 Upload Images

Images are uploaded to a given survey and must be organised by folder in your local computer or hard drive, where a folder represents a survey.

There are two ways to upload images: 1) One survey at the time and 2) Bulk Import.

Uploading Images

1 Begin on the "Surveys" tab

Alternatively, upload multiple survey images using the Bulk Import feature

2 Select the "Actions" button for the survey you're uploading, then choose "Images"

3 "Add Images" then navigate to the folder on your computer and click on "Upload"

Process for uploading your images survey-by-survey. Image files from each survey must be stored in a separate folder on your computer.

Upload images one survey at a time.

1. Go to the **Surveys** page.
2. Click on the "Actions" tab from the survey you want to upload the images to, then "Images". A pop-up will appear with any existing images you've uploaded for this survey.
3. Click on the blue "Add Images" button in the top right of the pop-up window, and navigate to the folder on your computer that contains the corresponding survey images.
4. Click "Upload".

Import Surveys - XLSX

Data Upload Requirements
Folder and file structure requirements for a successful data submission

folder to upload

- surveys.xlsx
- points.xlsx
- subfolder 1
 - image-1.jpg
- subfolder 2
 - image-1.jpg

Upload Instructions

Upload a folder containing metadata and associated images. Choose one of the following options:

- Upload a single Excel file with one row per survey.

OR

- Upload two Excel files:
 - One titled 'surveys.xlsx'
 - One titled 'points.xlsx'

Column headings must be:

surveys.xlsx:

- Survey Site
- Start Date Time
- Survey Collection Method
- Survey Image Directory
- Title (optional)
- Transect Number (optional)
- Depth (optional)

points.xlsx (optional):

- Point Image Path
- Point X Coord
- Point Y Coord
- Point Annotation (optional)

[Download Survey Template](#)

Follow the instructions here for to bulk upload surveys and photos together, and historic annotation points if you have them.

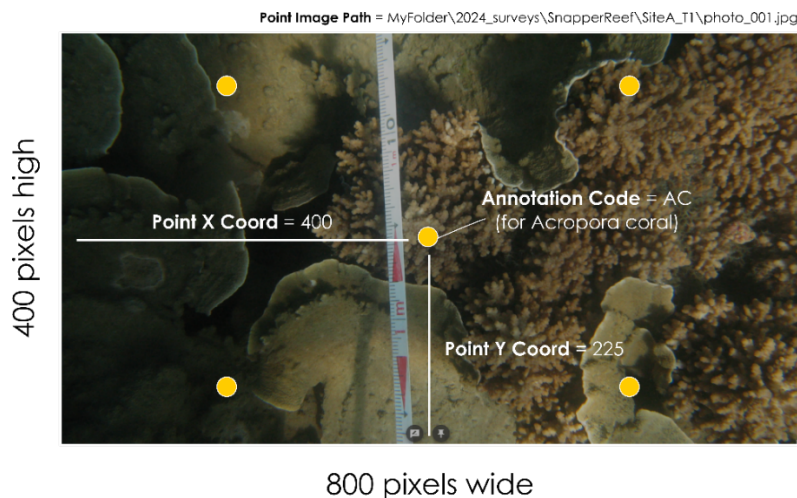
Bulk upload for multiple surveys.

1. Click on the blue "Bulk Import" button on the top right-hand side of the "Surveys" page.
2. "Download Survey Template" to get an Excel Spreadsheet template that is prepopulated with the sites in your project under the second *Reference_Sheet* tab. The main sheet will allow you to select the sites for each survey from the Reference Sheet.

NOTE: You must have created Sites prior importing images

3. Fill in the downloaded SurveyImportTemplate.xlsx, where each row represents a survey and a folder of images in your local hard drive (this also include USB stick, memory card or external hard drive). Here are important notes to consider:
 - i. **Survey Site:** contains a dropdown selection for the sites in your project. The spreadsheet will not allow you to enter new sites. If you need to include new sites, go back to the Sites page create the sites (as above) and download the template again.
 - ii. **Start Date Time:** is the date of collection and should be entered as dd/mm/yyyy. If time is important to capture, this field allows Date and Time entering in 12h or 24 formats (e.g., 01/12/2020 02:00 pm or 01/12/2020 14:00).

- iii. **Title** [Optional]: This can help to identify a specific survey
 - iv. **Survey Collection Method**: Dropdown select of methods option defined in your project.
 - v. **Survey Image Directory**: This is the name of the folder or location of a subfolder that contains the images for a particular survey (not the full name of the directory)
4. Once completed, it's important to save the file as "surveys.xlsx" inside the folder that contains all the other folders. For example, if you are uploading all the surveys in 2019 for your monitoring in Koror Island, Fiji, your images will be organised within a master folder: C:\\Fiji_monitoring\\Koror_Island\\2019. Within this master folder, you will have individual folders for each survey or row in the table. The Survey spreadsheet should be saved in the root directory (C:\\Fiji_monitoring\\Koror_Island\\2019). ReefCloud will upload all your images within this directory and organise them according to the information in this sheet.
 5. After completing the steps above, go back to ReefCloud and click on Choose Folder. This is the master folder containing all your images organised into folders as per the survey spreadsheet, as well as the surveys.xlsx spreadsheet with all the information for each survey and folder to link to.



NOTE: if you want to import historic points annotations (e.g. from another program such as CoralNet) this MUST be done at the same time as your survey bulk upload. You will need to create a second "points.xlsx" spreadsheet and save it in the same location as the surveys.xlsx spreadsheet. The points.xlsx spreadsheet should have four columns:

- **Point Image Path**: this is the image file name and location inside the directory, so that ReefCloud can link the annotated points to the correct photo as it's uploaded.
- **Point X Coord**: x,y, pixel location of the annotation point (dependent on photo size), usually available from previous annotation software.

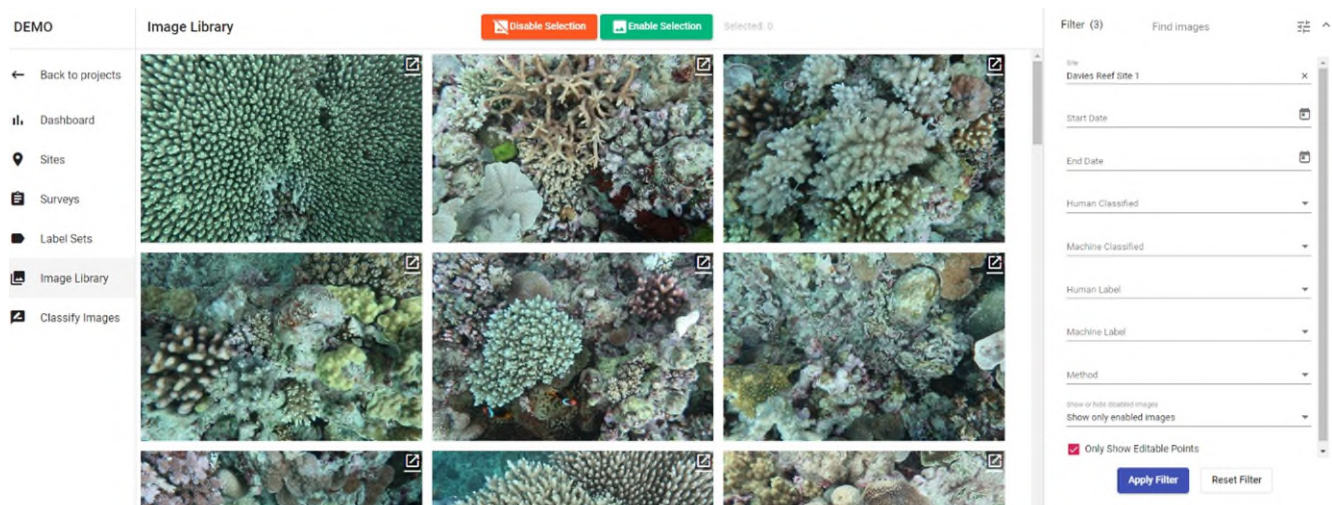
- **Point Y Coord:** x, y pixel location of the annotation point.
 - **Point Annotation:** the label code associated with the annotation point. This MUST match one of the "Codes" in your designated label set.
6. ReefCloud will analyse the folder and provide a summarise of the data that will be uploaded. Review and click "Next".
 7. You will be presented with a table summarising the number of images that will be uploaded to each survey. Review and click "Upload Surveys" to commence the upload.

Note: ReefCloud has been designed to accommodate variable internet speeds. You can select the speed that best suit your current internet services. Should internet drops during the download, ReefCloud will remember where it dropped and resume the upload automatically. This way you do not need to worry if you leave the upload running overnight.

2.2.3 Review your images

Uploaded images can be reviewed in ReefCloud using the "Image Library" menu from the side ribbon menu. From here, you can use different fields to filter the images you wish to review (Find Images tab on the left menu).

When reviewing your images, there may be images that are not adequate for analysing the benthic abundance (e.g., too blurry, or simply, not relevant). You can select this image, or using the Control Key in your keyboard, you can select multiple images at the same time. Once the image(s) is selected, use the Disable Selection (Orange) or Enable Selection buttons (Green) to exclude them or include them from the analysis.



Module 2.3. Analyse your photos

2.3.1 Train Automated Image Analysis

An algorithm for automated image analysis runs in the background of ReefCloud to help you extract information from the images, such as benthic cover. This algorithm has been preconfigured using data from other projects to maximise its accuracy. For it to work, you will need to manually analyse (i.e., annotate) several images in your project. This will train the automated algorithm and estimate the labels in the remaining images automatically.

This is an interactive process. The more images you manually analyse the better you train the algorithm. As the algorithm is trained, you can make use of the annotated images to search and review the labelled images using the “Filter tool”.

Manual image analysis for training

Images are analysed by annotating or identifying the benthic categories or labels that correspond to each of the points laid on the image. This method is commonly referred to as the Point Count Method, used to estimate the abundance of each identified label in the image. ReefCloud offers a tool to make this process easier, using the “Classify Images” tool.

Here are a few quick steps to analyse an image in ReefCloud:

1. Click on the “Classify Images” tab on the left hand side of the screen.
2. Filter the images that you want to annotate using the filter tool on the right-hand ribbon menu.
3. Select a point (or multiple points using the Control Key) from the image and click on the label you want to assign from the Classify Tool on the right-hand ribbon menu.

Some useful hints

- You can use the search option in the Classify Tool to get the label you are looking for. Once a point is selected, you can use the keyboard to search for the label.
- Hovering over the points will show you the labels assigned to each point by you or anyone in your project team (Human), or by the automated algorithms (Machine).
- You can use the icon at the button of the image to show all annotations across the points in the image.

Additional tools to help you analyse images:

- **Show Points.** This tool will display each of your points zoomed in at the bottom of the page.

- **Full Image vs Point View.** At the top of the image, you will see two buttons that allow you to flick between a full image view, showing all the points, or a point-by-point view across your entire image set. Depending on your preference you can use either view to annotate the images and flick between the views as you need them.
- **Filter by manual or automated classifications.** This option in the Filter Tool allows you to quickly select images or points based on its label. You can use this for quality checks among your project team or make use of the AI algorithm to help you annotate faster (e.g., search for all the hard corals and quickly annotate further the identity of each coral). Tip, for this, using the Point View makes it easier.
- **Search for images to annotate.** You can use the filter option to analyse the ones that have not been previously analysed by others in the project team. For this use the “Human Classified” field in the Filter Tool.

2.3.2 Label set editing and mapping

Managing your label set

You may wish to edit, export or delete your label set. This feature has proved particularly useful for reanalysing photos when taxonomy changes occur! Managing your label set can be done within a Project under the Label Sets tab on the left-hand side of your project.

The screenshot shows the 'Manage Label Set' interface in ReefCloud. The interface includes a sidebar with navigation options like 'Projects', 'Manage', 'Sites', 'Services', 'Label Sets', 'Spans', 'Analysis', 'Image Library', 'Classify Images', 'Home', and 'Report'. The main content area is titled 'Edit Label Set reefcloud-demo-project - AMS T1 - Essential labelset'. It features a 'Filter' section with a search bar and a 'Filter' button. Below this is an 'ADD LABEL' section with fields for 'Code*', 'Description*', 'Group Code*', and 'Keyboard Shortcut'. A table lists existing labels with columns for 'Code', 'Description', 'Group Code', and 'Keyboard Shortcut Code'. The table contains the following data:

| Code | Description | Group Code | Keyboard Shortcut Code |
|--------|-------------------------|------------|------------------------|
| CA,CEA | Crossed Coralline Algae | CA | |
| DM | Cyanostructural Mats | DM | |
| CA,CEA | Event Coralline Algae | CA | |
| HC | Hard Coral | HC | |
| HL,HC | Hard Coral Bleached | HC | |
| MA | Macroalgae | MA | |

Callouts highlight the following features:

- Search for labels using the "Filter" tool**: Points to the filter search bar.
- Add a brand new label here**: Points to the 'ADD LABEL' section.
- Sort labels by alphabetical order**: Points to the sort icon in the table header.
- Edit label descriptions, group code or add a keyboard shortcut to make annotating faster**: Points to the edit icons in the table.

Use this tool to:

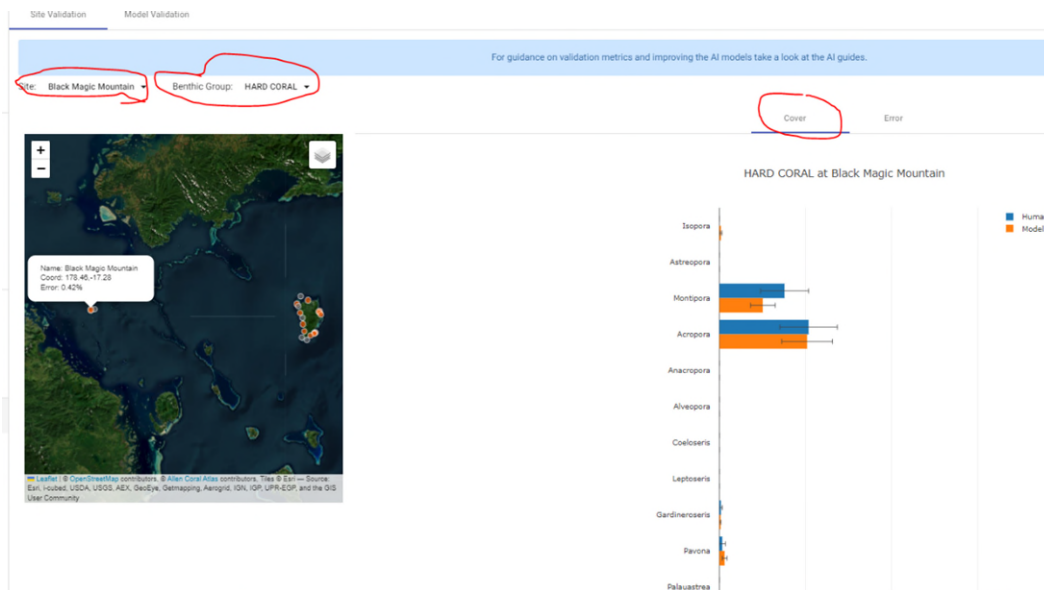
- View your label set. Click on 'Edit' under 'actions' on the right-hand side to view a pop-up box containing your codes, description and group codes. You can use the "filter" tool to search for

labels or groups in your set, click on the column headings to organise the labels by alphabetical order, and increase the number of items per page at the bottom of the pop-out.

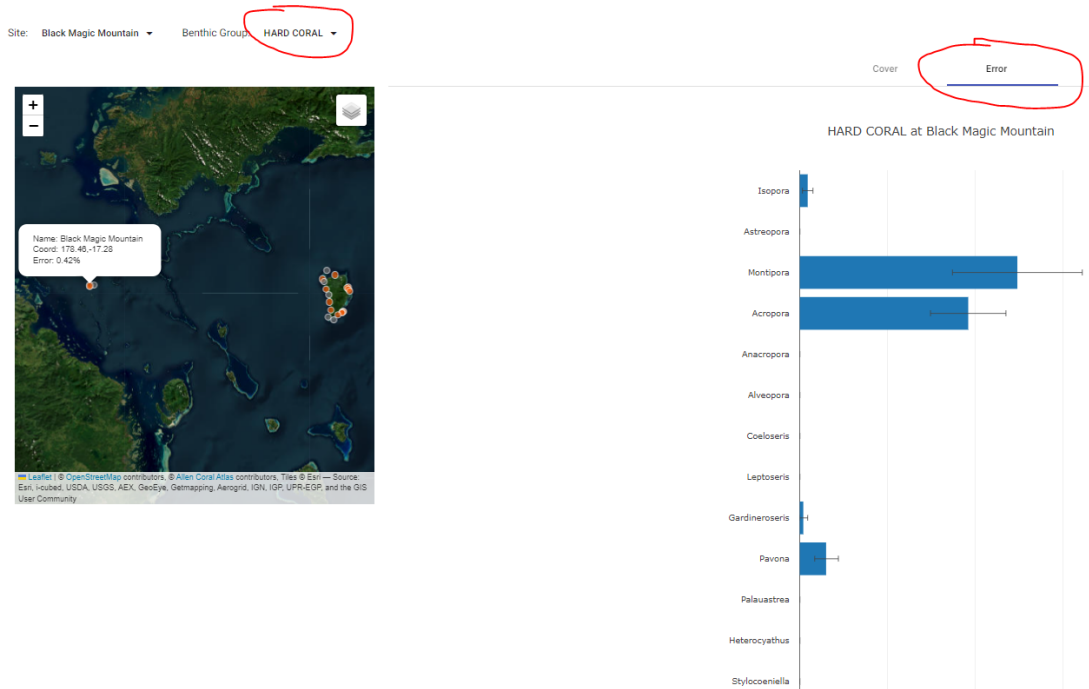
- Add new labels. For example, a new category for something you haven't come across before, or didn't think to include in your original label set. For a new label, you will need to come up with a unique code that isn't the same as anything already in your list.
- Edit or delete existing labels. Every part of the label aside from the unique code (and the label set name and description) is editable but do consider carefully whether deleting labels is necessary as it can disrupt any annotation work you've done previously. If you are editing one of the AIMS provided default label sets, this will only change the label set within the current project.
- Add a keyboard shortcut code (as a numerical character) for elements that appear frequently when annotating.
- Export the entire label set as a .csv file. You may want to do this if you want to share your unique label set with other projects (it will be in the correct format to upload to a new project) or with collaborators.

Label set mapping

Label set mapping is a crucial step that all ReefCloud users are encouraged to do. Mapping converts your imported labels into biological categories that are meaningful to ReefCloud so your data can be graphed within your project and compared between projects (if you have opted to share your results with the Public Dashboard). This allows you to validate AI point annotations based on how well the machine has been trained. The human vs machine annotation graphs are displayed on the report tab for benthic cover. Benthic category data is aggregated into 13 major benthic groups and displayed in the report tab.



Additionally, it shows you the error margin between human and machine annotation for each site within the project.



Under the Label Set menu, choose a "Benthic Category" from the dropdown list that is the closest taxonomic match to your label. The Benthic Category list has been adapted from WoRMS (the [World Register of Marine Species](#)) with some abiotic categories included. You will need to do this for every single label in your dataset to make use of the AI validation and reporting tools, as well as to contribute your data (if you have opted to share your project) to regional and global trends analysis.

There are also options to add information about Coral Growth Form, Substrate and Coral Condition.

DEMO [Label Sets / Label Mapping](#)

| Label | Description | GroupCode | Benthic Category | Substrate | Condition | Growth Form |
|-------|-----------------|-----------|------------------|-----------|-----------|-------------|
| A | Algae | A | Algae | | | |
| AB | Abiotic | AB | Sand | | | |
| HC | Hard Coral | HC | Hard coral | | | |
| OT | Other organisms | OT | Other | | | |
| SC | Soft Coral | SC | Soft coral | | | |
| SG | Seagrass | SG | Seagrass | | | |
| SP | Sponge | SP | Sponge | | | |

Items per page: 10 1 - 7 of 7

Mapping your label set so that ReefCloud can understand and make use of your data for global trends synthesis is an essential step in helping you and the global community make the most out of your monitoring work.

If you are using one of the default provided label sets, the mapping has already been done for you, and will only need to be updated if you edit the label set within the project.

Note: Dashboard and report summaries will ONLY appear once a label set has been fully mapped.

2.3.3 Validating AI results

The Report menu on ReefCloud allows you to monitor how your AI model is performing for your project. The model is assessed by comparing the amount of agreement between your manual annotations and the machine annotations across your project. It does this by comparing machine and human annotations across the manually annotated points.

Two reports are provided: a [Model Validation](#) which gives you an overall score for model performance, and a [Site Validation](#), which allows you to explore how the AI is performing at different sites and across different benthic categories.

To start exploring your model's performance, navigate to the "Report" tab for your ReefCloud project.

Understanding your AI model performance

The screenshot shows the ReefCloud Model Report interface. The main content area displays a map of sites with orange circles indicating error rates. A dropdown menu is set to 'Meli' and 'HARD CORAL'. A horizontal bar chart titled 'HARD CORAL at Meli' compares human and model annotations for various benthic categories. The x-axis represents 'Cover (%) ± 95 CI' from 0 to 10. The y-axis lists categories: Bleached Hard Coral, Branching Hard Coral, Encrusting Hard Coral, Foliose Hard Coral, Massive Hard Coral, Other Growth Forms, and Plate Hard Coral. Human annotations are shown in blue and model annotations in orange. Error bars represent 95% confidence intervals.

Callout boxes provide additional information:

- Access overall model performance scores (Accuracy and F1 score) under "Model Validation" tab
- Use the dropdown lists to explore how your AI model is performing at different sites and for different benthic groups
- Discover which of your benthic categories (labels) the AI needs more training in. Overlapping error bars suggest human and machine are reporting similar % cover values at that site
- Error rate for each site is indicated by orange circles, larger circles indicate greater disagreement between human and AI
- Explore model performance under the "Report" tab

Overview of site validation for your model for your project

Model Validation

Model Validation provides a graph with two scores: an average source **Accuracy** and an **F1 score**. These are two metrics that are typically used to assess the quality of classification models. Hover over the points on the graph to view the values for each score. As a rule, the higher the Accuracy and F1 score values, the better a model can classify observations.

- **Accuracy** is the percentage of all correctly classified observations: it reflects the amount of agreement between the Human and Machine across all annotated points in your project. For example, an Accuracy of 0.72 shows that in 72% of annotated points the Machine has generated the same label that the Human has assigned. Accuracy is a good metric for when the classes are balanced.
- **F1 score** is slightly harder to interpret, as it considers how the data are distributed. It does this by combining metrics for precision (the correct positive predictions relative to total positive predictions) and recall (the correct positive predictions relative to actual positives). F1 score is more useful when classes are imbalanced (e.g. some very rare classes or groups) and will penalise models that have too many false negatives more than accuracy will.

Since coral reef photo datasets are generally unbalanced, we suggest paying more attention to the F1 score.

The Model Validation plot shows how Accuracy and F1 scores are changing as you invest time in training. Each time you train your machine by annotating more points under the Classify Images menu, your model will learn, and a new score will be plotted on the graph, so you should expect to see your model improve over time.

The F1 score and Accuracy metrics are important to report if you want to publish your data.

Site Validation

Site Validation allows you to compare machine accuracy across sites and between classes. This can be useful for highlighting areas where you and the machine disagree, which may indicate that your machine needs more training.

The map displays an orange circle for each site: the larger the circle, the greater the disagreement between the Human and Machine at that site. Clicking on a circle displays an *Error* value, which is the % of annotations for that site where disagreement occurs. For example, an Error of 4.45% shows the Machine has assigned a different label to the Human in 4.45% of the points that have been annotated, (or in other words, a 95.55% Accuracy score at that site).

Large circles might indicate more training is needed at that site.

Grey circles indicate sites where no human annotations have been completed: so the machine can't be assessed. Blue circles indicate sites where there is complete agreement between the machine and human on labels.

For each site, you can further explore model performance for each label, by selecting a Benthic Group to dig into in the drop down menu (nb/ this information will not display if you haven't completed [label set mapping](#) so ReefCloud knows which Benthic Group your labels belong to).

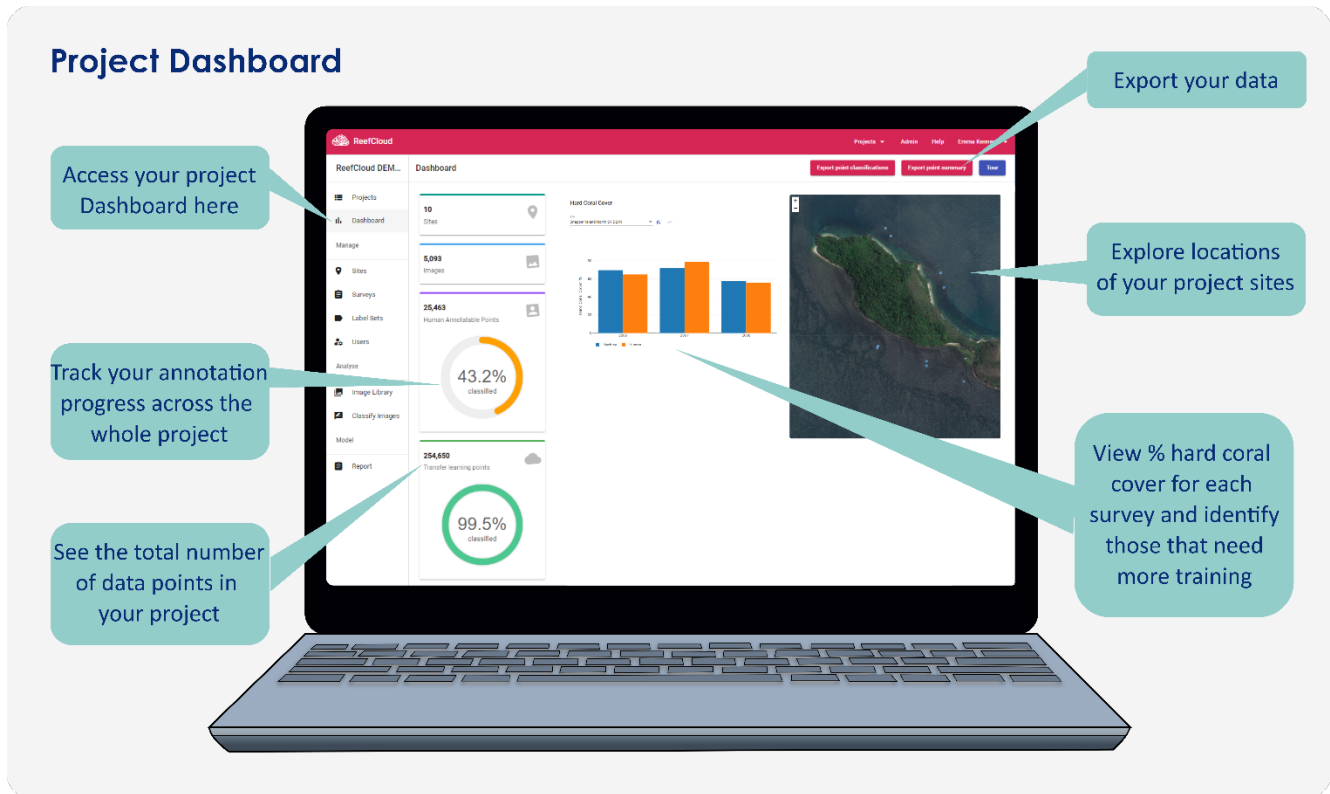
The **Cover plot** displays the estimated mean percentage cover of each benthic category across the site (between 0 and 100% cover), based on annotations across all photos within that site, with error bars showing 95% confidence intervals. Overlapping error bars suggest Human (blue) and Model (orange bar) are in agreement over estimated mean percent cover at that site.

The **Error plot** highlights the absolute difference in estimated cover by the Machine compared to the Human. This helps identify classes which might need a little more work: if blue bars are very large in this plot, we suggest returning to the Classify Images menu and providing more specific training for that class. You can filter the points by Machine classification so you can work specifically on training the model for that label. For example, if your "Pocillopora" category is showing a large blue error value, use the "Filter" drop down menu in the Classify Images tab to search for all instances of "Pocillopora" using the "points" view and correct any incorrect human annotations or confirm any machine classifications of "Pocillopora" that haven't been assessed yet.

Module 2.4. Explore results

2.4.1 View your project summary

At this stage, you can review the updated results from your project using the Project "Dashboard" tab, accessible from the left-hand ribbon menu.



Overview of the Project Dashboard page

The Dashboard is updated automatically to show you the latest statistics about your data and a map which can be used to navigate through the project sites and extract the total coral cover values from each site and over time. Information includes:

- **Sites:** the number of sites associated with your Project
- **Images:** the total number of uploaded photos in your Project
- **Human Annotatable Points:** a value for the total number of annotation points available across your project. This value will be the number of enabled images multiplied by the number of points you opted to use during the initial project set up. The plot shows the proportion of those points that have been annotated by you. Generally, we suggest annotating around 30% of the points across your dataset, but make sure you monitor how your AI model is performing using the "Model Report" tab: depending on the complexity and size of your

project you may find that you achieve a machine that performs well with considerably fewer annotations.

- **Transfer Learning Points:** this value reflects the additional work your AI model is doing across your project in terms of the total number of additional points its analysing in the background (up to 50 points per photo).
- **Bar plots:** view the total percentage hard coral cover (y-axis) reported across different surveys (x-axis), site-by-site, either by selecting site on the dropdown menu or clicking on a site on the map. For longer, regular time series you may want to change to a line graph to display your data, using the buttons. Blue bars (or points) represent hard coral cover for each survey reported by the machine, and orange represents hard coral cover for each survey based on your annotations. Orange bars are missing where you haven't annotated any photos from that survey - it is advisable to go back to "Classify Images" and annotate some images using the "Filter" menu to find images belonging to that survey. Hover over each bar to see the % coral cover value. Where bars show very different values, you should do some more work to train the machine for that survey. Hover your mouse down the right-hand side of the plot reveal a menu that allows you to zoom in, change axes, select areas and to download plot as a .png file.
- **Site Map:** see the locations of your project sites plotted on the Allen Coral Atlas satellite map. Select sites to view the site name and coordinates, and to change the bar graph.

What are the differences between "Human Annotatable Points" and "Transfer Learning Points"?

Under the "Dashboard" tab, you'll see there is a value given for the number of human annotatable points and a second value for the number of transfer learning points. The number of human annotation points are defined by you during the initial project set up and that remains fixed. The machine then always adds additional "transfer learning points" to each image to make the total number up to 50 points per image (i.e. if you have 5 points per image it will add 45, if you have 20 points per image it will add 30). These machine annotatable points can be seen under the "Classify Images" tab by unchecking the red "Only Show Human Annotatable Points" in the filter dropdown box, and the information will be also available in the downloadable data. They use your trained machine to pull additional information on benthic composition out of each photograph for you.

2.4.2 Export your data

Your project data can be exported as a .csv file using the red "Export Point Summary" and "Export Point Classifications" buttons on the top right of the Dashboard menu. Make sure you are happy with your AI model performance before exporting your data.

- **Point Summary** is the full dataset summarised by photo: for every enabled photograph in the dataset, % cover of all the benthic labels in your label set are listed in wide format, with each row representing one photo. Other columns contain the details of where the photo came from (date, site etc).
- **Point Classifications** presents your project data point by point: with every single annotation point in the dataset represented by a rows of data. Each row has the label assigned by the machine ("point_machine_classification" e.g. "TURF"), there's also a column for the human annotation (if it had one), and the other rows have the details of which photo it comes from, where on the photo (x,y coordinates), and the size of the photo, date, time location of the survey.

1 **Note:** Currently, machine transfer learning points (up to 50 points per image) are not included in the Point Classification export, because the file becomes very large. If you require this additional background machine classified data, please contact our team at support@reefcloud.ai and we can send it to you.

We are working on some template R scripts to help you produce graphical summaries from the .csv exports more easily.

2.4.3 Public Dashboard

The **ReefCloud [Public Dashboard](#)** is a publicly viewable website where synthesised data on hard coral, macroalgae and benthic composition from select ReefCloud Projects are displayed. Given appropriate [permissions](#), ReefCloud aims to share global trend data on coral reefs derived from ReefCloud Projects broadly using the Public Dashboard.

The **Public Dashboard** differs from the **ReefCloud Data Portal**, which requires a user account to access and the use of which is covered in the sections above.

Access the Public Dashboard by clicking on the green "Dashboard" button at the top right of the ReefCloud landing page. Click on the green "Explore Dashboard" pop-up to follow a tour of the site:

General Dashboard features

- **Search:** use the search icon on top left side bar to search for a region or a monitoring site.

-
- **Map layers:** switch on and off different map layers to assist your analysis. Available layers include:
 - Different boundary layers, including EEZs, MEOW and LME (Large Marine Ecosystem) boundaries can be toggled on and off.
 - "Site Name" labels for monitoring sites can be made to appear on the map by turning this button on.
 - Allen Coral Atlas layers: geomorphic coral reef habitat map and high-resolution coral reef satellite images can also be toggled on and off.
 - **Sites:** Click on an individual site, or a cluster of sites on the map to view insights. Hovering over a single site will display the Site Name, the Organisation that owns the Project that contains that site, and the last date that that site was sampled.
 - **Map style:** the square at the bottom left allows you to toggle between three different map styles to find a basemap that fits your reporting needs.
 - **Zoom in/Out:** use the + and - buttons at the bottom right to zoom in and out of the map or click the planet icon to zoom out to view the full global map.
 - **Feedback:** click on the speech bubble icon at the bottom right to send feedback to the team on the Public Dashboard.
 - **Share with others:** click on the "share" button at the bottom right to generate a shareable URL which loads the map location and displays the layers you have selected.

Benthic summary data

Click on a site or a cluster of sites to view the benthic monitoring summaries for the region.

Site-level data

Clicking on an individual site will reveal information on:

- **Hard Coral Cover**
 - This reveals information on the estimated proportion of the surveyed reef surface (derived from % cover from photos) that is covered by living hard coral.
 - *Hard coral cover.* Toggle the "Hard coral cover" button on and off to display the most recent known hard (scleractinian) percentage coral cover value for each site, represented by pink circles. Larger darker circles indicate higher levels of coral cover.
 - *Hard coral cover trend.* Explore the "Hard coral cover trend" plot, that reveals modelled change over time in hard coral cover (y-axis) over time (x-axis). The pink line shows the modelled trend line, overlaid on the 95% confidence interval. The dots represent real sampled data. This plot is only available if the site has been surveyed

multiple times. Hover your mouse over the plot to see how the coral cover values have changed with time. Major tropical cyclones, hurricanes and typhoons (wind icons) and heat stress events (thermometer icons) appear on the plot if they have impacted the site. Hover over the wind icons to reveal the name of the storm. Data can also be displayed by depth (filter either "deep" (>5m) or "shallow" (<5m) using the dropdown menu), in instances where surveys have been performed at multiple depths at the same location.

- **Macroalgae Cover**

- This shares information on the proportion of the surveyed reef (or % cover of photos) that is covered in living macroalgae (seaweed).
- *Macroalgae cover.* Toggle the "Macroalgae cover" button on and off to display the most recent known macroalgae cover value for each site, represented by green circles. Larger darker circles indicate higher levels of macroalgae.
- *Macroalgae cover trend.* Explore the "Macroalgae cover trend" plot, that reveals modelled change in macroalgal cover (y-axis) over time (x-axis). The green line shows the modelled trend line, overlaid on the 95% confidence interval (pale green). The dots represent real sampled data. This plot is only available if the site has been surveyed multiple times. Hover your mouse over the plot to see how the algae cover values have changed with time. Major tropical cyclones, hurricanes and typhoons and heat stress events will also appear on the plot if they have impacted the site.

- **Benthic Composition**

- This section shares summary information on the benthic composition of the surveyed reef, in terms of 12 broad benthic groups: Hard Coral, Soft Coral, Macroalgae, Turf Algae, Crustose Coralline Algae, Cyanobacteria, Seagrass, Hard Substrate, Rubble, Soft Sediment, Other Invertebrates and Other.
- *Benthic composition.* Toggle the "Benthic composition" button on and off to display the most dominant benthic group represented at each site on the map. Benthic groups are represented by different colours: hard coral is pink, soft coral blue, macroalgae green and turf algae red. The colour of the dot appearing on the map representing the site location indicates the benthic category that had the greatest proportion the last time the site was surveyed.
- Explore the "Benthic composition" bar chart, that reveals the reported proportion of each benthic category (y-axis) in different surveys (x-axis). Hover your mouse over the colourful bars to see the reported percent cover of each category, derived from survey photos. Major tropical cyclones, hurricanes and typhoons and heat stress events also appear on the plot if they have impacted the site.

This public site-level data are modelled, and therefore may look slightly different to your personal project data. ReefCloud uses site-specific models to provide estimates of the cover at a single site, informed only by data submitted from that local site.

The image displays a laptop screen with the ReefCloud dashboard. The dashboard is divided into several sections:

- Benthic Monitoring:** Includes a 'Hard coral cover' section with a legend (0-1%, 1-10%, 10-25%, 25-50%, 50-75%, 75-100%) and a 'Hard coral cover trend' line graph. A text box states: 'In 2022, the average hard coral cover for Great Barrier Reef Site 2 was estimated at 0.7%.' Below this is a 'Survey depth' graph.
- Disturbances:** A section for 'Depth' with options for 'Tropical cyclones' and 'Thermal stress'.
- Macroalgae cover:** Includes a legend (0-1%, 1-10%, 10-20%, 20-50%, 50-75%, 75-100%) and a 'Macroalgae cover trend' line graph. A text box states: 'In 2022, the average macroalgae cover for Great Barrier Reef Site 2 was estimated at 0.7%, ranging from 0.4% to 0.9%.' Below this is a 'Macroalgae cover (distribution by year)' bar chart.
- Benthic composition:** A section with a legend for 'Hard Coral', 'Macroalgae', 'Soft Coral', 'Turf Algae', 'Crustaceans', and 'Other'. A text box states: 'In 2021, hard algae was estimated to be the dominant benthic group at Great Barrier Reef Site 2.' Below this is a 'Survey Depth' bar chart.

 Callouts point to various features:

- 'Explore Benthic Summary data at the site and regional level' points to the Benthic Monitoring section.
- 'Changes in living hard coral cover over time' points to the Hard coral cover trend graph.
- 'Discover ReefCloud survey sites and projects' points to a map of the Great Barrier Reef region.
- 'Access environmental data such as exposure to cyclone damage' points to the Tropical cyclones section.
- 'Benthic composition' points to the Benthic composition section.

 A circular inset shows a map of the Great Barrier Reef region with a callout for 'Hayman Island Site 2'. Another circular inset shows a bar chart for '4MW exposure levels (hrs)' with a legend for 'Low (< 10 hrs)', 'High (10 - 15 hrs)', and 'Moderate (5 hrs)'. A text box states: 'The last tropical cyclone event in Mackay Whitunday 4MW leading to potential destructive waves was observed in 2011 with 102% of reef area exposed.' Below this is a 'Timeline' bar chart from 1985 to 2018.

Some of the features of the Public Dashboard include high-level summaries of benthic cover both for sites and regions, environmental data layers on heat stress and cyclone damage and maps of ReefCloud sites and projects.

Regional-level data

Clicking on a cluster of sites or a region (outlined blue) will reveal information on:

- **Hard Coral Cover**
 - This section reveals information on the average estimated proportion of living hard coral cover at the selected region, derived from broad spatial scale models that are derived from both monitoring and environmental data.

-
- *Hard coral cover estimate.* Toggle the "Hard coral cover" button on and off to display the most recent estimated hard coral cover mean value for the region, represented by pink circles. Larger darker circles indicate higher levels of coral cover.
 - *Hard coral cover trend.* Explore the "Hard coral cover trend" plot, that reveals modelled change over time in hard coral cover (y-axis) over time (x-axis). The pink line shows the modelled trend line, overlaid on the 95% confidence interval. This plot is only available if the site has been surveyed multiple times. Hover your mouse over the plot to see how the coral cover values have changed with time. If you select a larger region, it is less likely that tropical storm and heat events will appear on the graph, since (depending on the footprint of the natural disaster) not every single site will have been affected by high degree heating weeks or reef-damaging waves at the same time.
 - *Hard coral cover distribution by year.* Activate the toggle to explore regional changes in hard coral cover through time on the map. Use the slider to move through time, and watch as the modelled regional percent coral cover estimate changes on the map. The bar graph shows how the number of surveyed sites (y-axis) that belong to each of five reef health categories (0-10% coral cover, 10-30%, 30-50%, 50-75% and 75-100% coral cover) changes through time as you scroll.

- **Macroalgae Cover**

- This section reveals information on the average estimated proportion of macroalgae across the selected region, derived from broad spatial scale models that employ both monitoring and environmental data.
- *Macroalgae cover estimate.* Toggle the "Macroalgae cover" button on and off to display the most recent estimated algal cover mean value for the region, represented by green circles. Larger darker circles indicate higher levels of coral cover.
- *Macroalgae cover trend.* Explore the "Macroalgae cover trend" plot, that reveals modelled change over time in estimated macroalgae cover (y-axis) over time (x-axis). The green line shows the modelled trend line, overlaid on the 95% confidence interval. This plot is only available if the site has been surveyed multiple times. Hover your mouse over the plot to see how the algae cover values have changed with time.
- *Macroalgae cover distribution by year.* Activate the toggle to explore regional changes in estimated mean macroalgae through time on the map. Use the slider to move through time, and watch as the modelled regional percent algal cover estimate changes on the map. The bar graph shows how the number of surveyed sites (y-axis) that belong to each of five reef health categories (0-10% macroalgae cover, 10-30%, 30-50%, 50-75% and 75-100% cover) changes through time as you scroll.

As well as site-specific models that provide estimates of benthic cover at individual ReefCloud monitoring sites, the ReefCloud system combines datasets from across lots of different projects, and uses it to create a different type of broad spatial-scale statistical model which maps both known and unknown information on hard coral cover and macroalgae cover (median and upper/lower credibility intervals) across all known coral reefs (both monitored and unmonitored) in the region. The broad-scale models use a spatial grid and information about the environment (currently cyclone activity and degree heating weeks) alongside monitoring data to generate benthic cover estimates.

These broader spatial scale models provide estimates of cover at all sites regardless of whether photos exist inside ReefCloud or not. Importantly, these models are informed by all available monitoring and environmental data for the entire region and thus, the predictions for any given site are the result of both the observed data extracted from photos for that site as well as the more general patterns in its neighbourhood. Consequently, it is possible that the two different models may yield slightly different estimates if they are both compared for a single site or an area that only had a single monitored site.

Is my ReefCloud data contributing to the Public Dashboard?

The default is your ReefCloud Project data is private, unless you explicitly opt to contribute it to the global effort to track reef changes, either during [project set up](#) or later. If you make your data "public", it means your *Project Name*, *Project Description* and *Organisation Name* may appear on the ReefCloud public dashboard, along with simple benthic summaries (hard coral, soft coral, macroalgae, turf algae, CCA, cyanobacteria, seagrass, hard substrate, soft sediment, rubble, other invertebrates and other) derived from your photo datasets and annotations. This includes the location and name of your sites, depths, year of your surveys and some basic summary statistics, including hard coral cover summaries. If you do not want your data to appear in this way, you can adjust your Project privacy settings.

Your photos, labelsets and detailed analyses will always be private.

For more information see our [Privacy FAQ](#) and review the ReefCloud [Terms and Conditions](#).

Note: Currently, checking "Public" does not mean your data will automatically appear on the ReefCloud Public Dashboard: it still needs to go through internal QA/QC process and our science team will work with you to check you are comfortable before data contributes to global reporting summaries. *for this to happen, you will first need to map your primary project label set to our standardised global label set, using the [label set mapping function](#).

Environmental pressures

The ReefCloud Public Dashboard also uses global environmental data on heat and storm pressures on coral reefs to help us interpret observed changes the regional and global trends in benthic

composition. Currently, two environmental layers are available on the ReefCloud Public Dashboard: one related to heat stress, and one to tropical storm activity, both known to drive large-scale coral mortality on reefs.

Click on a cluster of sites or a region (outlined blue), and then scroll down in the left-hand pane and expand the "Environmental Pressures" section to explore how reefs are affected by 1) thermal stress and 2) cyclones.

Thermal stress

Mass coral bleaching has become one of the most visible and damaging environmental impacts of climate change. When the water temperature surrounding reefs rises above the long-term average maximum summer temperature for extended periods, corals can become heat-stressed, leading to coral bleaching and, eventually, death. Bleaching is the process by which corals lose their internal symbiotic algae (zooxanthellae), that give them their distinctive colours and main energy sources. If a coral is severely bleached for an extended period, disease and death become likely. Over the past decade, severe coral bleaching has become more extensive, frequent, and intense.

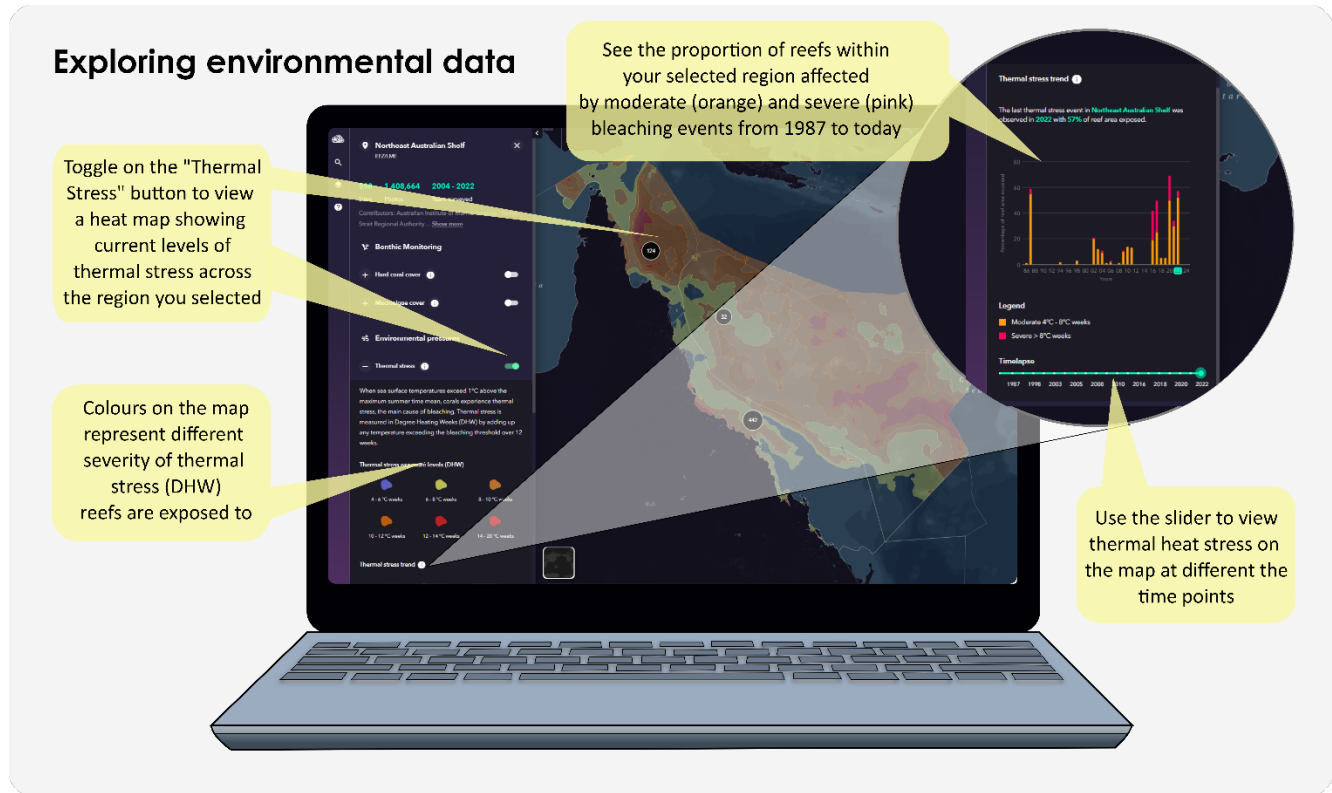
The Degree Heating Week (DHW) metric used on the Public Dashboard shows how much heat stress has accumulated in an area over the past 12 weeks (3 months). DHW is a widely used indicator and predictor of coral bleaching and can be estimated from long-term temperature logging and remotely sensed Sea Surface Temperature (SST) data. The units for DHW are "degree C-weeks", combining the intensity and duration of heat stress into one single number. Based on research at NOAA Coral Reef Watch, when the heat stress reaches four-degree C-weeks, observers can expect to see significant coral bleaching, especially in more sensitive coral species. When heat stress reaches eight C-weeks or higher, widespread bleaching and significant mortality are expected.

The DHW indicator is calculated by accumulating temperature readings that are more than one degree Celsius over the historical maximum monthly mean temperature for a given location. Thus, if the temperature is 2°C above the summer maximum for 4 weeks, the corresponding DHW indicator is (2 °C x 4 weeks) 8 DHW. Over time, the thermal stress accumulates over a 12-week sliding window.

Expand the "Thermal Stress" tools section by clicking on the "+" button on the left hand panel.

- **Thermal Stress Exposure.** A heat map with colours representing current DHW values will appear over the region selected on the map, when you toggle on this green button. Six classes of DHW are displayed, ranging from 4-6°C weeks (enough to trigger bleaching) right up to 14-20°C weeks (the most extreme bleaching events experienced to date).
- **Thermal Stress Trend.** View the "Thermal Stress Trend" plot to see the proportion of reef area (within the region selected) exposed to moderate (orange = 4-8°C weeks) and severe (pink = >8°C weeks) bleaching events through time (since NOAA records began in 1985). Use the green slider below the plot to watch the distribution of thermal stress change on the map across your selected region through time.

See ReefCloud Manual Part 3 for more information on how to [access and interpret this data](#) for your own analyses.



ReefCloud Public Dashboard has tools to explore exposure of coral reefs to thermal stress

Tropical cyclones

A cyclone is a rapidly rotating storm system with low atmospheric pressure at its calm centre (eye), inward spiralling rainbands, and strong winds forming in sufficiently warm sea surface temperatures in the world's tropical regions. In the southern hemisphere, these tropical storms are called cyclones and rotate clockwise. In the northern hemisphere, cyclones are called hurricanes (western hemisphere) or typhoons (eastern hemisphere) and rotate in an anti-clockwise direction. If sufficiently long-lasting, the extreme winds generated by these storms can build powerful waves, severely damaging coral reefs and shorelines.

By modelling where extreme waves could form during a cyclone (based on the location and size of the eye, the air pressure, the size of the cyclone and its speed and direction), it is possible to predict a cyclone 'damage zone' beyond which major damage to reefs will not occur. This zone is defined as the area within which the average height of the top one-third of the waves likely meets or exceeds 4 metres (H_s – significant wave height). We call this the 4MW ($H_s \geq 4m$) zone. Field data from 8 past cyclones in the GBR and Western Australia has shown such zones perform well at capturing severe damage – noting that because reef vulnerability is highly variable at <1km scales (due to the variability in reef structure), not all parts of the reefs within the damage zone will be damaged.

Expand the "Tropical Cyclones" tools section by clicking on the "+" button on the left hand panel to view 4MW model data for your region.

- *Cyclone path.* Red lines, indicating the path of the most recent cyclones across reef areas, appear on the map when you toggle on the green "Tropical Cyclones" button. Only cyclones that affected the region you selected on the map appear. The name of the cyclone will appear alongside the track.
- *Storm damage exposure.* A heat map with green colours representing the number of hours of exposure to damaging waves (wave heights equal to or over 4m are enough to damage coral) will appear over the region selected on the map, when you toggle on the green "Tropical Cyclones" button. Four classes damage are displayed, ranging from moderate (0-5 hours of exposure to damaging waves) right up to 20 hours (>10 hours is classed as extreme exposure).
- *4MW exposure trend.* View the "4MW exposure trend" plot to see the proportion of reef sites (within the region you selected) exposed to moderate (pale green = < 5 hours 4MW) to high (5-10 hours) to extreme (>10 hours) exposure to damaging waves, each year from when records began. Where >100% of the reef area appears for any given year, some sites in your region would have been exposed to multiple cyclones or the same cyclone circling back across a reef over which its already passed. Scroll the green slider back in time to see historical cyclone tracks for each year appear on the map, and the associated footprint of exposure to damaging waves (green heat map), change on the map across your selected region through time.

See ReefCloud Manual Part 3 for more details on how to access and interpret this data.

Glossary

Definitions of common terms used in ReefCloud and associated documents

ReefCloud Data Portal

The ReefCloud [Data Portal](#) is the free-to-use website which supports coral reef monitoring teams globally to store, manage and analyse coral reef benthic imagery using machine learning. Once a user account is set-up, the Data Portal allows teams to build an AI model with an informative label set, import and annotate benthic photo data, and visualise and export results within projects. Project permissions are managed within the Data Portal, where varied levels of access to users within a team can be applied.

ReefCloud Public Dashboard

The ReefCloud [Public Dashboard](#) is a publicly viewable website where synthesised data on hard coral, macroalgae and benthic composition from select ReefCloud Projects is displayed. Given [appropriate permissions](#), ReefCloud aims to share global trend data on coral reefs derived from ReefCloud Projects broadly using the Public Dashboard.

Project

A Project is a [private](#) space inside the ReefCloud Data Portal created for you and your collaborators to store and manage benthic imagery and metadata, annotate photo data, and visualise and export results related to your specific coral reef monitoring needs.

Site

A Site is a fixed geographic location (defined by a latitude and longitude) selected by users to make repeated measures over time as part of a coral reef monitoring sampling design. Within ReefCloud, a site is the minimum georeferenced spatial unit for a collection of photos. Sites remain fixed inside a Project, even if just visited once. Sites may contain multiple transects, at multiple depths, and may be sampled multiple times (see Survey below).

Survey

A Survey for the purposes of ReefCloud is a collection (such as a transect) of [downward facing photos](#) nested within a Site, occurring at a specific defined point in time. Often, coral reef monitoring involves multiple surveys at a single site, and these may be repeated over time.

Human Annotatable Points

The total number of Human Annotatable Points represents the number of point coordinates overlaid per image multiplied by the total number of images in each Project dataset. These Human Annotatable Points are annotated by the user to [train the model](#) within a Project given a defined Label Set. Tip: users should aim to annotate between 10-15% of the available Human Annotatable Points (across surveys) to adequately train the Model.

The number of Human Annotatable Points and their arrangement across each photo are defined during the initial Project set-up and remain fixed for your Project.

To view and annotate these points within a Project, click the "Classify Images" tab. A point (or multiple points) can be selected and annotated with the appropriate label, enabling machine learning. How points are viewed (including size and opacity, as well as annotation status as Unclassified, Human Classified, Machine Classified) can be adjusted by the user using the 'paint bucket' button on the top right.

Transfer Learning Points

The total number of points annotated in any given image in ReefCloud is always 50. This number includes the Human Annotatable Points defined by the user when creating a Project. For example, if a Project is set-up to include 5 Human Annotatable Points per image, the machine will annotate an additional 45 randomly dispersed points per image, totalling 50 Transfer Learning Points per image (and so on). This allows for data standardisation across ReefCloud analysis and reporting.

Therefore, the total number of Transfer Learning Points represents the total number of points annotated by the machine multiplied by the total number of images in a given Project dataset.

The additional machine annotatable points cannot be seen by the user on a given image, but the information will be available in the classification data exported.

Model

Each ReefCloud AI Model is Project specific, building on prior learning from large benthic imagery datasets to become 'smarter' through [Machine Learning](#) given knowledge gained from Human Annotatable Points labelled by the user.





Australian Government



AUSTRALIAN INSTITUTE
OF MARINE SCIENCE



ReefCloud

<https://reefcloud.ai>