Measuring Coral Vital Rates using TagLab Semi-automatic Coral Annotation and Temporal Linking across Fixed Sites: Standard Operating Procedures and Time Savings Estimate

Corinne Amir, Thomas Oliver, Mia Lamirand, Courtney Couch

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration

National Marine Fisheries Service
Pacific Islands Fisheries Science Center

NOAA Technical Memorandum NMFS-PIFSC-139
https://doi.org/10.25923/s2ym-tn10

May 2023

Measuring Coral Vital Rates using TagLab Semi-automatic Coral Annotation and Temporal Linking across Fixed Sites: Standard Operating Procedures and Time Savings Estimate

Corinne Amir[1,2], Thomas Oliver[2], Mia Lamirand[1,2], Courtney Couch[1,2]

[1] Cooperative Institute for Marine and Atmospheric Research
University of Hawaii
1000 Pope Road
Honolulu, Hawaii 96822
[2] Pacific Islands Fisheries Science Center
National Marine Fisheries Service
1845 Wasp Boulevard
Honolulu, HI 96818

NOAA Technical Memorandum NMFS-PIFSC-139

May 2023

U.S. Department of Commerce

Gina Raimundo, Secretary

National Oceanic and Atmospheric Administration
Richard Spinrad, PhD., Acting NOAA Administrator

National Marine Fisheries Service
Janet Coit, Assistant Administrator for Fisheries

About this report

Pacific Islands Fisheries Science Center technical memoranda are issued to promptly disseminate scientific and technical information to marine resource managers, scientists, and the general public. Their contents cover a range of topics, including biological and economic research, stock assessment, trends in fisheries, and other subjects. Administrative reports typically have not been reviewed outside the Center; therefore, they are considered informal publications. The material presented in administrative reports may later be published in the formal scientific literature after more rigorous verification, editing, and peer review.

Other publications are free to cite PIFSC administrative reports as they wish, provided the informal nature of the contents is clearly indicated and proper credit is given to the author(s).

Recommended citation

Amir C, Lamirand M, Couch CS, Oliver T. 2022. Measuring coral vital rates using TagLab semi-automatic coral segmentation and temporal linking across fixed sites: standard operating procedures and time savings estimates. PIFSC Technical Memorandum, TM-PIFSC-139, 32 p. doi 10.25923/s2ym-tn10

Copies of this report are available from

Pacific Islands Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
1845 Wasp Boulevard, Building #176
Honolulu, Hawaii 96818

Or online at

https://repository.library.noaa.gov

Table of Contents

List of Tables

List of Figures

1. Introduction

Scleractinian corals form the foundation of coral reefs by constructing the framework on which reef-associated organisms rely for habitat and food. As a result, changes in coral growth, fission, fusion, recruitment, and mortality (i.e., coral vital rates) have direct consequences on the structure and function of coral reef ecosystems (Done 1992; Edmunds and Riegl 2020). Incorporating coral vital rates into robust models used to assess the impacts of environmental drivers on reef dynamics can help inform which management actions are most likely to improve reef resilience.

NOAA's Ecosystem Sciences Division (ESD), formerly the Coral Reef Ecosystem Division, has been monitoring Pacific coral populations and benthic communities since the early 2000s in a coherent effort now known as the Pacific National Coral Reef Monitoring Program (NCRMP). ESD monitors the status and trends of coral reefs across 40 primary islands, atolls, and shallow banks in the U.S. Pacific. To date, ESD has used snapshot visual assessments of coral communities and benthic photoquadrat imagery at randomly selected sites to generate coral demographic metrics (i.e., colony density, size structure, partial mortality). However, these methods do not track the same corals over time, limiting our ability to measure how coral colony-specific growth and mortality are impacted by factors such as colony characteristics (e.g., size, life history strategy) and external disturbances (e.g., temperature stress) (Brito-Millán 2019; Furby et al. 2017, Morais et al. 2021).

Photogrammetry, a method of producing geometrically accurate large area imagery, has increased in popularity as a tool for studying spatio-temporal trends on coral reefs. Large area image analysis reduces costs and complexity of field operations, provides a permanent record of benthic communities, and can be used to track hundreds to thousands of coral colonies across multiple sites and time points, thus providing the ecological and spatial replication necessary to test the links between vital rates and environmental conditions (Rodriguez et al. 2022). However, manually annotating imagery and tracking coral colonies across time is labor intensive, taking approximately 40 hours to annotate and link corals within ~10m^2 of reef across two time points. Currently, fully manual annotation cannot keep up with the speed at which imagery is collected. To address this limitation, machine learning technologies have increased in popularity as a tool to reduce image annotation time while maintaining accuracy.

One such example is TagLab, an open-source AI-assisted software created by the Visual Computing Lab (http://vcg.isti.cnr.it/) that uses a manually assisted workflow to semi-automatically annotate and track coral colonies across multiple time points (Pavoni et al. 2021). This document provides the standard operating procedures (SOP) for the integration of TagLab into our current vital rates workflow as outlined in Rodriguez et al. (2022). The workflow includes 1) preparing sampling quadrats (optional) and a geodatabase in ArcGIS Pro, 2) semi-automatically annotating coral colonies within the specified sampling region of each orthomosaic in TagLab, 3) semi-automatically linking live coral colonies across time points in TagLab, and 4) merging TagLab coral colony species ID and linking to ArcGIS Pro geodatabase information to estimate vital rates. This SOP also provides a time savings comparison between manual annotation using the previous Vital Rates workflow (Rodriguez et al. 2021) and our TagLab-assisted Vital Rates workflow. We posit that, although TagLab remains an ongoing project of the Visual Computing lab and requires additional testing, it reduces personnel hours by 40%, making it a worthwhile approach to quantifying coral vital rates.

2. Prepare Files in ArcGIS

In this section, ArcGIS Pro 2.8.0 or later is used to create random sampling quadrats and a geodatabase for recording metadata and organizing shapefiles, fixing orthomosaic alignment issues if they arise, and exporting GeoTIFFs and shapefiles for use in TagLab. Each site will have its own geodatabase and set of quadrats that are used for every time point available. Given the time-consuming nature of manual and semi-automated coral annotation, a randomized sub-sampling strategy is used to provide enough coral colony transitions across a wide range of size classes to fit robust demographic models and still proceed efficiently through many sites' worth of data. In our case, square quadrats (0.5 m^2 area each, 15-25 per site) are randomly "placed" throughout the region of overlap between orthomosaics of the same site and corals with centroids that fall within the quadrats are annotated. This tutorial assumes a basic understanding of ArcGIS. Ensure that you have an ArcGIS Pro Advanced license to use all necessary tools and functions.

2.1 Create an ArcGIS Project:

1. Open a new ArcGIS project and use the 'Add Folder' tool under the 'Insert' tab to add the folder containing the orthomosaics and other TagLab-related files (e.g., M:\FixedSiteProducts\HAW_OCC_010\TagLab).
2. Upload all available orthomosaics for a given site using the 'Add Data' tool under the 'Map' tab.
3. Set the coordinate system for each orthomosaic. Under 'Analysis,' click on 'Tools' and search for Define Projection (Data Management Tools).
    a. Input Dataset or Feature Class = year_site-name_orthomosaic.tif
    b. Under 'Coordinate Systems,' set 'Current XY' to 'WGS 1984 UTM Zone 4N' ('Projected Coordinate System' > UTM > WGS > Northern Hemisphere).
    c. If not previously done, right click to 'Add to Favorites.'
    d. Zone changes depending on site location.
4. The orthomosaic should already be properly scaled if it was scaled and oriented in Agisoft; however, confirm it is correctly scaled by using the Measure tool under the 'Map' tab and measuring an object of known distance (e.g., a scale bar).
5. In most cases, the model colors will be incorrect. In the Raster Layer tab, click on the drop down menu under 'Stretch Type' and change to None.
    a. If the orthomosaic was not previously color corrected, right click on the orthomosaic in the Contents pane, select symbology, and change the RGB values.
6. All orthomosaics should appear within the same region of the Map window. If this is not the case or the alignment is otherwise incorrect, refer to the following

section.

2.2 Align and Export Orthomosaics:

On rare occasions, orthomosaics do not align atop one another when imported into ArcGIS. When this error occurs, orthomosaics must be aligned in ArcGIS and exported for use in TagLab. If imported orthomosaics are already aligned in ArcGIS, skip this section.

1. Select one orthomosaic to act as the reference orthomosaic (typically the orthomosaic with the most recent time point and/or most accurate metadata). All the other time points will be aligned to this orthomosaic. Right click on the reference orthomosaic in the Contents panel and select Zoom to Layer.
2. In the Contents panel, select the orthomosaic that is getting aligned to the reference orthomosaic and select the ‘Fit to Display’ within the Georeference tab. This will move the orthomosaic to the same display extent as the reference orthomosaic.
    a. To access the Fit to Display tool, open the Imagery tab and click on Georeference to open up the Georeference tab.
    b. You may need to change the zoom settings on the reference model to improve the alignment between the orthomosaics.
    c. If the ‘Fit to Display’ tool is disabled, the orthoprojection and reference orthomosaic may be using different coordinate systems or one may not have a defined coordinate system. To fix this, from the Analysis tab, open the ‘Tools’ section and search for Define Projection (Data Management Tools).
        i. Input Dataset or Feature Class: new [georeferenced] orthomosaic
        ii. Coordinate System: WGS 1984 UTM Zone 4N
        iii. If the coordinate systems match but the Fit to Display tool is still disabled, click Set SRS.
3. To fine tune alignment between the two models, click on Add Control Points within the Georeference tab. Select a point on the orthoprojection and the identical point on the reference orthomosaic. When both points are chosen, you may notice an orthomosaic jump to its new location.
    a. Choose a point that is unlikely to change between years, such as bolted down science equipment or shrimp/crab burrows in coral.
    b. Choose 3-5 control points to improve model alignment.
    c. If needed, use the rotate, move, and scale tools to fine tune alignment.
4. Once the two orthomosaics are aligned, click Save in the Georeference tab and close the Georeference tab to remove the control points from the Map window.

5. Ensure that orthomosaic colors are corrected (i.e., remove Stretch Type) once alignment is completed.
6. Orthomosaics need to be exported from ArcGIS in order to align with the quadrats in TagLab. Prior to exporting, ensure that shapefiles and orthomosaics have the same spatial reference coordinates. In some cases, the orthomosaic will need linear units converted from degrees to meters.
    a. In the Geoprocessing tab, search and select Project Raster (Data Management Tools).
        i. Input raster: orthomosaic
        ii. Output raster: Save to the site's ARC folder (but not inside the default geodatabase) and add .tiff to the end of the site name.
        iii. Output coordinate system: Select one of the orthomosaics from the same site with an accurate geometric and projected coordinate system.
        iv. Select Run.
        v. Once the new tiff appears in the contents pane, fix the symbology by navigating to the Appearance tab and changing Stretch Type to None.
7. Export updated orthomosaics by opening the Share tab and selecting Export Map.
    a. File Type: TIFF
    b. Name: Year_Site-Name_mos (save to the site ARC folder)
    c. Image compression: LZW.
    d. Pixels: Conserve the existing width:height ratio and choose a width similar to the orthomosaic exported from Agisoft to maintain a high resolution. Make pixel dimensions identical among all exported orthomosaics.
    e. Check "Write GeoTIFF tags."
    f. Color depth: 32-bit with Alpha
    g. Do NOT alter the Map window view in between orthomosaic exports.

2.3 Create Random Sampling Quadrats:

1. To create the quadrats, start by generating random points in the orthomosaic region with multi-time point overlap. In the geoprocessing pane, select the Create Random Points (Data Management Tools) tool (Figure 1).
    a. Output Location: Site geodatabase
    b. Output Point Feature Class: RandomPoints
    c. Constraining Feature class: auto fill
    d. Choose the polygon tool to trace the region of overlap between orthomosaics.

e. Number of points: 25 (Long)
f. Minimum allowed distance: 1 meter (Linear Unit)

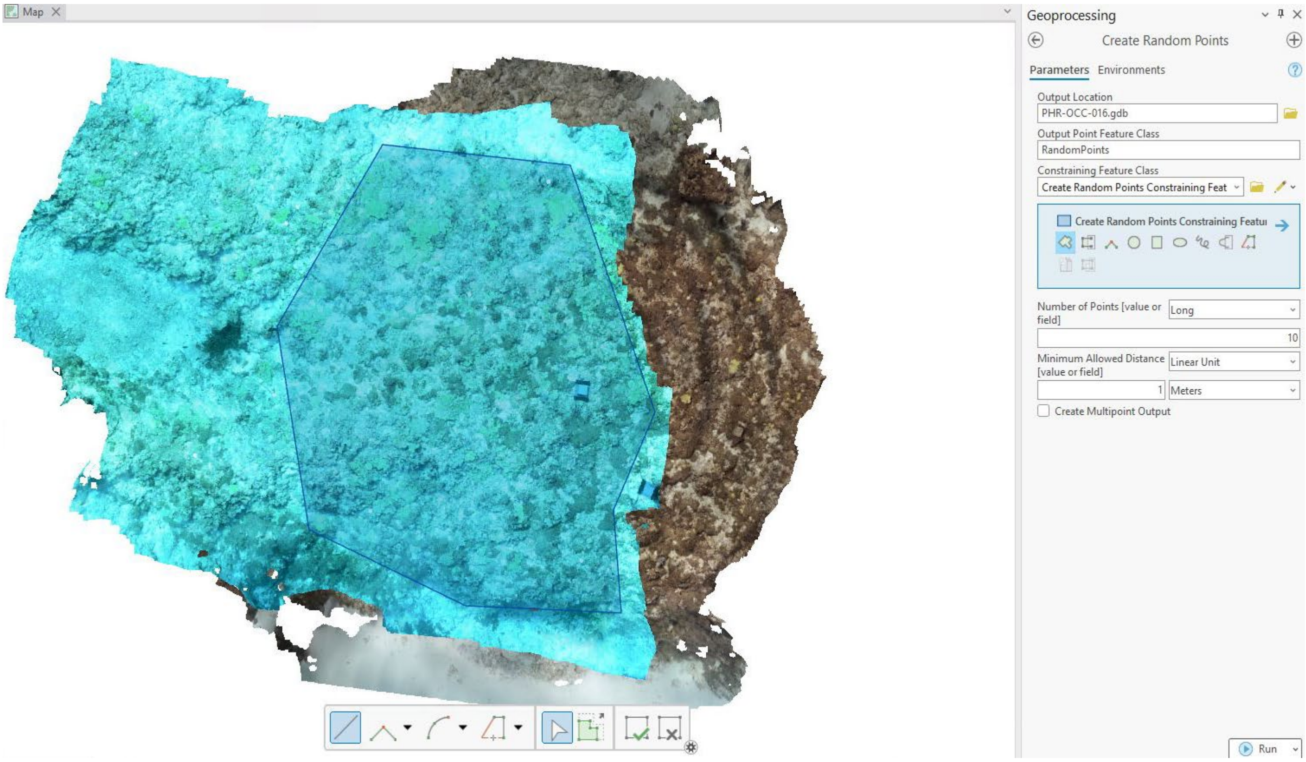


Figure 1. Create Random Points (Data Management Tools) tool allows the user to create a region in which random points are constrained (left). This tool is also used to set the number of random points and their minimum distance from one another (right).

2. In the geoprocessing pane, select the Buffer (Analysis Tools) tool to create a circular buffer around the random points (Figure 2).
   a. Input Features: RandomPoints
   b. Output Feature Class: autofill
   c. Distance: 0.3535 Meters (Linear Unit)
   d. Method: Planar
   e. Dissolve Type: No Dissolve

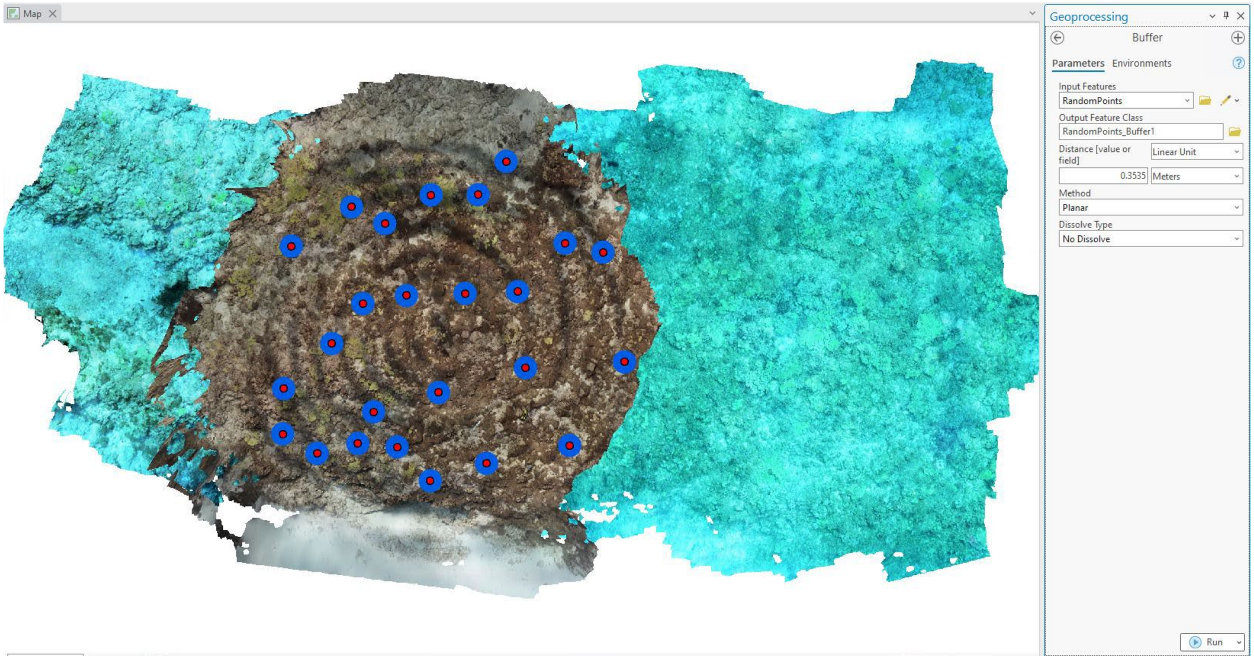


Figure 2. The Buffer (Analysis Tools) tool allows the user to create a buffer (blue) of a specific diameter around the previously created random points (red).

3. Turn the circular buffer into a square using the Minimum Bounding Geometry (Data Management) tool (Figure 3). Although this step is not required, it is done at the request of members of the computer science community that prefer working with polygons similar to pixels and square grids commonly used in automated and semi-automated image analysis.
    a. Input Features: RandomPoints_Buffer
    b. Output Feature Class: rename as Quadrats
    c. Geometry Type: Rectangle by area
    d. Group Option: None

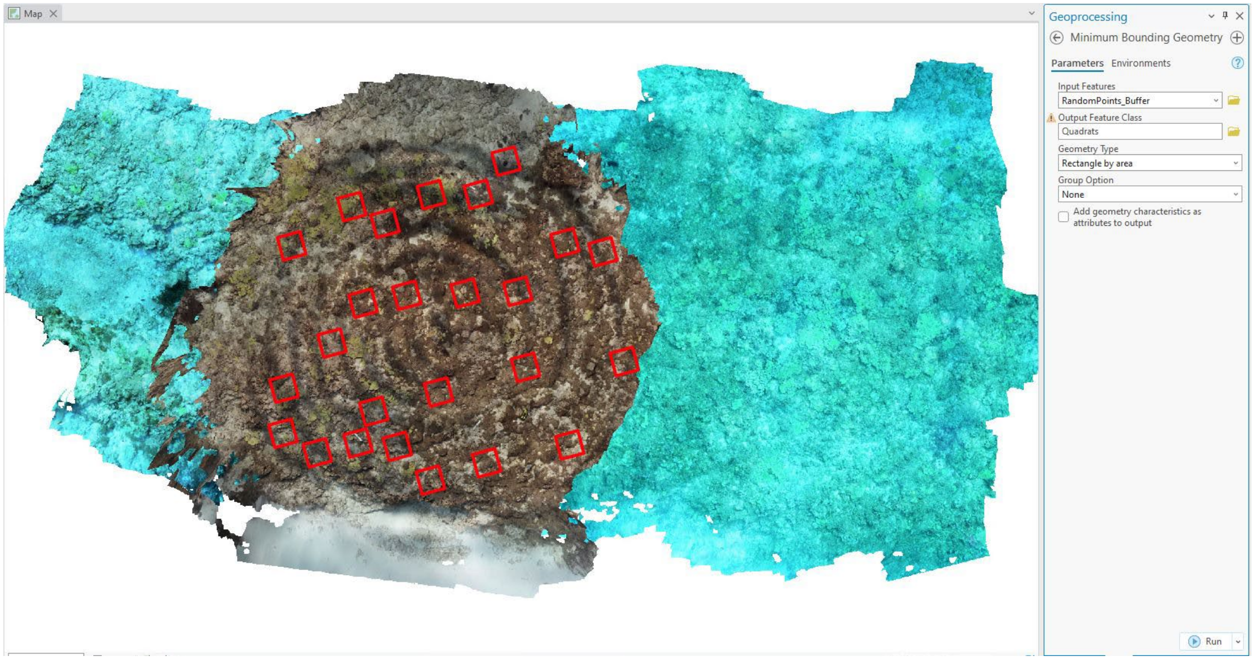


Figure 3. The Minimum Bounding Geometry (Data Management) tool allows the user to turn the circular sampling region into a square. Once quadrats have been made, the user can change the symbology to no fill and a thick (3 point width) brightly colored perimeter to assist with annotating corals.

4. Convert the quadrat geodatabase feature class into a shapefile feature class using the Feature Class to Shapefile (Conversions Tools) tool.
    a. Input Features: Quadrats
    b. Output Folder: Save to the ARC folder and keep the same file name.
    c. Change the symbology to no fill color and a red (or a similarly bright, contrasting color) perimeter with 3 point width. The quadrat color will not carry over to TagLab, but while using ArcGIS, the color is helpful for keeping track of the quadrats' location.

2.4 Set up the Geodatabase:

Prior to starting annotations, a geodatabase in ArcGIS will be set up for easier metadata recording and file organization. The template shapefile within the geodatabase will be imported into TagLab to maintain backwards compatibility between the two platforms. After coral annotations and linking are completed in TagLab, shapefiles will be imported back into ArcGIS where the metadata will be added.

1. Refer to *Measuring coral vital rates using structure-from-motion photogrammetry at fixed sites: standard operating procedures and error estimates* Appendix III - Setting up the Geodatabase.

(https://repository.library.noaa.gov/view/noaa/32739) to create the geodatabase and attribute tables required for collecting vital rates data.

2. Once the geodatabase and template feature class (labeled as “template” in the geodatabase) have been created, convert the feature class into a shapefile using the Feature Class to Shapefile (Conversions Tools) tool.
    a. Input Features: Year_Site-Name_Initials
    b. Output Folder: Save to the site’s Arc folder (outside of the geodatabase).
3. Before saving, make sure the shapefile has the same spatial reference coordinates as the site orthomosaics. Both files should have a projected coordinate system of WGS 1984 UTM Zone 4N (zone will change depending on site location). To change the coordinate system of a shapefile, use the Project (Data Management Tools) tool within the Geoprocessing Toolbox.
    a. Input Dataset: Shapefile with incorrect coordinate system
    b. Output Dataset: Keep the same name as previous
    c. Output Coordinate System: WGS_1984_UTM (add in zone specific to the site location.)
4. Save all changes to the Arc Project.

3. Setting up TagLab

This section outlines the process of exporting coral annotations using TagLab version 2023.1.23. TagLab is regularly updated; therefore, some steps may not align with more recent versions of the software.

3.1 Preliminary Steps:

1. Please refer to https://github.com/cnr-isti-vclab/TagLab for information regarding TagLab dependencies install and updates regarding software compatibility. Dependencies required prior to opening TagLab include:
    a. Python form 3.8 or greater (Python 3.7 will stop receiving security updates in June 2023).
    b. CUDA 11.6 or 11.7
2. When installing Python, a pop up window will appear, prompting the user to complete the download process. In the pop up window,
    a. check Add to PATH at bottom,
    b. select custom installation,
    c. keep all optional features,
    d. advanced options > customize installation location, and
    e. install in the following location: c:\Program Files\Python.

3. Download TagLab from https://github.com/cnr-isti-vclab/TagLab
    a. Click on the green “Code” tab at the top right corner of the GitHub page and download as a zip file.
    b. Unzip the file and save it to the computer’s C drive. The file path should be C:\TagLab-main.

3.2 Open TagLab:

1. Open a command prompt window and change the directory to the TagLab folder file path: `cd C:\TagLab-main`.
2. To start the program, type `python TagLab.py` into the next command line. TagLab may take several seconds to open (Figure 4).

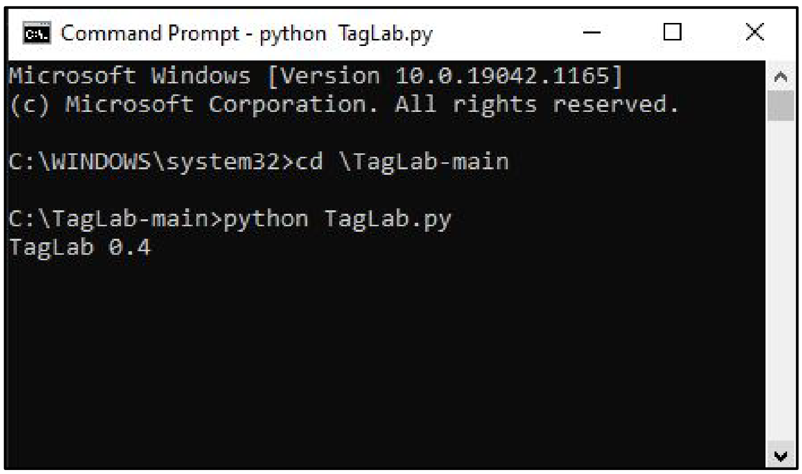


Figure 4. Command prompt window containing code required to open TagLab. If the command prompt directory is already within the C drive, the abbreviated code `cd \TagLab-main` can be used to access the TagLab folder.

3. If TagLab does not open, check the command prompt window for error messages. There are several common error messages.
    a. Make sure you are using the correct Python and CUDA software versions.
        i. To check if you have the correct software version, type `python --version` or `nvcc --version` to view the current version in use.
    b. If TagLab requires an update prior to opening (after running `python TagLab.py`, a message will appear saying to update TagLab before opening), use the code `python update.py`.

4. Using TagLab

4.1 Navigate TagLab:

The TagLab Interface:

Following Figure 5, annotation and linking tools are located in the toolbar on the far left. The Labels window (top right) contains the labels dictionary with all required species codes and associated RGB fill values used to assign species codes. The Layers window (right, second from top) displays all loaded orthomosaics and their associated annotation layers. The Data Table window (right, third from top) contains all data regarding the annotations, and shapefile information will be stored there. Region Info window (right, second from bottom) provides detailed information regarding individual patch annotations. The Properties tab contains TagLab-derived data that is auto-filled, and the Attributes tab contains ArcGIS-derived information from the imported attribute table that can be manually edited. The Map Preview window (bottom right) maintains full view of the map when zoomed in, and the gray box displays the region currently in view in the center screen. The center screen view can be changed by moving the gray box in the Map Preview window.

- To pan around the map regardless of the tool currently in use, press ctrl + left mouse button or, in the Map Preview (bottom-right of the workspace), drag the gray box to your desired location (Figure 5).
- Regardless of the tool selected, zoom is always accessible by scrolling.
- Press ctrl + z to undo a command.
- The term “genet” is used in TagLab to describe the group of individual coral patches that make up a single coral colony (genet = colony).
- All individual patches and quadrats within a given shapefile will be labeled with a unique ID number. To check the ID, patch size, etc., double click on the delineation and its associated information will appear in the Region Info box. IDs, species codes, etc. for all annotations within a shapefile can be found in the Data table, where unique ID is labeled as Id, and species code is labeled as Class (Figure 5).
- In TagLab, a Map is the combination of orthomosaic and digital elevation model (if uploaded) along with their associated metadata that includes date, pixel size, and name.
- For a list of shortcuts, click Ctrl + H (or navigate to Help > Help), but keep in mind that some of these shortcuts and tools may be outdated (Figure 6).
- For additional information regarding the TagLab interface, go to file:///C:/TagLab-main/docs/TagLab.html

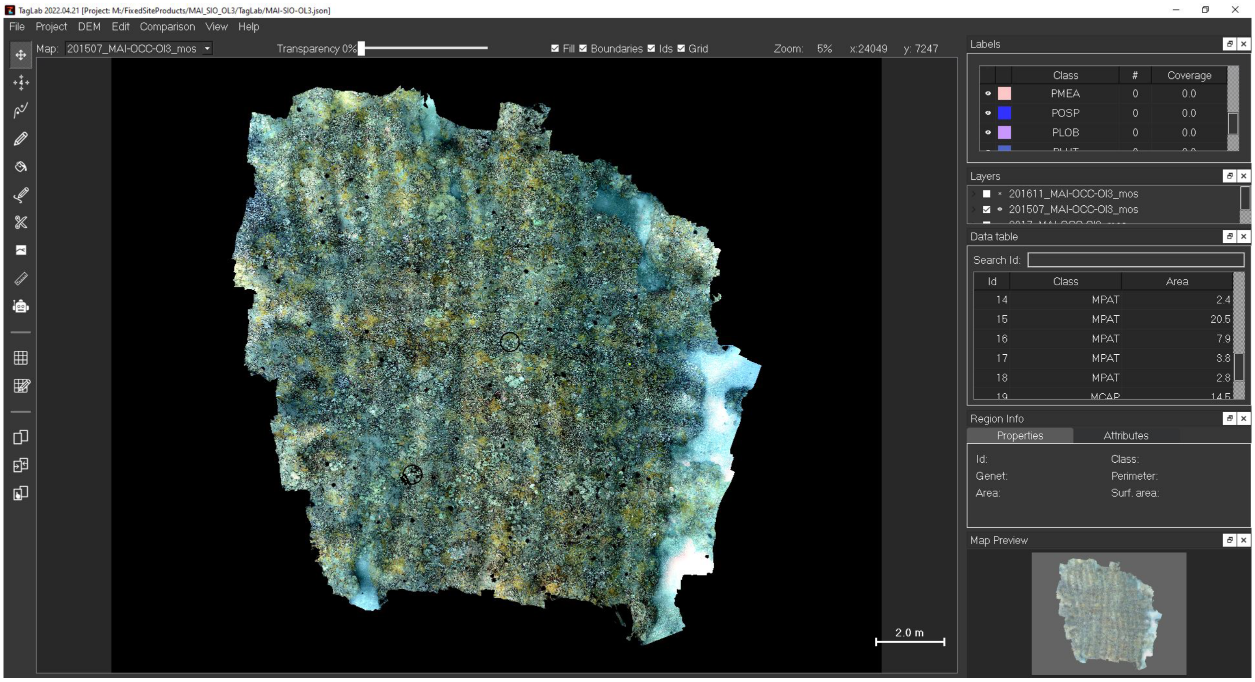


Figure 5. The TagLab interface.

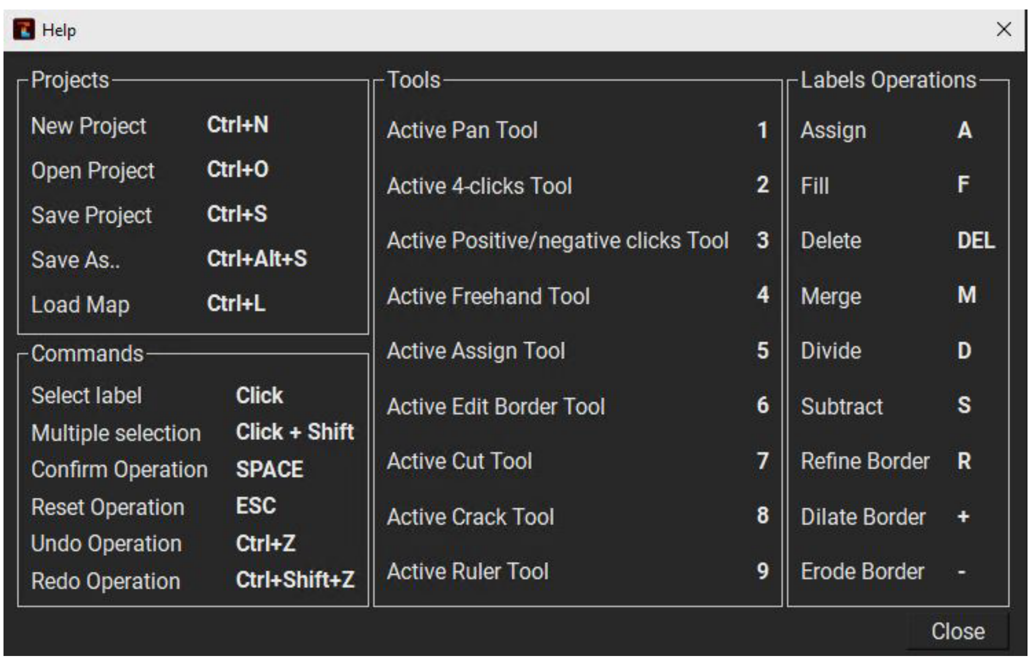


Figure 6. Panel display of TagLab shortcut keystrokes. This window can be reached by selecting Help > Help.

4.2 Create a TagLab Project:

1. To create a new TagLab project, select File > New Project.

2. Import the orthomosaics into TagLab (Figure 7).
    a. Project > Add New Map
        i. Map Name: same as orthomosaic
        ii. RGB Image: the file path of the orthomosaic (click the 3 dots on the right side to browse for the orthomosaic).
        iii. Depth Image: the file path of the DEM (optional).
        iv. Acquisition Date: the date that the raw images were collected.
        v. Pixel size (mm): leave blank.
    b. Currently, TagLab does not support map sizes larger than 32767 × 32767 pixels.
    c. Map settings and file paths can be changed later by going to Project > Maps Editor.

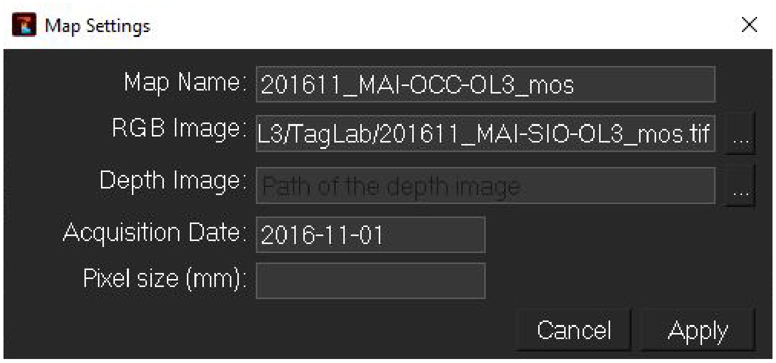


Figure 7. Select Project > Add New Map and the Map Settings window will appear.

1. The quadrat shapefile must be separately added to orthomosaics within the project in order to appear atop each orthomosaic. Import the site-specific quadrat shapefile by selecting File > Import > Import Shapefile. In the Shapefile Attribute Editor window:
    a. Shapefile type: Labeling layer
    b. Do not import any fields
    c. Select class name: None
2. (Optional) Import the ArcGIS-produced shapefile used for coral annotations into TagLab. Select File > Import > Import Shapefile and choose the shapefile labeled TYear_Site-Name_Initials within the site Arc folder. The Shapefile Attribute Editor will appear automatically (Figure 8).
    a. Shapefile type: Labeling layer
    b. Fields to import: all attribute table columns
    c. Select class name: Spec_Code
    d. If annotations already exist within the shapefile, ensure that species code names and associated RGB values match the label dictionary loaded into

TagLab. If these values do not match, TagLab will crash when trying to upload the shapefile.

e. Select Ok

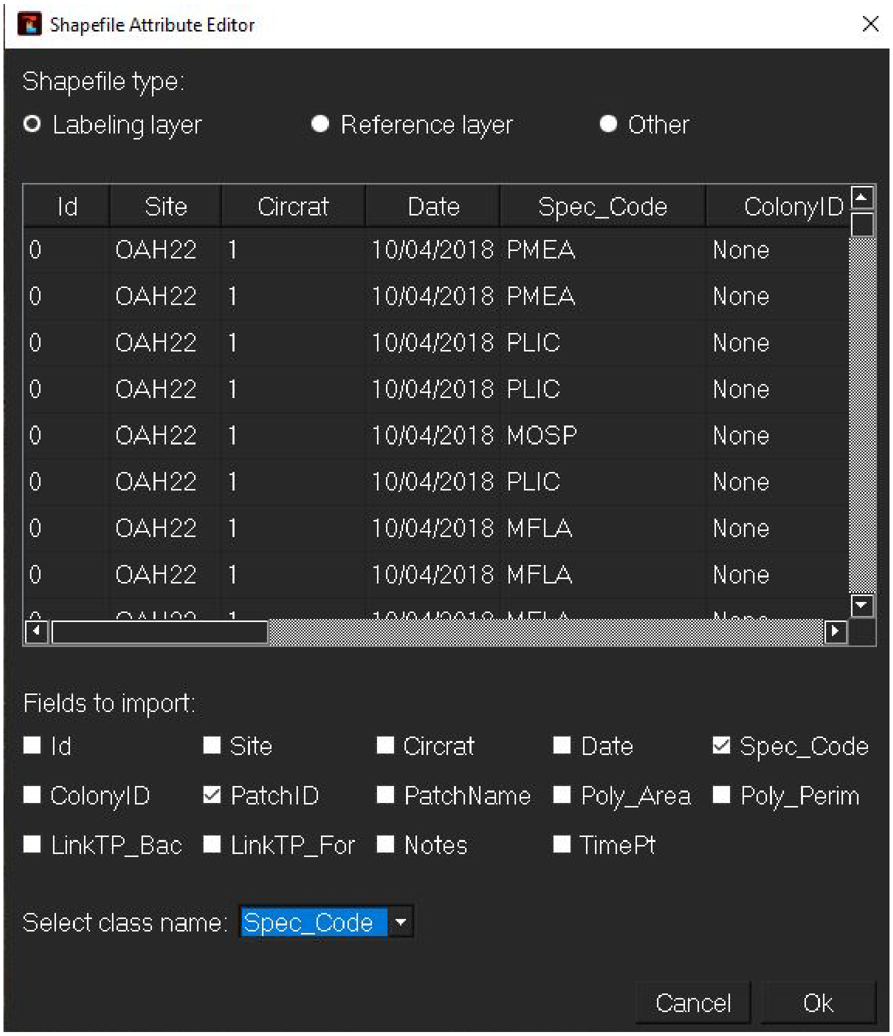


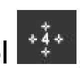
Figure 8. The shapefile attribute editor allows the user to choose which fields in the Arc attribute table are imported into TagLab. Fields imported into TagLab will be visible in the Data Table window.

3. If the label dictionary in TagLab is missing several species codes or contains incorrect RGB values, edit the labels dictionary by going to Project > Label dictionary editor.
    a. Do NOT alter the dictionary if it is already in use for other projects or annotators! If it is necessary to alter a label dictionary, notify the project lead before doing so.
    b. Double click on the incorrect label and change the RGB values and/or species code name. When complete, click Update. New labels can be

added as well using the label editor.
    c. When all species codes are in the label dictionary, click Save and save to M:\FixedSiteProducts.
4. Once maps and shapefiles have been imported into TagLab, go to File > Save as and save the TagLab project in the site-specific Products folder.
    a. Do NOT close down TagLab without saving changes to your project.
    b. Enable automatic save by going to File>Preference.

4.3 Annotate Coral Patches:

Previously, annotations were completed manually in ArcGIS. However, annotations can now be completed in TagLab using both manual and semi-automatic annotation. Below are some tips and explanations on how to use TagLab's annotation tools. Most tools can be found on the left side of the TagLab interface (Figure 5). However additional tools are available via keystrokes outlined within Help > Help (Figure 6). For additional information regarding TagLab tools, go to file:///C:/TagLab-main/docs/TagLab.html. For information regarding criteria for annotating coral patches, refer to *Measuring coral vital rates using structure-from-motion photogrammetry at fixed sites: standard operating procedures and error estimates* Section 1: ArcMap Segmentation and Annotation (https://repository.library.noaa.gov/view/noaa/32739).

1. Create new coral annotations using either the 4-clicks segmentation tool , the positive/negative clicks  tool, or the freehand segmentation tool . Oftentimes, the 4-clicks segmentation and positive/negative clicks tools can reduce annotation time.
    a. To use the 4-clicks segmentation tool (Figure 9):
        i. Hold shift and use the left mouse button to place four points on the coral patch's extremes (extreme top, extreme bottom, extreme left, extreme right) and press spacebar to create the delineation.
        ii. When the 4-clicks segmentation tool is in use, it is not possible to select any other coral patches.
        iii. Oftentimes, 4-clicks segmentation tool requires fine-scale editing and addition of partial mortality patches within the coral patch's perimeter. To add these edits, continue to step 2.

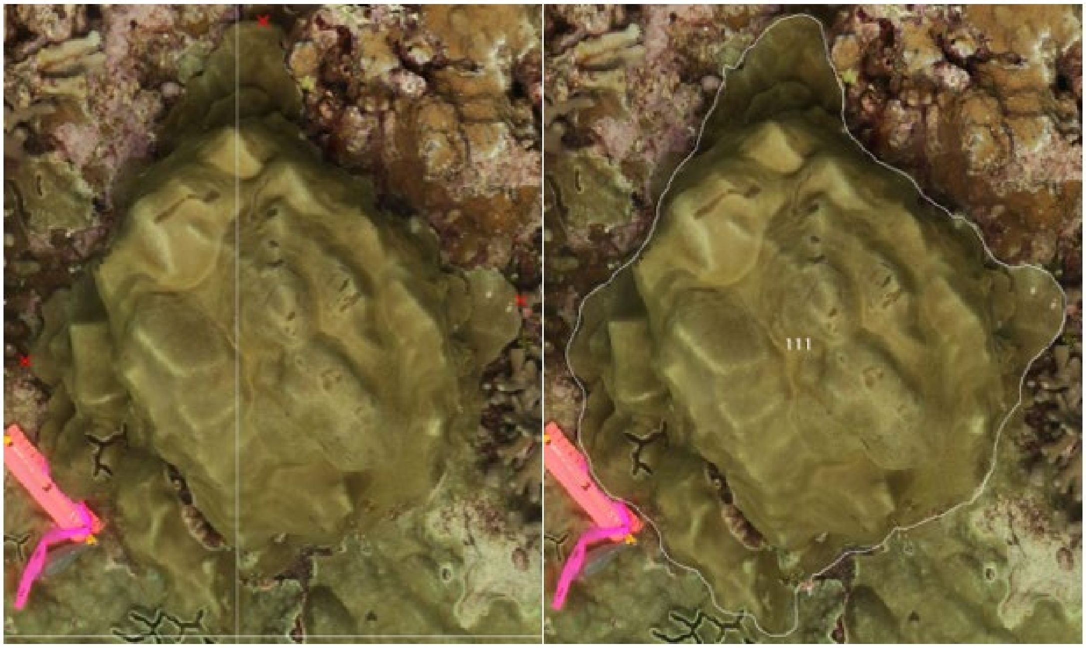


Figure 9. 4-clicks segmentation tool. Red crosses will appear for the first three clicks (left). The final fourth click triggers automatic segmentation. After completing the fourth click, TagLab may take a few seconds to load the new delineation (right).

b. To use the positive/negative clicks tool (Figure 10):
   i. Zoom into the coral you wish to annotate, framing the entire coral patch.
   ii. Place a positive click (shift + left click) near the center of the coral patch.
   iii. Add additional positive and negative (shift + right click) points as needed and press space bar to confirm.

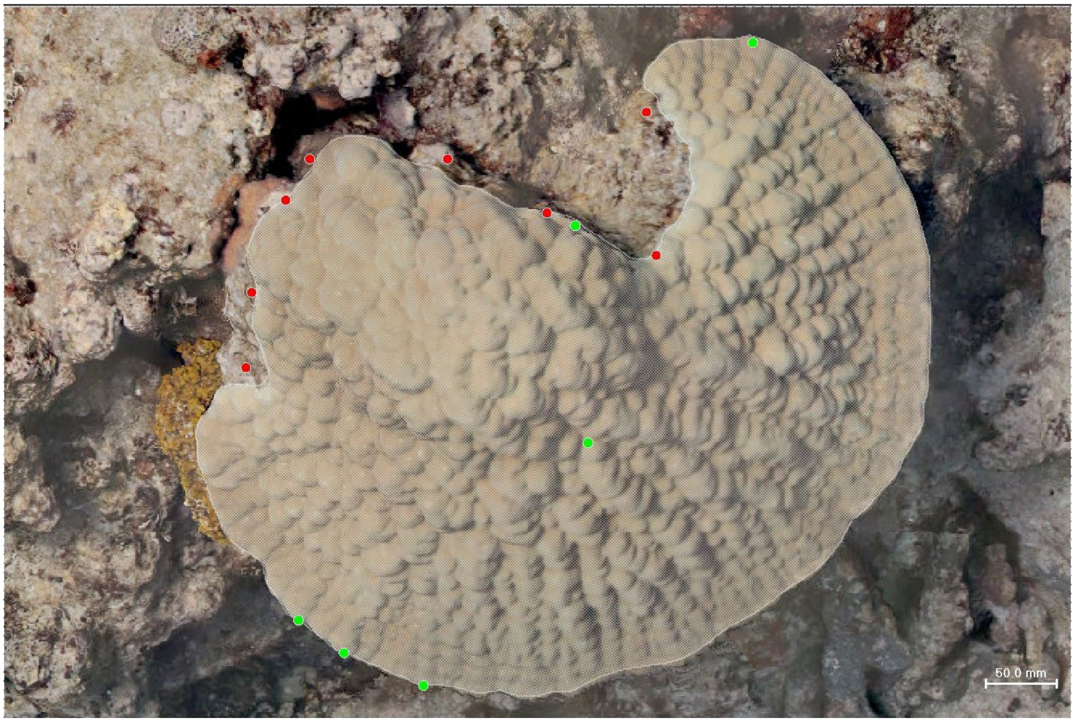


Figure 10. Positive/negative clicks tool. Positive clicks (green circles) add area to the coral patch and negative clicks (red circles) remove area from the coral patch.

c. To use the freehand segmentation tool (Figure 11):
   i. Hold down the left mouse button and trace the perimeter of the coral patch. Release the left mouse button and press the spacebar to save the annotation.
   ii. If the spacebar is pressed but the delineation does not turn white, there may be a hole in the delineation. Close the hole and press the spacebar again.
   iii. Rather than creating a single continuous line, multiple lines can be linked together to create the perimeter around a coral patch (Figure 11).

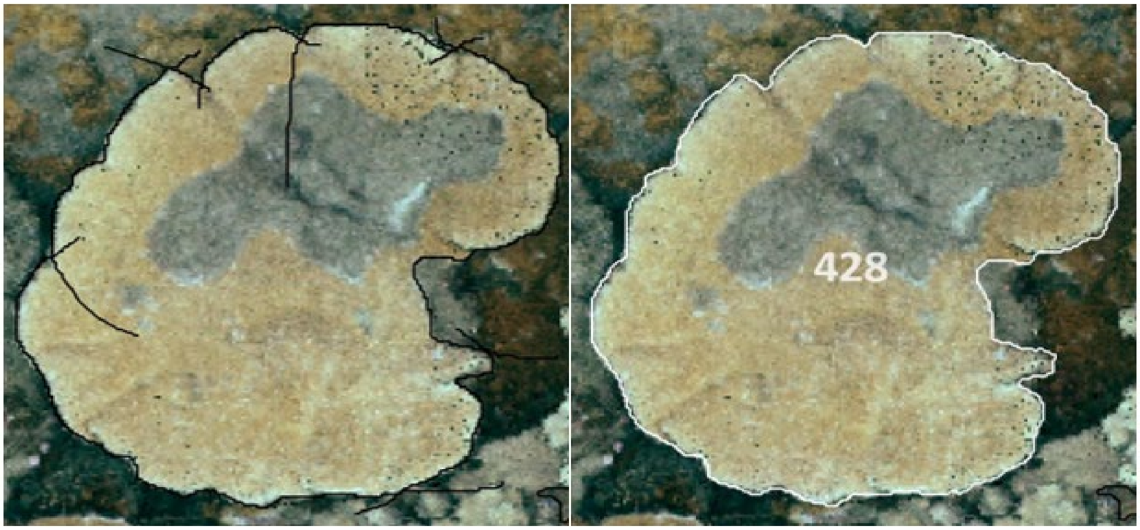


Figure 11. Freehand segmentation tool. Connections between separate segments making up a single patch are exaggerated and will be removed once the patch is completed. Use exaggerated segment ends to ensure small spaces between segments do not exist. If there are any spaces, the patch may not save.

2. To edit patch borders and add in partial mortality within the patch, use the edit border tool , The refine and cracks  tools are also available. For more information on the latter two tools, go to file:///C:/TagLab-main/docs/TagLab.html.

   a. To make fine-scale edits along the coral patch perimeter, select the edit border tool and, with the existing patch delineation selected, draw (left click and hold) a segment that intersects the existing delineation at two separate points (Figure 12, top left). Press spacebar to complete the edit. The section of line outside the annotation will be added and the section of line within the annotation perimeter will be removed from the patch (Figure 12, top right).
   b. To remove partial mortality within a coral patch, select (double click) the patch you wish to add the partial mortality border to and annotate the partial mortality by left clicking and moving the mouse (Figure 12, bottom left). Once complete, press the spacebar to save (Figure 12, bottom right).

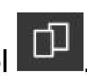
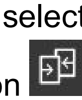
Figure 12. Edit border tool. The gray perimeter is the existing annotation and the black segments are the edited regions (left). Once edits are complete, press the spacebar to save changes (right).

3. To assign a species code to a coral patch, select the patch(es) to which you wish to assign a species and, in the Labels panel, double click on the species code. Make sure to double click the species code name rather than the colored box in the Labels panel.
    a. To remove a species label, select the patch(es) and double click on the Empty label within the Labels panel.
4. To delete a patch, select the patch and press the delete button.
5. To merge patches together, select both patches (select one patch, hold shift, and click on the other patch(es)), and press the letter m.
6. To separate patches, use the cut segmentation tool , draw a line along the border between the two coral patches, and press the spacebar when complete (Figure 13).

Figure 13. When using the cut segmentation tool, ensure that the existing patch annotation is selected (patch will turn white when selected) and the new border line (black) cuts through at least two parts of the patch perimeter (left, red arrows). Additional edits may be needed after splitting the patch to properly outline all live coral tissue (right, red arrow points out region where the perimeter for the coral on the left needs editing).

4.4 Link Coral Patches:

The goal of this SOP is to generate data to track patterns of colony-level change. We do that by first annotating contiguous live coral patches. Once all coral patches have been annotated at every time point, the annotator will link patches from each time point to the closest consecutive time point. Patch linkage will be used to analyze growth, mortality, fission, fusion, and recruitment. During the patch linking process, individual coral patches are grouped into colonies (also called genets), which are displayed within the TagLab interface during the patch linking process.

1. Open a TagLab project with two or more coregistered maps with completed coral annotations in TagLab.
2. With the earliest time point in view, select the Split Screen tool . The closest subsequent time point will automatically appear on the right side of the working view.
    a. Ex: If the 2014 time point is in view when the Split Screen tool is selected, the 2014 time point will appear on the left side of the working view and the 2015 time point will appear on the right side of the working view.
    b. Use the drop down lists at the top of the TagLab interface to change which orthomosaics are in view after Split Screen has been selected (Figure 14).
3. Select Comparison > Compute Automatic Matches or click on  to

automatically link patches between the two time points in view.

a. If a notification pops up asking to replace all existing matches, only select Yes if manual alterations have not been made or you wish to overwrite manual alterations between the two selected time points.

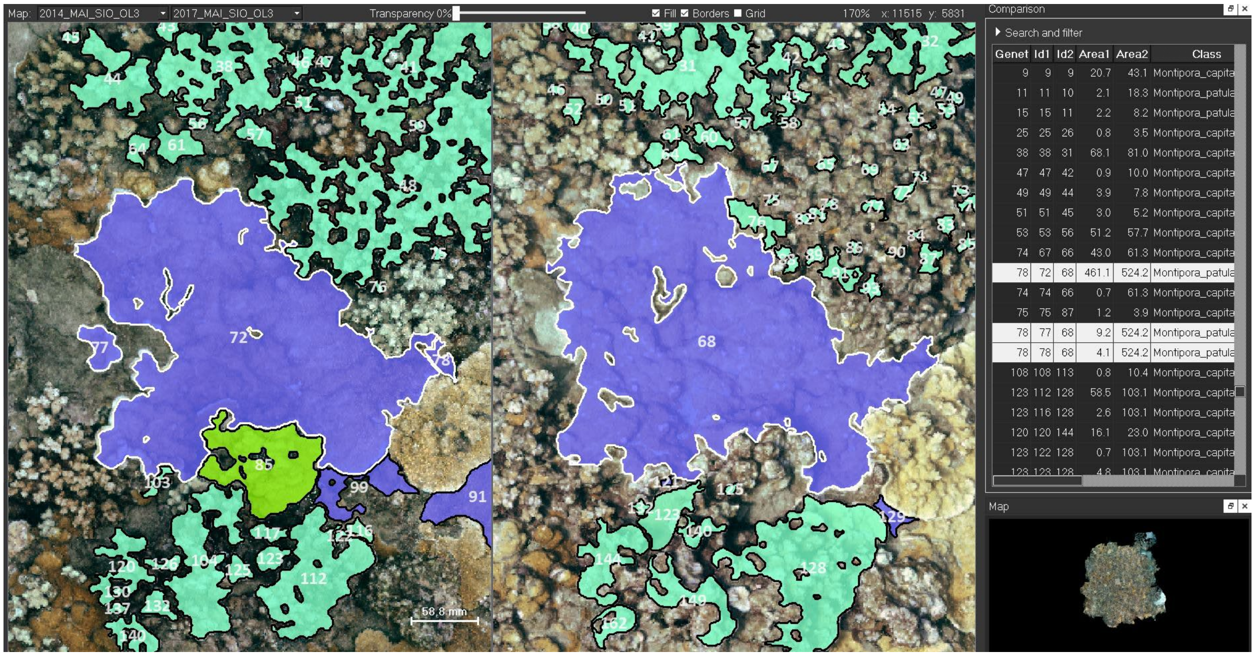
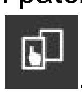


Figure 14. TagLab interface when Compute Automatic (or Manual) Matches is selected. Both time points will be in view (earlier time point on the left) and the Comparison table will appear on the right side of the interface. To search for patch links, select a patch within either time point or double click on a row in the Comparison table. In this example, selecting a single patch in one time point (the later time point) will select multiple patches in the other time point if a fission or fusion event has taken place (in this example, a fusion event has occurred for the purple colony).

4. Links between patches can be manually edited by selecting the Add Manual Matches Tool .
    a. To group patches from the same time point into the same colony ("genets"), select one of the patches, hold shift, and left click on the remaining patches. Press the spacebar to link the patches in the comparison table (each patch should be highlighted in the table after pressing the spacebar (Figure 14)).
    b. To group patches between time points, select a coral patch from either time point, hold shift, and left click on the same patch(es) in the other time point; press the spacebar to save.
    c. To remove an existing link between patches, select one of the patches and press delete. This action will remove ALL matches among patches in

the genet rather than a single patch.

5. Export Data from TagLab

Coral annotations and linking completed in TagLab will be imported as shapefiles into ArcGIS to merge with the geodatabase. Maintaining a geodatabase provides an easy format for editing, adding metadata, and organization. Other TagLab export options include exporting CSV files containing all data located within the data tables, comparison tables (exported separately), and images of annotations (exported as GeoTIFFs or PNGs).

5.1 Export Shapefiles:

1. Once all annotation and patch linking is complete. Save the TagLab project and select the first time point available.
2. To export the shapefile associated with the time point currently selected, go to File > Export > Export as Shapefile.
    a. Save to the site ARC folder as TYear_Site-Name_Initials
3. Repeat until all completed time points have been exported from TagLab.

5.2 Import and Format Shapefiles in ArcGIS:

1. Open the existing ArcGIS site project and in the Catalog pane, navigate to the site's Arc folder.
2. Add the TagLab shapefiles to the Contents pane and open the attribute tables.
    a. All columns within the attribute that are from TagLab will end in "_TL."
3. The shapefiles exported from TagLab will contain all the quadrats as well as the annotations. To remove the quadrats from the shapefiles, select all rows created for the quadrats and delete them.
4. To add additional information to the attribute tables (i.e., metadata such as site name, annotator initials, and other repeating values), refer to *Measuring coral vital rates using structure-from-motion photogrammetry at fixed sites: standard operating procedures and error estimates* Section 1: ArcMap Segmentation and Annotation (https://repository.library.noaa.gov/view/noaa/32739) for information on populating attribute tables in ArcGIS.
5. Once all edits to the attribute tables are complete, save each attribute table and copy it into the geodatabase.
    a. In the catalog pane, right click on the shapefile and select Copy.
    b. Right click on the geodatabase and select Paste.

6. Time Savings Comparison of TagLab-assisted Annotation and Manual Annotation in ArcGIS

In this section we provide time savings estimates of using TagLab versus ArcGIS for annotating and temporally linking coral patches. Manually, this is the most time-intensive component of extracting metrics for coral vital rates. For reference, in a previous study conducted by NOAA ESD, across 7 sites ranging from 2-6 time points, it took an average of 54.7 ± 7.5 hours per two-time point site (an average of 20 quadrat subsamples per site) to annotate and temporally link corals in ArcGIS.

In this study, we chose a random sample of quadrats from sites used by Rodriguez et al. (2022) to compare the time required for manual coral patch annotation and linking to ArcGIS versus semi-automated annotation in TagLab. Quadrats were 0.5 m^2 and contained approximately 10–50 coral patches per quadrat in each time point. Annotators kept track of time required for annotating each quadrat and linking time points separately for both ArcGIS and TagLab. For this comparison, we did not consider project setup time (i.e., importing shapefiles and orthomosaics, creating attribute tables), nor was our goal to quantitatively compare coral area or perimeter calculations between ArcGIS and TagLab (though qualitatively, they are very similar).

6.1 Results:

In total, 5 quadrats were surveyed across three sites, resulting in 256 total patches annotated and linked. These sites included Rodriguez et al. (2022) study sites from Hawaii, Maui, and Pearl & Hermes. Four of the quadrats were annotated and linked across two time points and 1 quadrat was annotated across three time points. Time spent annotating a single quadrat was very similar between TagLab and ArcGIS (Table 1). However, linking corals in TagLab resulted in a 41% reduction in hands-on time compared to linking in ArcGIS (Table 1). Overall, TagLab resulted in a 14% reduction in personnel time. As these estimates stem from a relatively small number of quadrats and inter-quadrat variability is high, we treat these values as pilot data.

Table 1. Average time (minutes) required to annotate and link coral patches in TagLab and ArcGIS, with extrapolation to total quadrat time in both 2 and 3 time point cases. Then there is further extrapolation to Total Annual Annotation/Linking Time assuming 10 sites, each containing 15 quadrats, evenly split among 2 and 3 time point sites.

Quadrat-Scale Annotation and Linking (0.5 m^2)	TagLab Time (minutes ± SE)	ArcGIS Time (minutes ± SE)	Mean TagLab Improvement (minutes ± SE)	Mean TagLab Percent Improvement
Annotation Time: Single Quadrat	36.8 ± 6.7	36.8 ± 4.5	0 ± 8.1	0% ± 21.9%
Linking Time: *Two Time Points*	16.7 ± 5.3	28.3 ± 8.0	11.6 ± 9.6	41.0% ± 33.9%
Total Quadrat Time: *Two Time Point Extrapolation*	90.3	103.6	13.3	12.8%
Total Quadrat Time: *Three Time Point Extrapolation*	143.8	170.5	26.7	15.7%
Total Annual Time: 10 Sites: 8@2TP / 2@3TP, 15 quads each (person-hours)	*252.5 person-hr*	*292.5 person-hr*	*40 person-hours*	*13.7%*

6.2 Conclusion and Recommendations:

Overall, our results suggest that extracting vital rates data from large area imagery does not vary greatly between TagLab and ArcGIS. However, incorporating TagLab into our vital rates workflow could improve labor efficiency by 14%. Given that the workflow for extracting vital rates is labor intensive, any and all improvements in efficiency are meaningful.

TagLab is an ongoing project of the Visual Computing Lab and remains a novel software with consistent updates to their semi and fully automatic segmentation and linking tools. Currently, NOAA ESD has only utilized several of TagLab's semi-automatic tools that provide varying degrees of accuracy and require manual edits to rectify. As TagLab continues to improve the accuracy of their semi-automatic tools and as NOAA ESD incorporates TagLab's fully automated annotation tools, time savings are expected to increase significantly. By engaging with TagLab and generating region and taxa-specific training data, improvements in semi and fully automated tools are expected to increase as seen with other organizations currently using TagLab (Pavoni et al. 2021).

TagLab provides a more user-friendly interface for both annotating and linking corals than ArcGIS. TagLab was created specifically to meet the needs of annotating corals and provides tools that quickly and easily outline the complex morphologies that corals form. Conversely, ArcGIS is predominately used for mapping and spatial analysis. While its metadata and shapefile compilation abilities are helpful, the interface is not attuned to the needs of our annotators, and it does not provide tools specifically designed to outline live coral patches.

TagLab and ArcGIS both have advantages and disadvantages when it comes to extracting vital rates data. Currently, there is a place for both ArcGIS and TagLab to exist within the vital rates workflow. Given that unique coral patch IDs are preserved between TagLab and ArcGIS, we can use them interchangeably as needed in the future.

Acknowledgements

We thank Gaia Pavoni, Massimiliano Corsini and Federico Ponchio for providing TagLab and offering their technical expertise throughout the process of onboarding and improving our use of the software. This work is funded by the NOAA Coral Reef Conservation Program, project 31360.

References

Brito-Millán M, Vermeij MJ, Alcantar EA, Sandin SA. 2019. Coral reef assessments based on cover alone mask active dynamics of coral communities. MarEcol ProgSer. 630, 55-68. https://doi.org/10.3354/meps13128

Done TJ. 1992. Phase shifts in coral reef communities and their ecological significance. Hydrobiologia 2471, 121–132. doi:10.1007/BF00008211.

Edmunds PJ, Riegl B. 2020. Urgent need for coral demography in a world where corals are disappearing. Mar Ecol Prog Ser. 635, 233-242. doi:10.3354/MEPS13205.

Furby KA, Smith JE, Sandin SA. 2017. Porites superfusa mortality and recovery from a bleaching event at Palmyra Atoll, USA. PeerJ, 5, e3204. https://doi.org/10.7717/peerj.3204

Morais J, Morais RA, Tebbett SB, Pratchett MS, Bellwood DR. 2021. Dangerous demographics in post-bleach corals reveal boom-bust versus protracted declines. Sci Rep. 11, 18787. https://doi.org/10.1038/s41598-021-98239-7

Pavoni G, Corsini M, Ponchio F, Muntoni A, Edwards C, Pedersen N, Sandin S, Cignoni P. 2021. TagLab: AI-assisted annotation for the fast and accurate semantic segmentation of coral reef orthoimages. J Field Robot, 39(3), 246–262. doi: https://doi.org/10.1002/rob.22049

Rodriguez C, Amir C, Gray A, Asbury M, Suka R, Lamirand M, Couch CS, Oliver T. 2021. Measuring coral vital rates using structure-from-motion photogrammetry at fixed sites: standard operating procedures and error estimates. U.S. Dept of Commerce, NOAA Technical Memorandum NMFS-PIFSC-120, 90 p. doi:10.25923/a9se-k649