ARMS Plate Photo Analysis

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Plate photos are analyzed the same way as settlement tiles. Several options are possible: quantification of the grey areas to get a measure of percent cover, annotation of functional groups, annotation at the lower taxonomic levels. The following protocol is a guideline to help you design your own plate photo analysis. Depending on the specific question, protocols can be modified by the user.

Materials:

- Plate photos (17 photos per ARMS – the bottom of plate 1 is not analyzed because it is never colonized)
- Photo editor (e.g. Adobe Photoshop)
- An image annotation tool:
    - CPCe (Coral Point Count with Excel extensions) program (windows)
    - CoralNet web-based program (this protocol)

ARMS Plate Photo Pre-processing (Photoshop)

Opening files, naming conventions

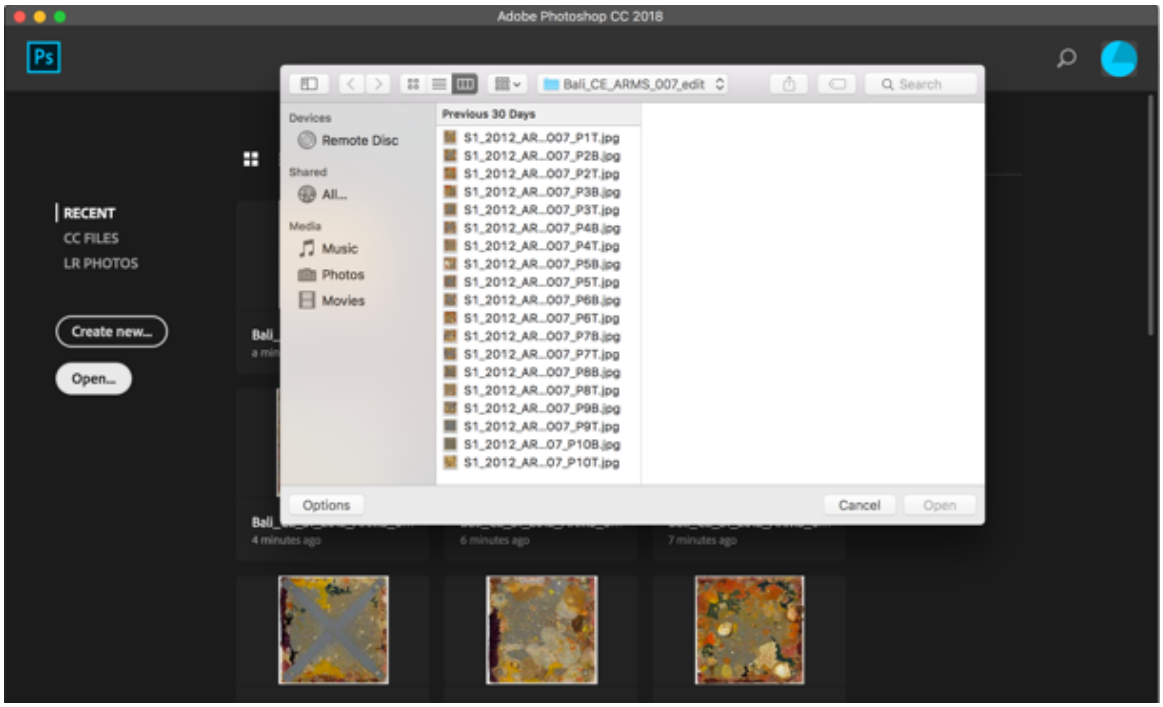
1) Open a full-resolution, stitched .jpg in photoshop.

These files are very large and will likely require a great deal of memory. The size of a stitched .jpg may vary (depending on the type of camera used) but generally falls within the range of 100-250 MB.

We name ARMS plate image files using the format:
"ExpeditionCode_Year_Site/ARMS_PlateNumber_Top/Bottom_stitched.jpg"

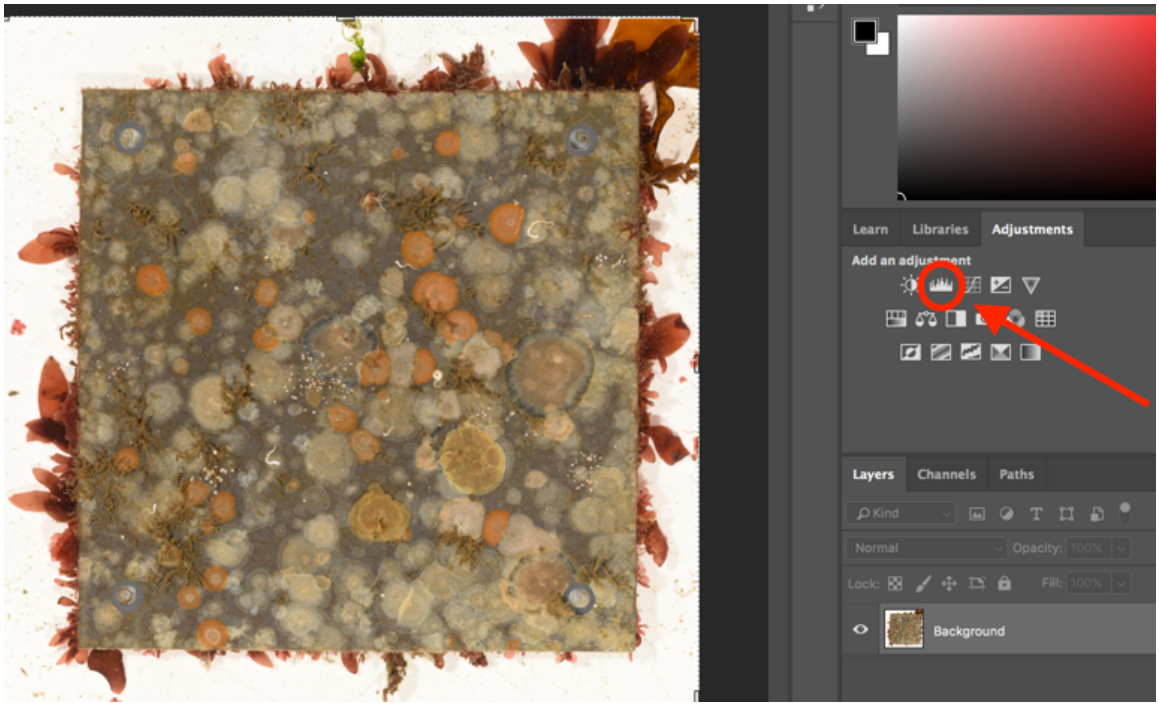
Because ARMS are deployed in triplicate, each site will typically have an A, B, and C-labelled ARMS unit.

Example:
2018 Koumac expedition: "KOU_2019_ARMS_03B_P5T_stitched.jpg"
expedition code = KOU (Koumac), ARMS site = 03, ARMS = B,
P5T = plate 5 top



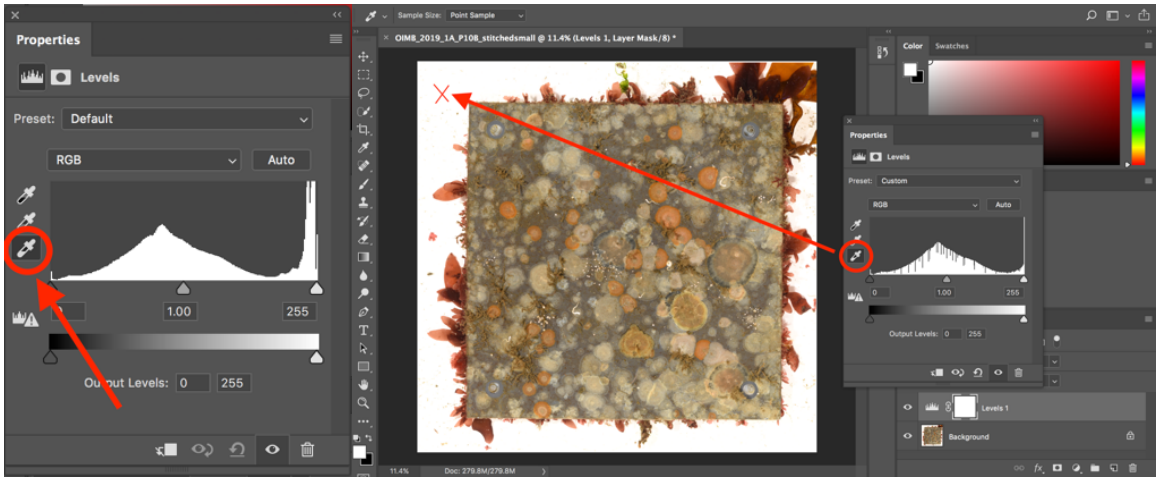
Correcting white/color balance

2) Select “Levels” to create a new Levels adjustment layer.

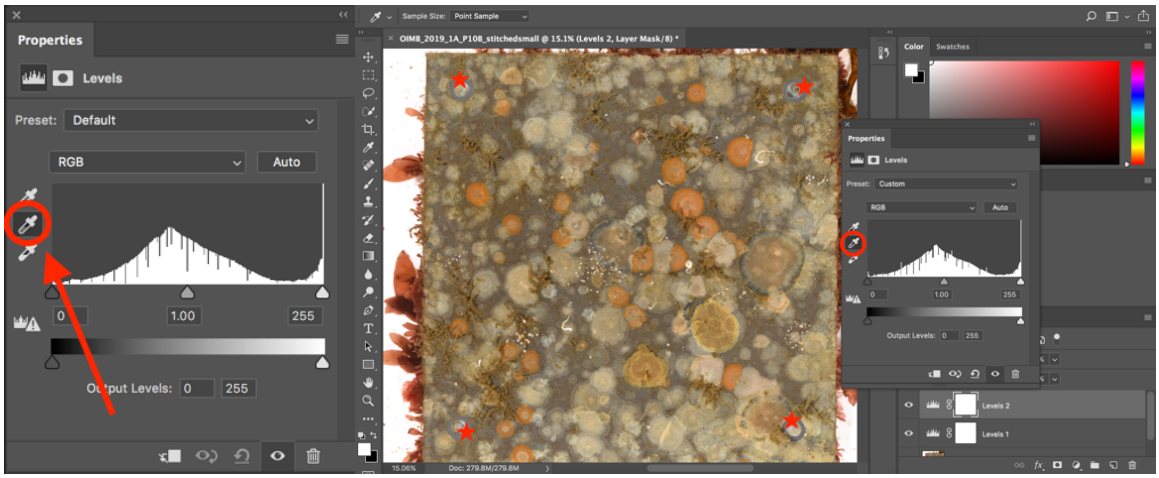


a) First, adjust the white balance of the photo by selecting the white eyedropper in the “Properties” popup window, and then selecting an area

around the plate that appears white (see the "x" in the image below for an example). Avoid selecting a point in the plate's shadow and avoid debris that may be in the tray. Make sure that when adjusting the "true white" the light colors on the plate do not become overexposed. Testing multiple points will allow for the best adjustments.

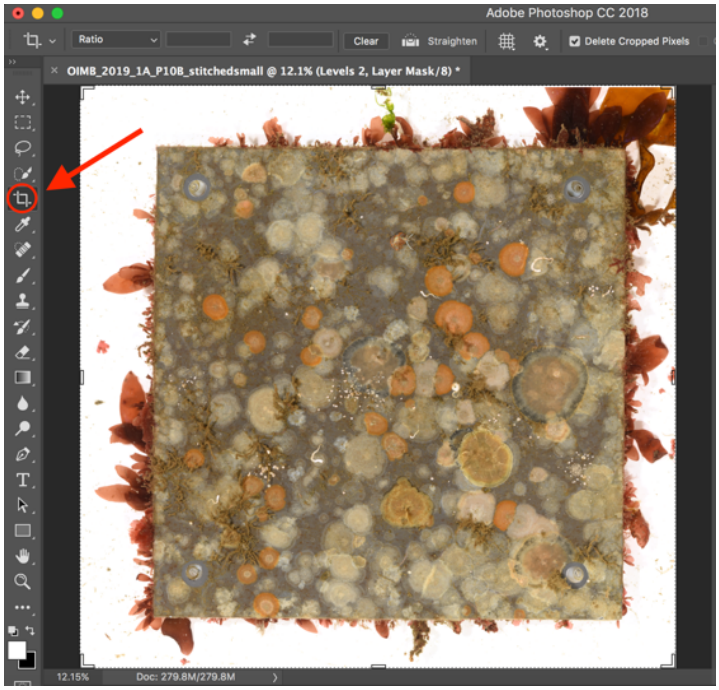


b) Close the properties window and re-select the "Levels" icon to create a new layer. Now, follow the same procedure from 2a with the grey eyedropper to adjust the color balance of the photograph. Select an area that is medium grey, like a non-recruitment area (see stars in the image below). The bare rings where ARMS spacers or washers were removed provide reliably empty plate space. The image may now have a very slightly yellow tint.

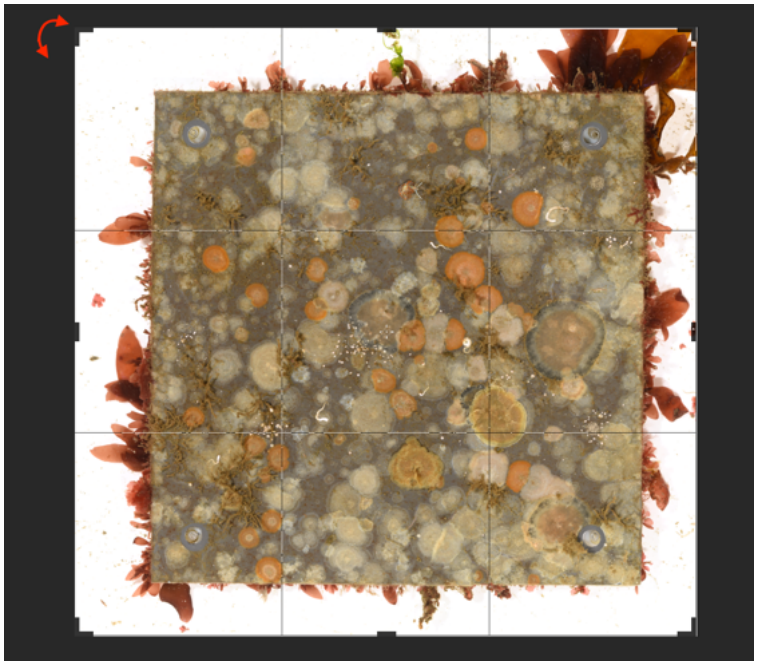


Cropping the image

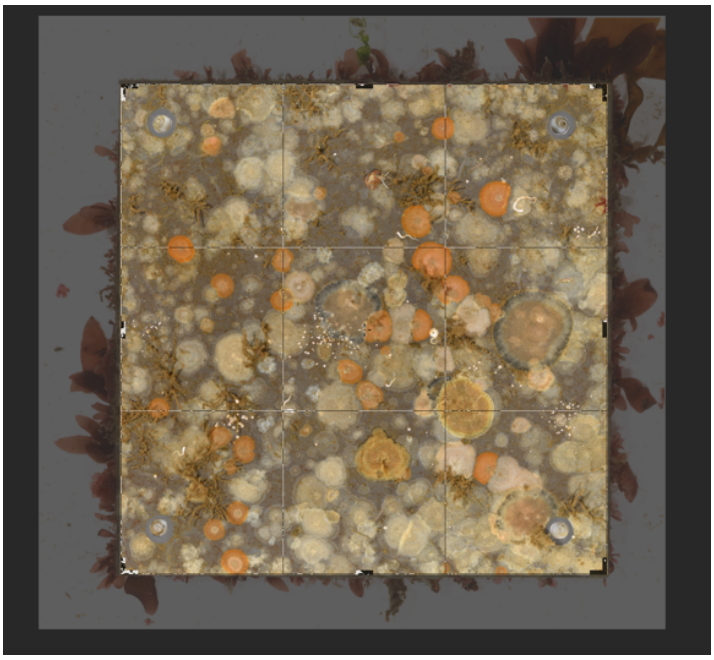
3) Select the "Crop" tool on the left toolbar. A border should appear around the photograph.



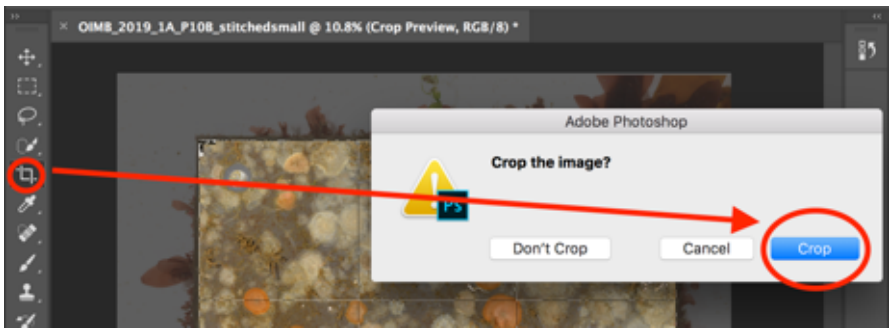
a) First, move your mouse from the photo to one of the outside corners until a curved double-headed arrow appears (see example in image below). Hold down the mouse and a 3x3 grid will appear. Adjust the tilt of the photograph so that the plate is aligned with these grid lines. It should be as straight as possible so that cropping the photo eliminates as little of the plate edge as possible. The photo may appear straight, but check with the grid to be sure.

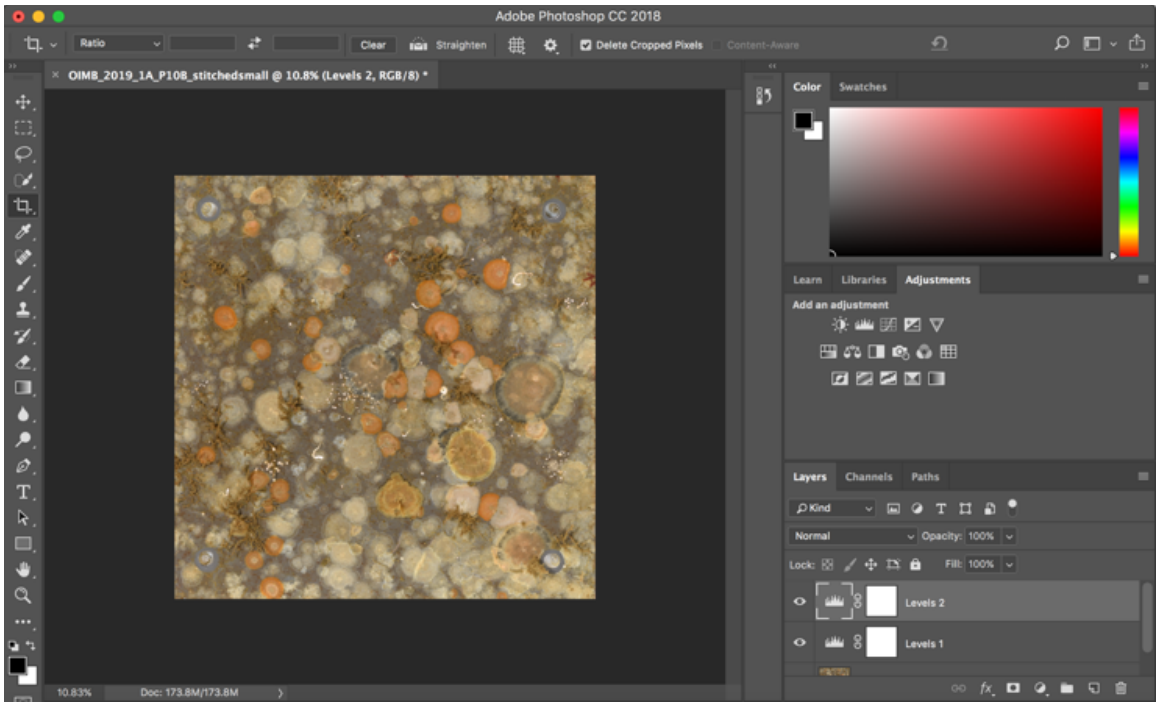


b) Now, drag the edges of the photograph inward using the crop tool so that all the white background of the photo is eliminated. It is ok that some edges of the plate will be cropped along with the white border. If the slider is not providing enough control to make very small adjustments, it helps to zoom in (shortcut "CMD +") to allow for finer pixel increments.



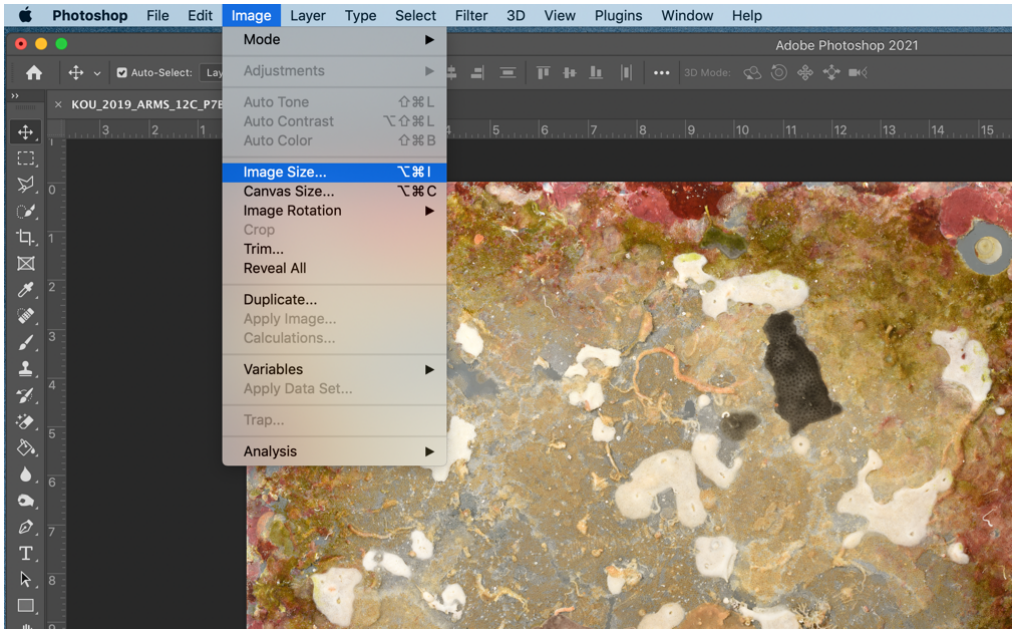
c) When satisfied with the cropped edges, re-select the crop tool. Photoshop will ask if you want to crop the image. Select "Crop" (see first image below). Alternatively, double clicking the non-greyed out part of the image (rather than selecting the "Crop" tool) will also finalize your image crop. You should now have something similar to the second image below.

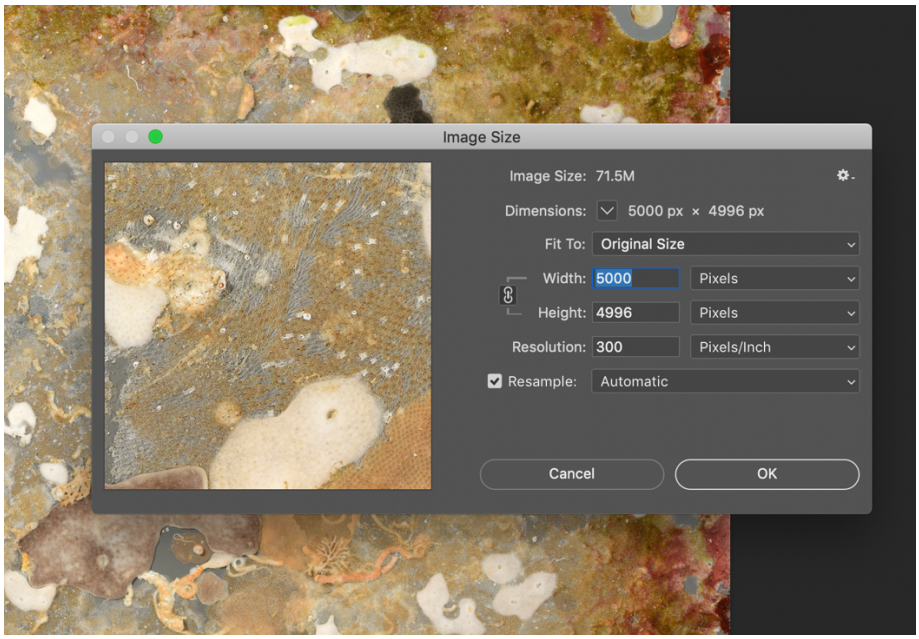




Changing the image size and saving your files

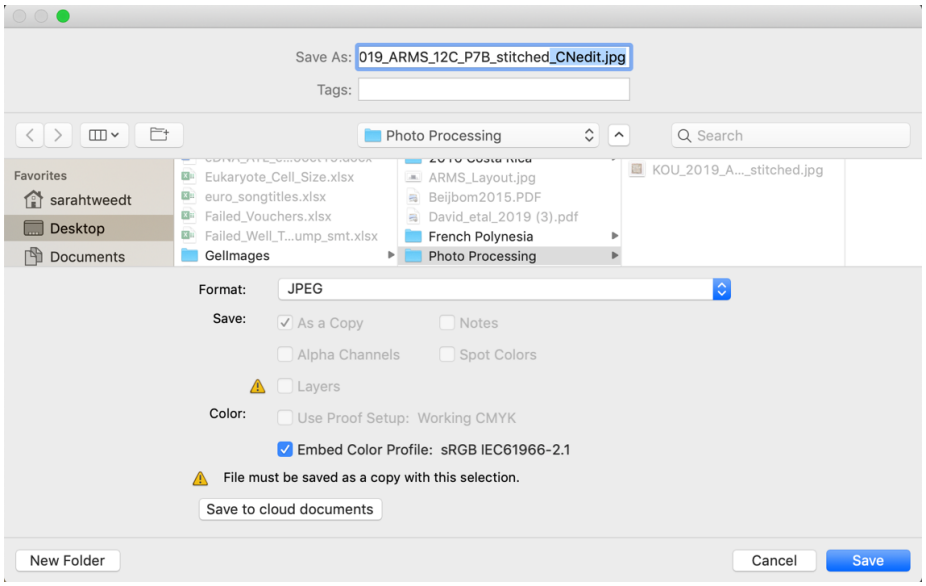
4) Go to “Image” at the top photoshop menu bar, and select “Image Size”. Our target image size for CoralNet upload is approximately 5000 x 5000 pixels. First, change the width of the image to 5000. The height should self-adjust to a value near 5000 as well. Make sure the units are in pixels. Also ensure that the resolution is 300 pixels/inch or change it to 300 if it is not. Click “OK”.



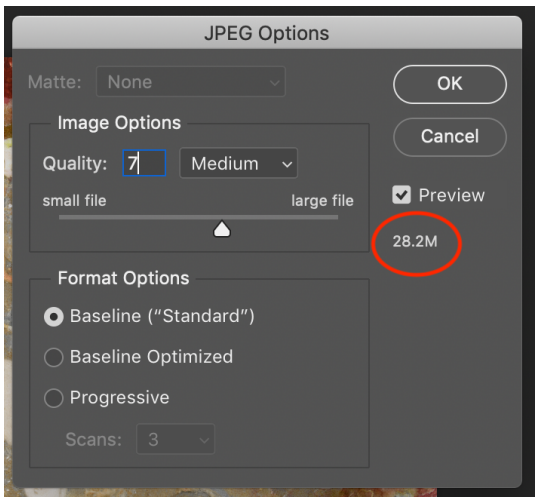


5) Before you save your image, be sure you have created a directory for your edited photos that is separate from the folder(s) containing the full-res stitches. Give this a useful title, such as "2019 Koumac Plates CoralNet Edited."

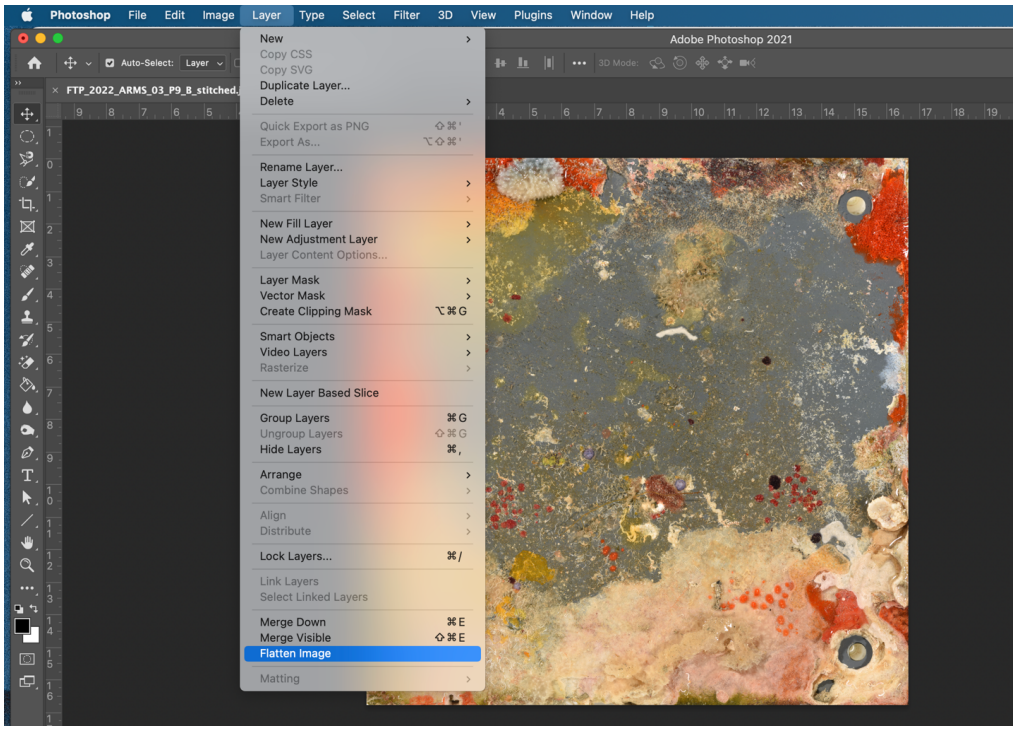
6) Go to "File" and "Save As". Maintain the file name, but add a suffix to designate that this is a CoralNet edited photo. For example, your edited version may be saved as "KOU_2019_ARMS_03A_P6T_stitched_CNedit.jpeg". You may also want to add a number to indicate the size of the newly edited photo, so your suffix may be something like "_CN30". Select the folder where you want to save the file, change the file format to JPEG, and click "Save".



Now, a “JPEG Options” popup window will appear asking you what compression you would like to save with. At medium quality (7), check and see what the file size will be (see red circle in image below). CoralNet allows photos to be 30 MB maximum. Dither the quality up or down to find the setting where the file size will be as close to 30M as possible without going over. Click “OK”.



Note: If you have issues and/or cannot save your edited plate image as a .jpeg (e.g. the option to save as .jpeg is greyed out), you may need to flatten the layers before you can save. Go to the top menu bar and find “Layer” and “Flatten Image”. This merges our color correction layers. Now save the .jpeg as instructed above.



Once you have saved your CoralNet-edited image, you can move on to the next plate. It is not necessary to save the working photoshop file. Be sure you do NOT over-write the original stitched image file!

ARMS Plate Photo Annotation in CoralNet

Establishing a CoralNet account

1) Go to https://coralnet.ucsd.edu
2) Select the "Register" option.
3) Create a username, enter an email address, and choose a password.
4) Enter your name and affiliation.
5) Enter your "Reason for registering." This could be something along the lines of "I will be utilizing CoralNet to annotate settlement plate images."
6) Enter your "Project Description." This will be a little more specific, such as "We will be quantifying and comparing sessile macroinvertebrate ARMS plate coverage across multiple regions."
7) Fill in "How did you hear about us?" and select "Register."

Creating a new Source

CoralNet organizes projects as "Sources", i.e. the *sources* of the images you'll analyze. The photo learning engine is specific to an individual source, so what the identification algorithm learns from source A will not be available to source B by default. Because different oceanic areas have different flavors of benthic diversity, the deep-learning engine is most accurate when it is trained on and applied to photos from the same geographic region. For example, an engine trained on Indonesian ARMS will work well for additional Indonesian ARMS, but not as well on ARMS from the Caribbean.

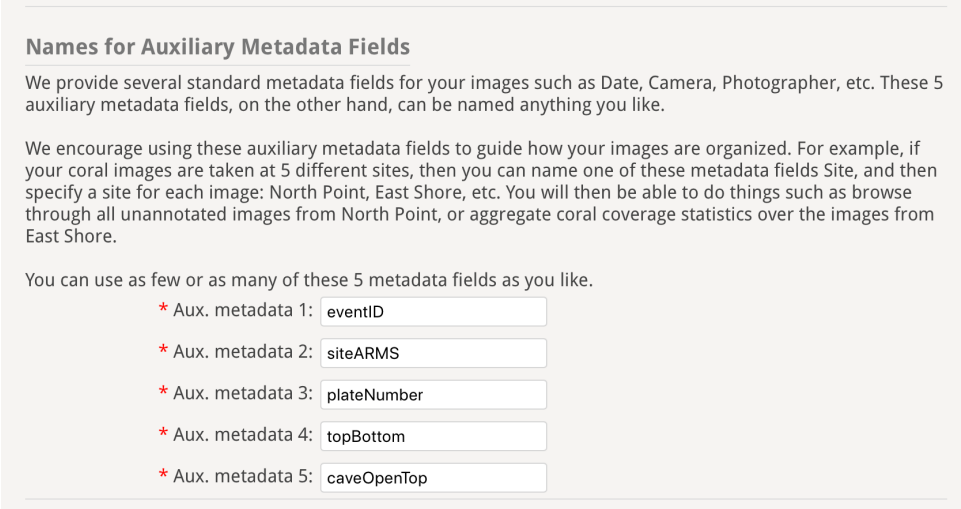
When you create a new source, you will specify up-front your ARMS-specific metadata fields, plate photo dimensions, and your desired point annotation regime.

8) On your account homepage, below "Your Sources" select "+ Create a new Source."
9) Fill in the name of your Source. This should be a succinct project name, such as "Koumac ARMS", plus some information about the point sampling regime for the project. We usually start with a uniform grid (see step 14 below), so a good source name could be "Koumac ARMS Uniform".

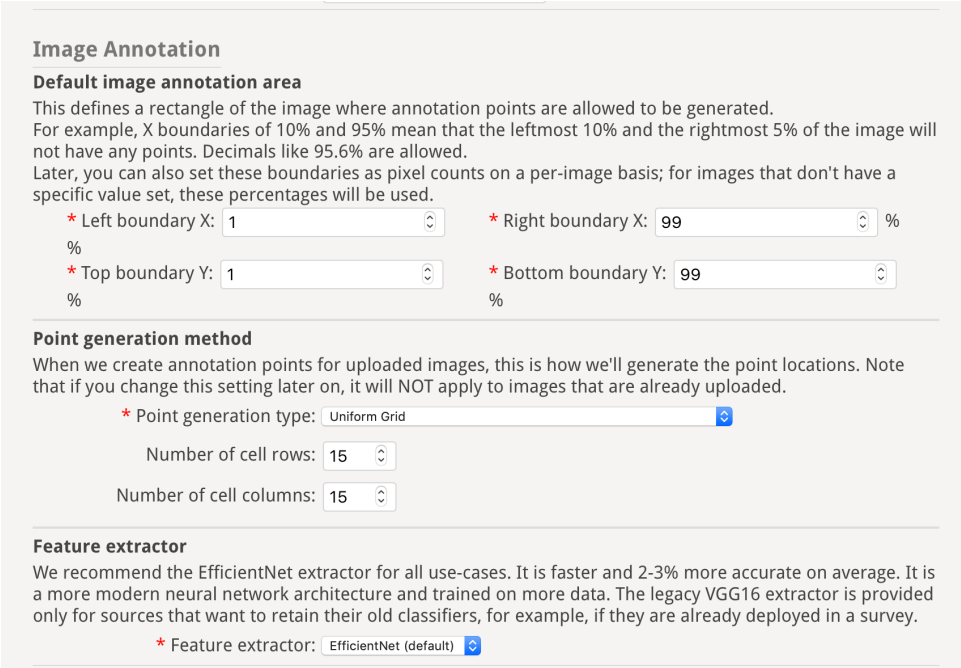
** Note: If you decide to change the point sampling regime within a source, you can adjust the name of the source and point selection details later **

10) Change the visibility to "Private." This can be changed to public later if you so choose.
11) For "Affiliation", use your institution.

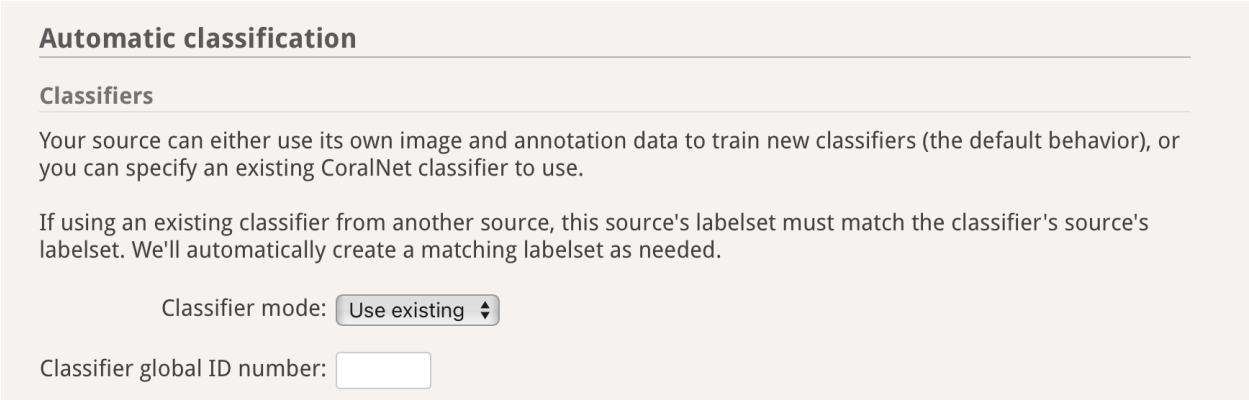
12) Fill in “Description” to reflect the specific experimental region and goals of this project. For example, “This source is for annotating ARMS plates from Koumac, New Caledonia, using a uniform grid.”
13) Fill in the auxiliary metadata fields. These are metadata fields pertinent to our images that are not supplied by CoralNet as defaults. See image below for these values:



14) Fill in image annotation information as shown below. ARMS plates have a recruitment edge effect, but since we crop during pre-processing we don’t need to overly adjust boundaries. We ensure annotation points do not fall on an edge by making our available point area 1% away from each photo edge. Use the new feature extractor (default).



**Note: When setting source annotation parameters, CoralNet users are now able to either train a new classifier or use an already-trained classifier from another source. This may be useful if you plan to annotate ARMS from the same geographic area as another source and expect to have similar sessile communities. To use a classifier from another source, set "Classifier mode" to "Use existing", as shown below. You will need to have the desired classifier's global ID number, which can be found by viewing the backend of the other source (see second photo below). If you elect to use a classifier from another source, the labelset (see "Choose labelset" section) must be identical to the other project, so CoralNet will automatically populate labels. You will skip the "Choose labelset" section.

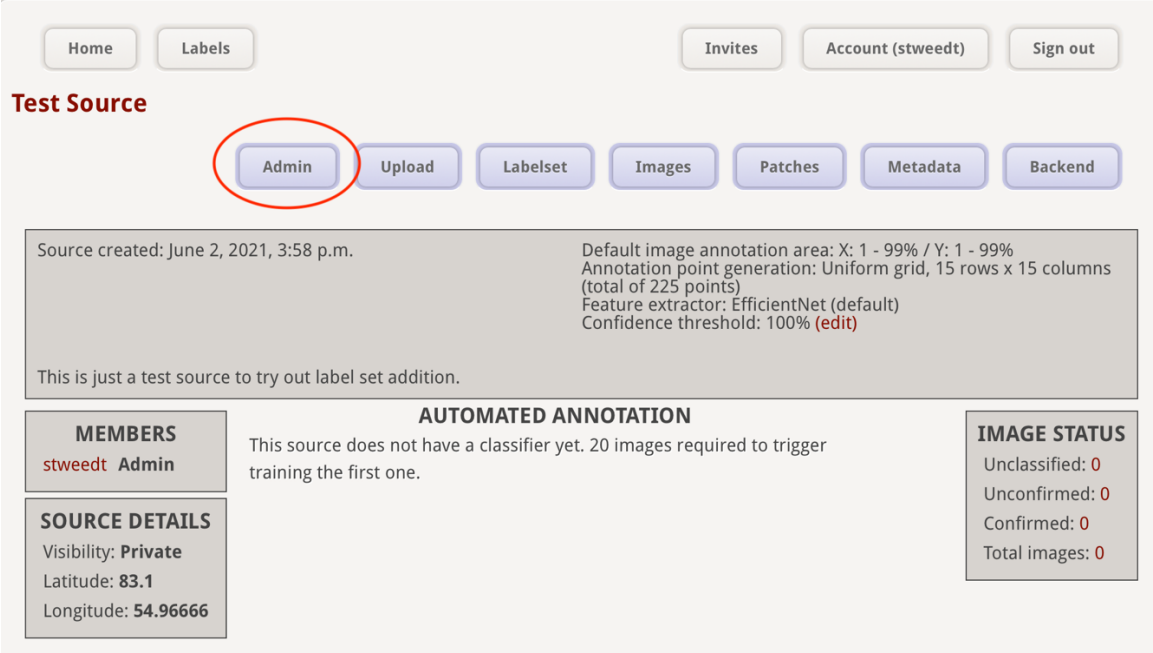


15) Enter the approximate latitude/longitude of the project. You may choose to use rounded coordinates to represent the general area rather than exact ARMS locations.

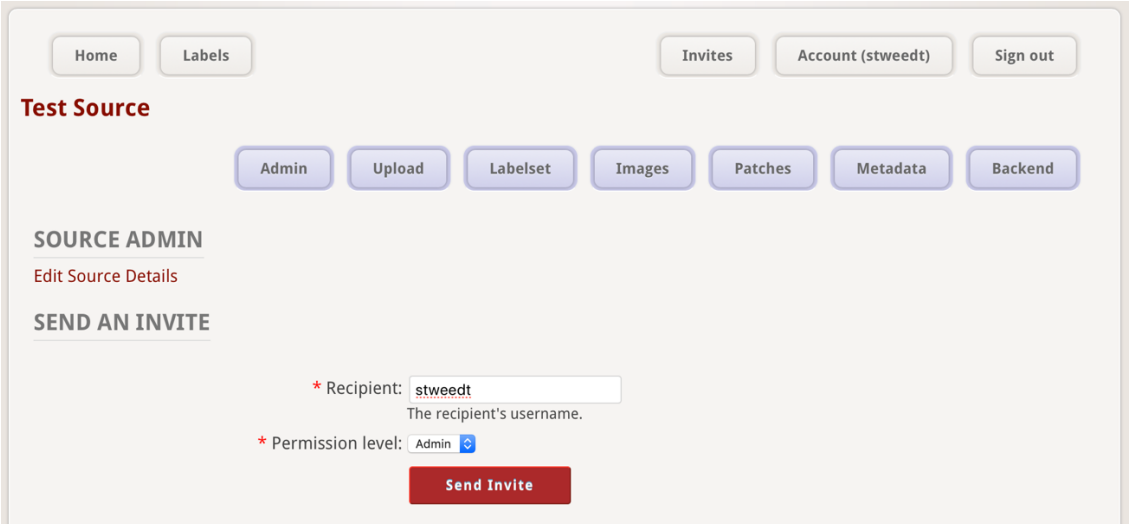
16) Click "Create Source".

Now that you have initialized an empty source, you may invite additional users to your project. For example, you may add a supervisor to the source as an additional administrator. This will ensure that your mentors and/or collaborators can access the CoralNet data you generate.

17) In your Source homepage, click "Admin", circled in red in the photo below:



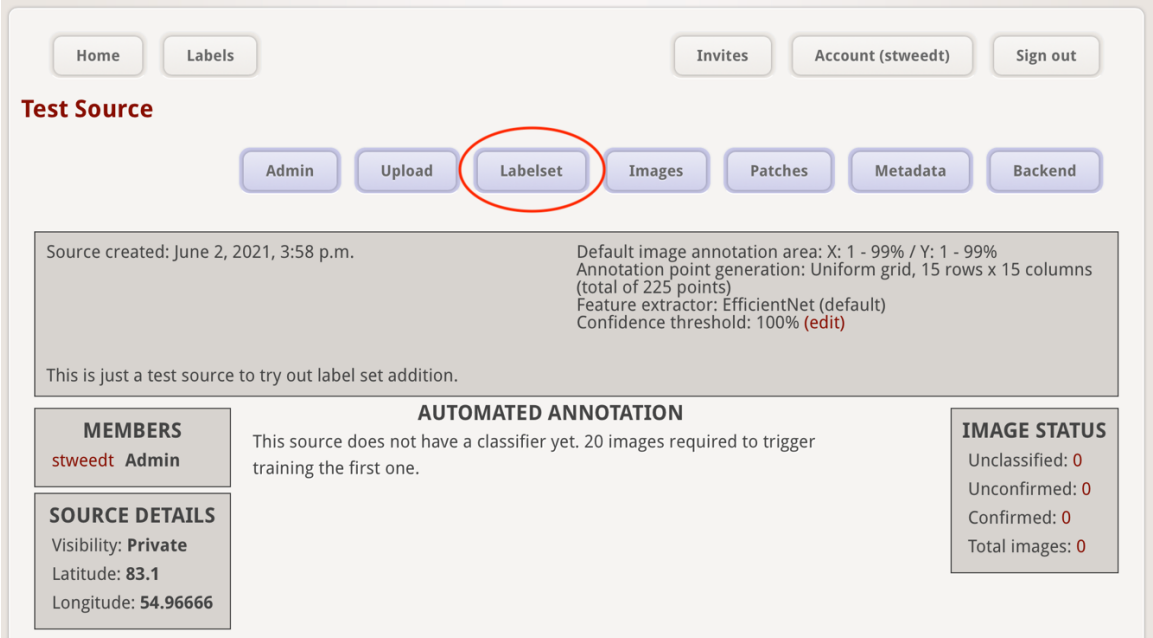
18) Send an invitation to an additional project administrator. They will need to also have a CoralNet account, as you will send an invite via their CoralNet user name.



Choose the Labelset for your source

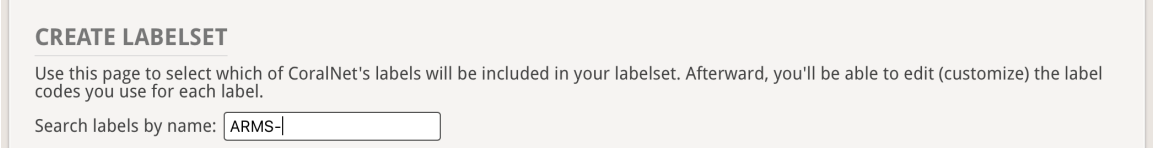
We have created a standard set of labels for annotating different kinds of settlement plates spanning numerous ocean regions and experimental designs. You will populate your own source labelset from this standard list. Alternatively, if you have elected to use a classifier from another source, labels should already be selected for your source.

19) Click on “Labelset” in your Source homepage:



20) Click “Choose labels for your labelset”.

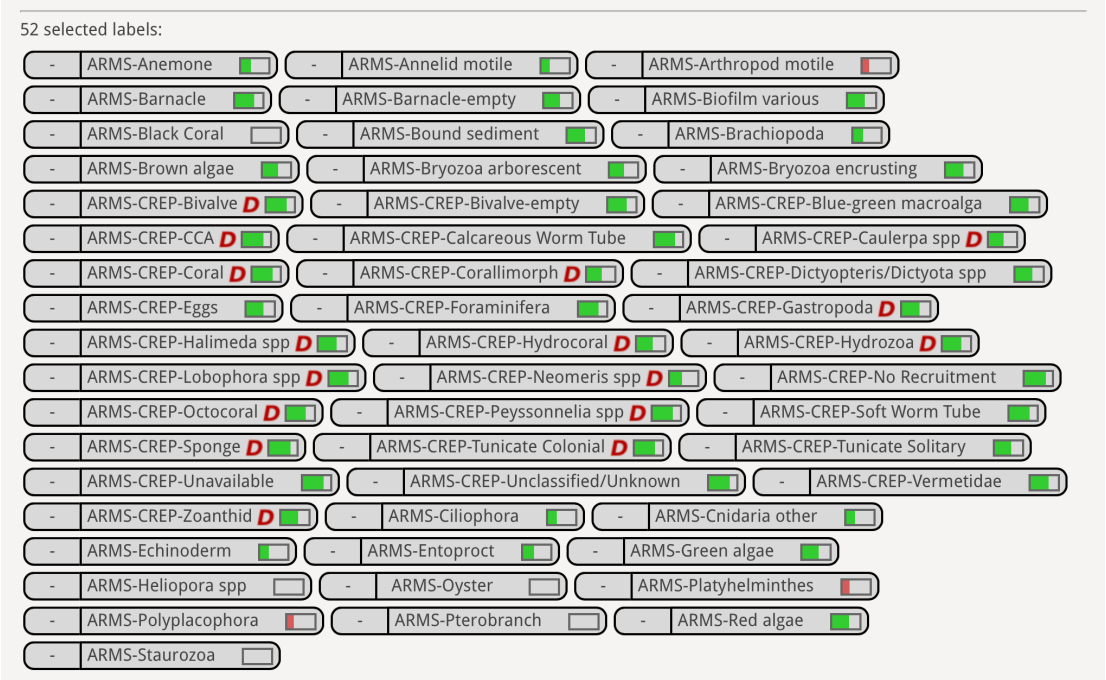
21) Under “Search labels by name”, type in “ARMS-” (see photo below). This will bring up labels with the ARMS prefix, including our standardized labels but also extras created by other users.



For a complete labelset, add all labels as seen in the second photo below to your Source labelset. **A full table of labels is found at the end of this protocol.** Alternatively, review labels with a mentor/colleague to determine if a subset of the standard labels is appropriate for your study (see note below). If you do not see a label you may need to type in the exact label name to find it, e.g. “ARMS-Red algae”. Click the “+” on the left side of the label name to add the label. Do not add ARMS labels that are not in the provided label set, as these are not standardized and are usually redundant.

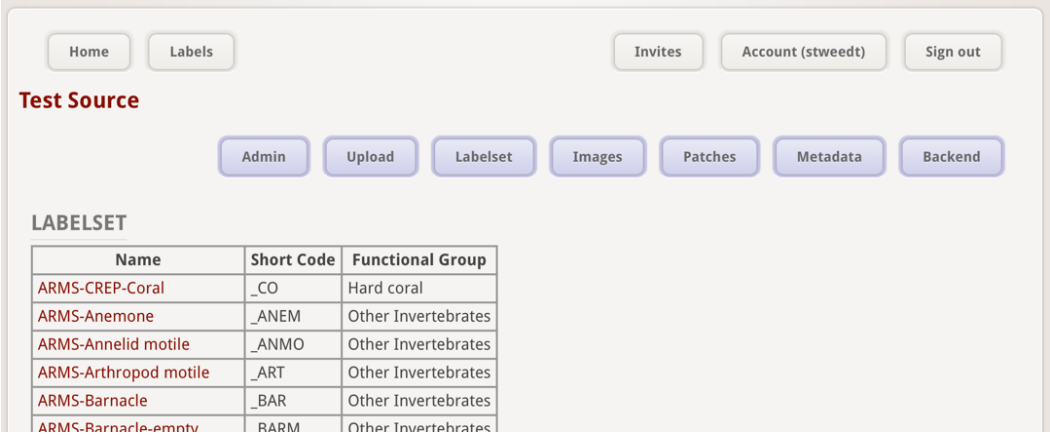
** Note: The complete label set includes taxa you may not see on your batch of ARMS, as well as genera of interest to specific projects. You may not need to use every label when you are annotating (this is okay). For example, the “ARMS-Oyster” label will be useful for oyster-reef habitat analyses, whereas its parent category “ARMS-Bivalve” will suffice for most other projects. Likewise, specific

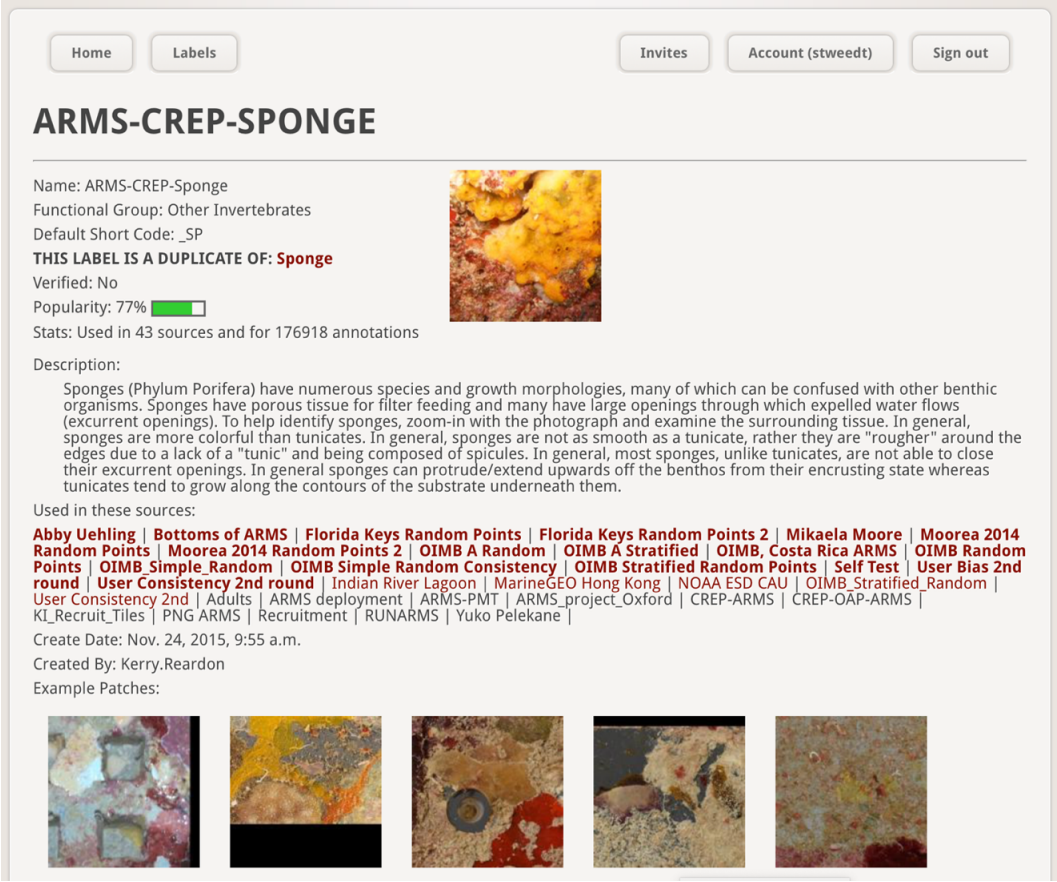
labels for macro algae (e.g. ARMS-Peyssonnelia spp, etc) will be useful for some users, but others may opt to use “ARMS-Red algae” or “ARMS-Green algae”. You should discuss with your mentor and / or project lead which optional labels are appropriate for your ARMS plate analysis **



^ A full labelset is shown above. As the labels get used more frequently across users, the green meter will fill up. Don’t worry about the red “D”, which is just CoralNet’s flag indicating that an ARMS label describes the same taxon as another label in the system. Those labels are used in underwater reef images, whereas these have been created for use in close-up settlement plate images.

22) Click “Create Labelset”. Now you will see your entire list of labels on the Source’s Labelset page (see example below). Clicking a label name will bring you to the label’s homepage, which provides a description of the label and images others have ascribed to that label. These images may be helpful in determining whether the label is correct for a point you are attempting to classify. Label “ARMS-CREP-Sponge” is shown in the second photo below as an example.



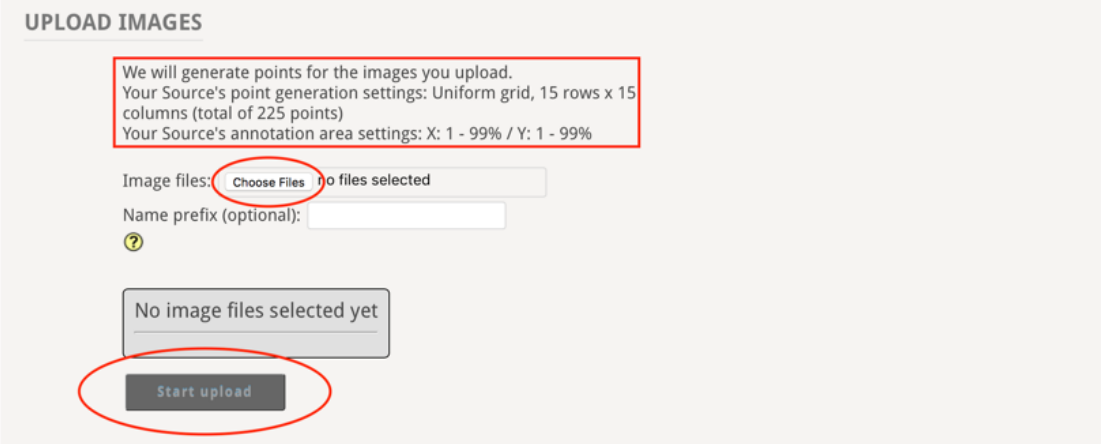


23) Once your labelset is finalized, we are ready to upload our plate images.

Upload photos and metadata

24) Navigate to the “Upload” tab in the toolbar. This function will be used to upload the .jpgs that were edited in photoshop.
25) Under “Upload,” select “Upload Images.”

26) Under "Upload Images", the source parameters are listed (see image below). Double check to make sure these are correct. Then, select "Choose Files" and add the CoralNet edited .jpgs. Select "Start upload" and wait until each jpg is 100% uploaded.



27) Next, upload photo metadata. Click the "Upload" tab in your Source toolbar. Under "Upload", select "Upload Metadata." This will be a .csv file you have prepared, with each row corresponding to a photo file. An excel template file "CoralNet_Metadata_Template.xlsx" provides useful headers. The column "Name" should list the complete filename of every uploaded photo file. Fill in siteARMS, plateNumber, topBottom, and caveOpenTop fields for each image.

- Additional ARMS field metadata may be supplied, such as metadata found on the field information management system < https://geome-db.org >.
- "Date" is the date the ARMS was processed and must be in the format YYYY-MM-DD. This column should be formatted as plain text so that Excel does not automatically re-format the date; do this by highlighting the column, selecting Format → Cells, and under "Number" select "Text."
- "eventID" is a specific ID for each ARMS, with the format: expeditionAcronym_year_site_ARMS.
- Some CoralNet-specific metadata fields (e.g. Height, Water Quality, Strobes, Framing gear, White balance) are optional; these may be left blank.

Once you have made your metadata file in Excel, save this as a .csv file and upload to CoralNet. The site will automatically check over your file to make sure everything looks okay. If there are issues, you will get an error message. Some likely issues may be due to:

- Misspellings in file names that cause a mismatch between your uploaded photos and the metadata file. CoralNet will tell you that you are missing metadata for some number of photos.

- Edits were made to the .csv file in Excel, but not saved. Make sure that you save a fresh .csv file if you make any changes to your metadata.
- Date format is wrong. This could be due to Excel automatically re-formatting the date.
- You have information in a CoralNet-specific field that does not meet CoralNet requirements (e.g. having an "NA" in column Height is flagged as an error because it is not a numeric value.)

If you are only analyzing a few images and/or would prefer to input metadata directly into CoralNet (rather than via bulk .csv upload), you can navigate to the "Metadata" tab in the toolbar. Text boxes will appear next to each plate image name and you will be able to input data or edit fields manually.

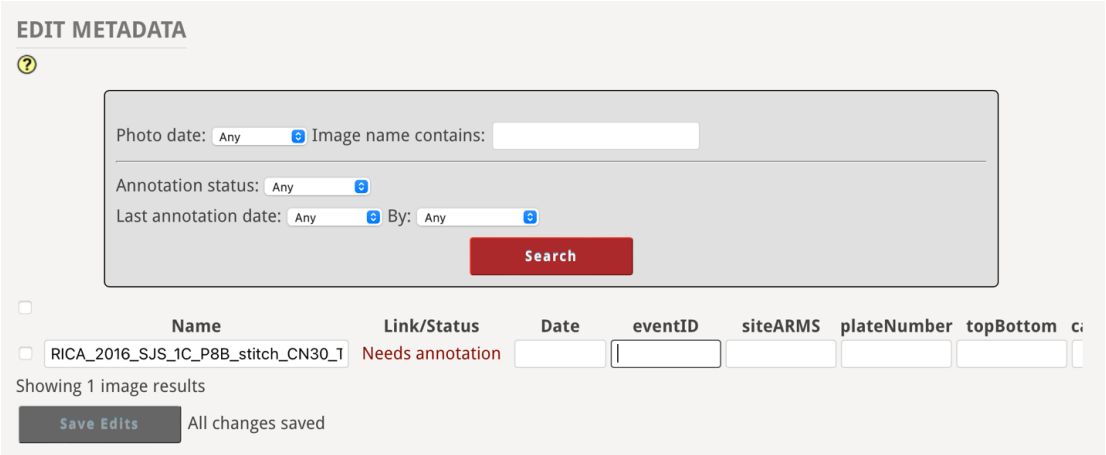
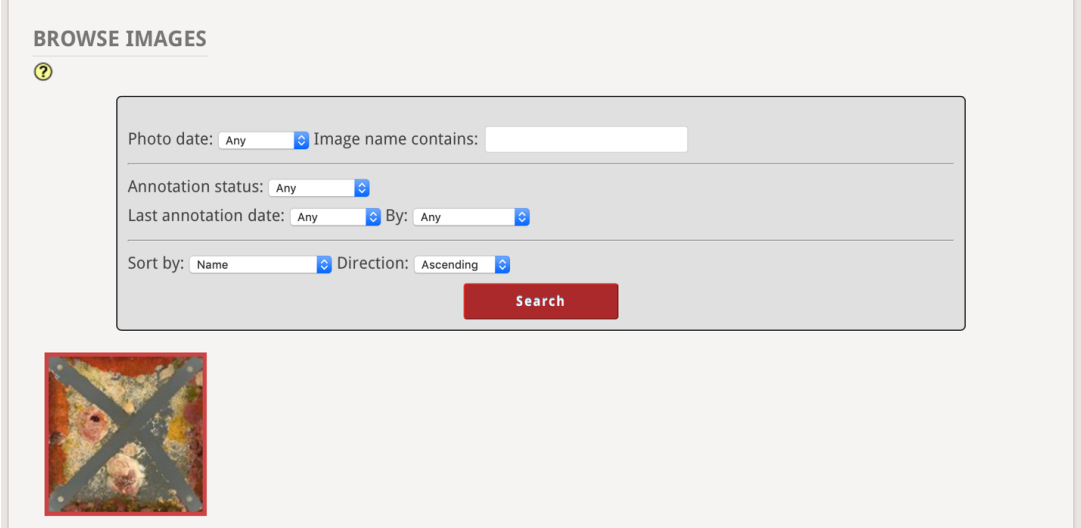


Photo annotation

28) If you elected to train a new classifier, you will need to manually annotate 20 plates to train the learning engine on your data before it will be able to assist with identifications. To do this, navigate to the "Images" tab in the toolbar. The previously uploaded images should be here, each with a red border, as shown below.

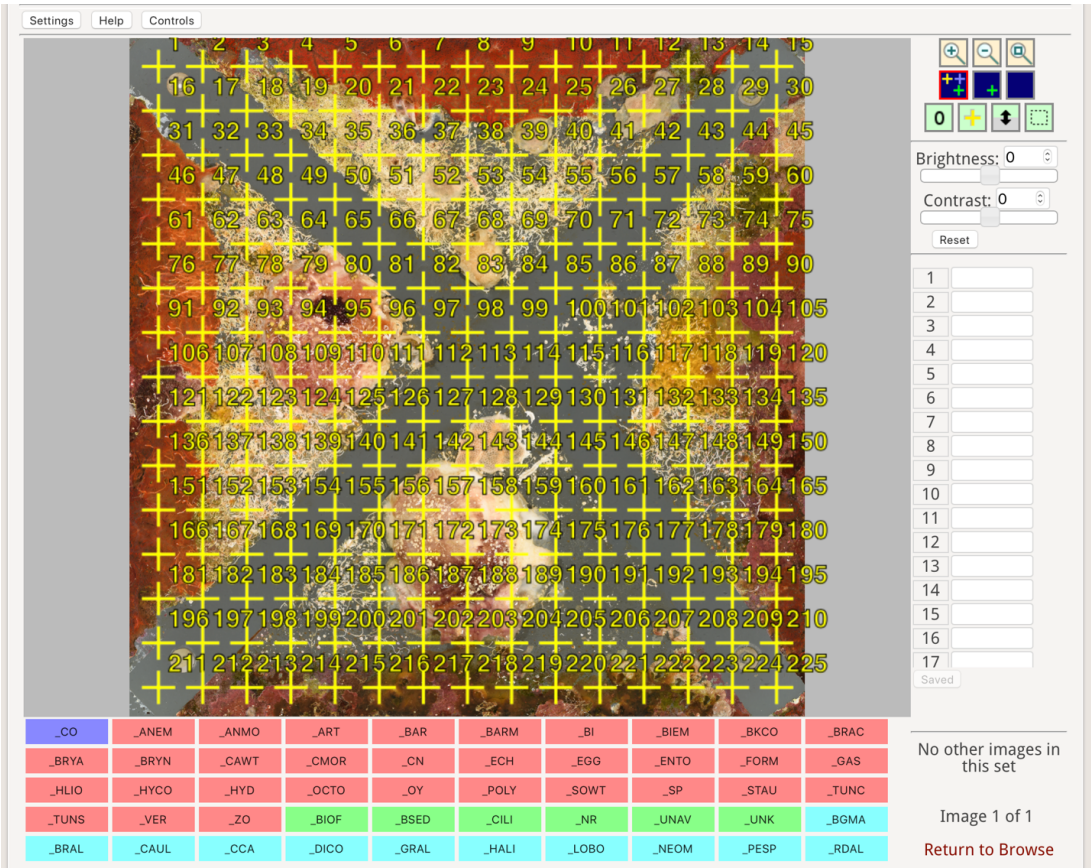
*** Note: You will want the first 20 plates you annotate to span as much diversity as possible across your ARMS project. Select the most widely different-looking plates in your set to annotate first. ***



29) Click on an image and you will be brought to that image's information page. The image metadata and the annotation status of the image are listed below the image itself. Along the top, a tool bar contains the following: "Image Details" (you are currently here), "Annotation Tool", and "Annotation History". To see the history of your changes as well as any updates the CoralNet algorithm makes to the photo's annotations, you can click "Annotation History". Most recent changes will be listed first.

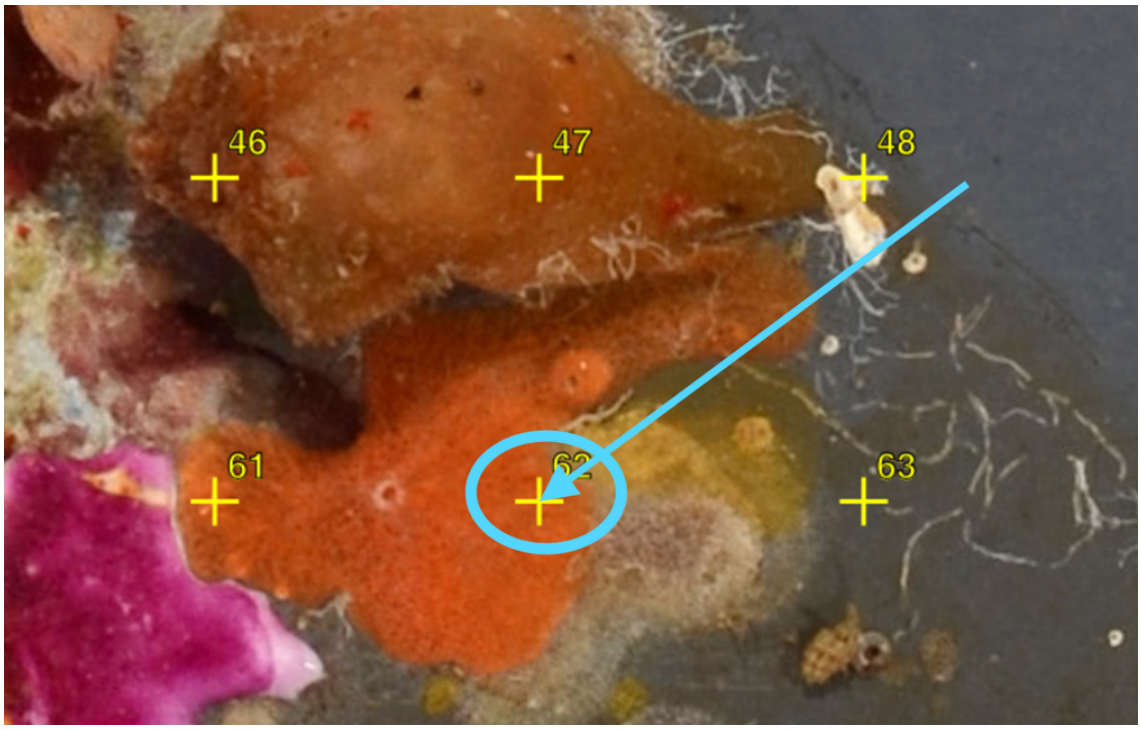
30) Select "Annotation Tool". This will bring you to a page that looks like the image below. Your photo is overlain by the grid specified when creating your Source. There are 225 points in total, arrayed along the 15x15 grid. Each of these points corresponds to a number that is listed on the righthand toolbar.

Along the bottom of the image is the list of labels that make up the ARMS labelset. If you need clarification on the shorthand label codes, hovering your mouse over each code reveals the full label name in a small temporary pop-up bar. The label codes are organized by functional groups: purple = hard coral, red = other invertebrates, green = other categories, blue = algae. Label codes are listed alphabetically within each color-coded group.



31) Single-click on or near the first point (#1) to zoom in on that area. It can take some time for the resolution to load, so wait a few seconds after zooming before clicking again to zoom more. Make sure you have an appropriate perspective on the point in question before deciding on a label (i.e. zoom in and out when necessary). Zoom out by right-clicking (ctrl + click), or via the (-) magnifying lens button on the top left of the righthand toolbar.

32) Now, identify what is directly underneath the middle of the plus sign (+) on the image. Identifying what is directly in the middle of the (+) is critical since there can be multiple organisms that meet in the viscinity of the (+). In the example below, the middle of the plus associated with point #62 is directly on top of a sponge, so the code _SP would be selected. If you have an encrusting organism (e.g. a bryozoan) growing on top of another (e.g. calcareous worm tube), you must decide which organism to choose. Usually it is most appropriate to select whichever is likely to contribute the most biomass to the scraped sessile metabarcoding ARMS fraction (DNA sample). Discuss general rules to follow with your mentor / project lead.



33) To annotate the point, click on the blank text box beside the point's corresponding number in the righthand column list of points. You will know the point has been selected when the plus sign (+) and corresponding number on the image turns green. Un-annotated points are yellow, annotated points are purple, and the one currently being annotated is green. Type in the appropriate label code when you have identified what is underneath the center of the (+). You may also fill in this box by clicking on the appropriate label code in the menu below the image. Once you assign a label code the point will turn purple, and the program will automatically move to the next point (which is now green).

34) Continue annotating like this, zooming in and out for clarity and perspective, until all 225 points have been identified on the image. You will know you have completed the plate when every point is purple.

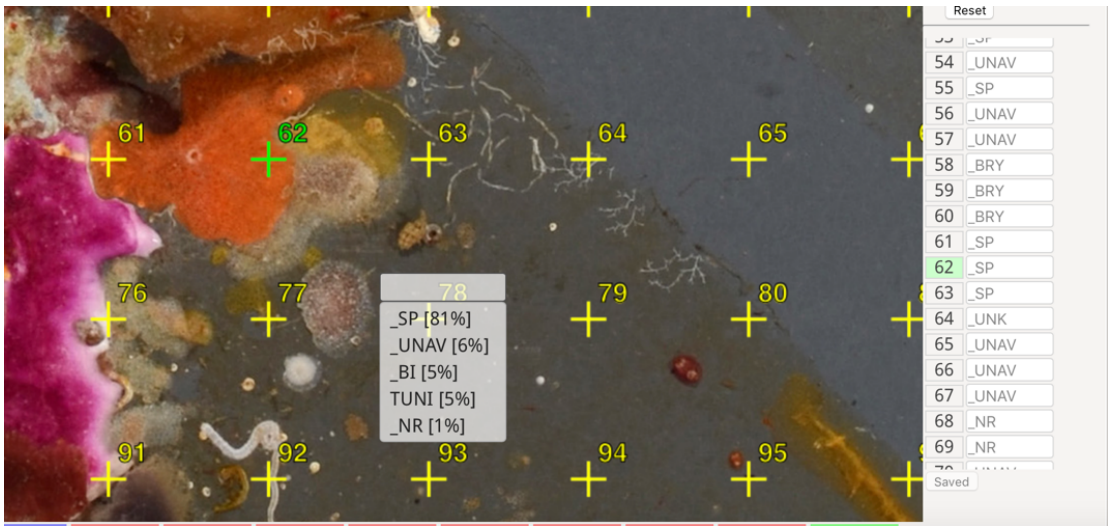
35) When the annotations are complete, click the "Save" button at the bottom of the righthand column toolbar. Once saved, "ALL DONE" will appear in blue lettering. Remember to save your annotations via "Save progress" if you need to stop in the middle of annotating a plate. This will save your progress until you return to the annotation tool.

36) Click "Return to Browse" after you have saved. You will return to the list of images. Choose a new plate and repeat this annotation process. You can always return to previously completed plates and change annotations if necessary. Remember to save after any changes to finalize corrections.

37) After 20 images have been completely annotated, the program will begin to make suggestions for labeling points based on your annotation history. The program will need a few hours (usually overnight) in order to process the visual data and generate suggestions. If the program has completed its suggestions for all points on a plate, the plate will have an orange border in the list of images. If annotations have been confirmed/completed, the plate will have a green border in the list of images.

38) In order to review the classifier's suggestions, begin by selecting a plate with an orange border in your image menu. Then, select "Annotation Tool". There will now be light grey codes in the annotation list on the righthand toolbar, as seen in the image below. These are the codes the classifier believes most likely correlate to each point.

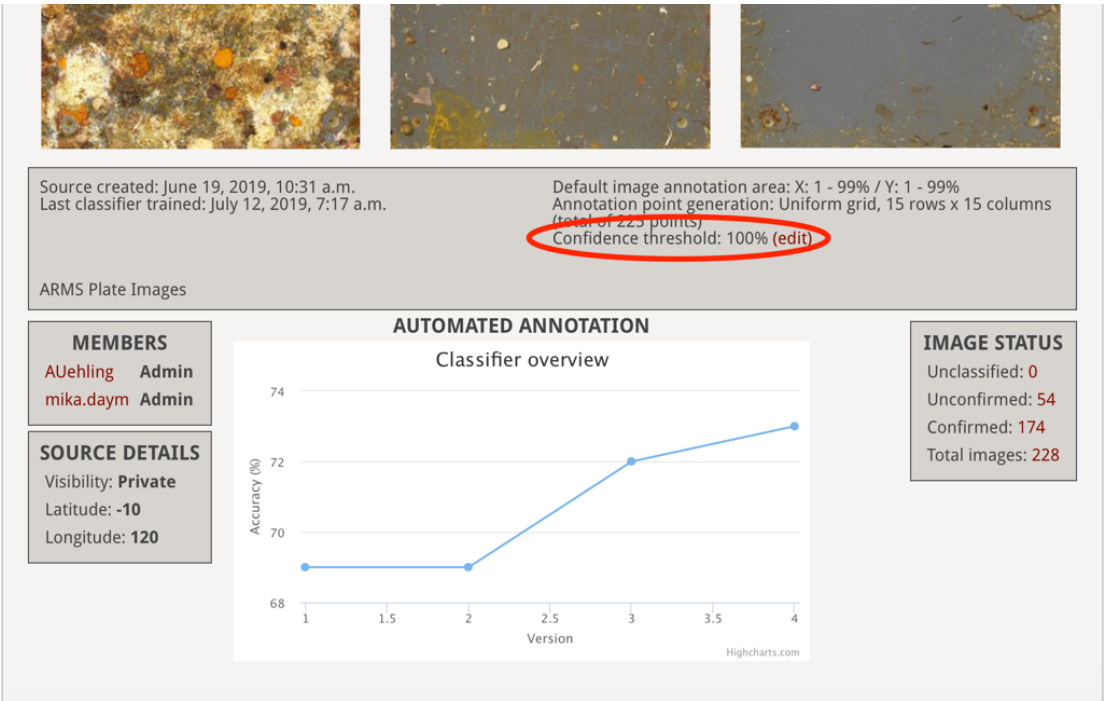
39) Select the first point. Now, a list of suggestions will appear accompanied by likelihood percentages, as seen in the image below. Here, you can see that the program is 81% sure that what lies below point 62 is a sponge, 6% sure it is unavailable, 5% sure it is a bivalve, and so on. The percentage of confidence in the first choice will improve as more annotations are completed and the classifier has more data to work with.



40) Determine the correct ID for the organism underneath the point. If the correct label is on the list of suggestions, click on this label and it will appear in the box in the righthand list. Using the same example above, since #62 is a sponge, you would click the first suggestion "_SP". You can see that the box at the right already has this code, but once selected the code will become bold. If the first suggestion is not chosen, the suggestion on the right will change. If the correct label is NOT on the list of suggestions, follow the same procedure as before and choose from the label menu below the image.

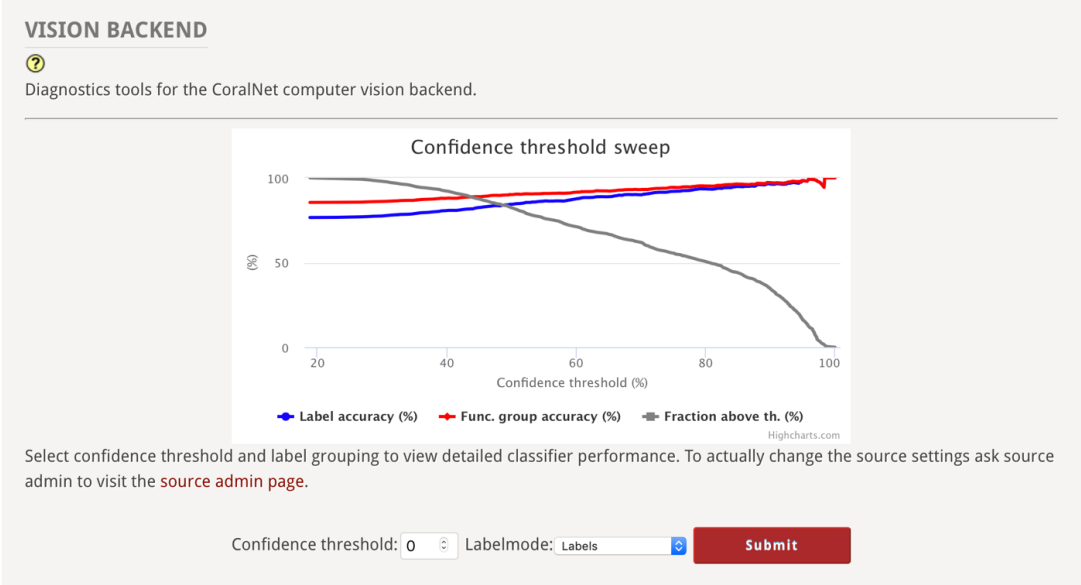
41) Continue accepting or changing suggestions until you have completed the plate. Like before, save when complete. As suggestions are accepted or rejected, the classifier will continue learning and will update suggestions on incomplete plates overnight. These changes and associated timelines can be viewed for each plate under "Annotation History". The program will NOT change any previous manually-confirmed annotations; once selected and saved, an annotation is set unless you return to the image to alter it manually.

42) At the top of the page is a "Home" button. Select this to return to your main homepage. Click on your Source link to go to your Source homepage. This page will now show the training progress of the automated annotator in percent accuracy. It will also include a confidence threshold (see image below). The confidence threshold is how "sure" the program has to be about its suggestion for a point before assigning a **confirmed** label on its own. For example, if the confidence threshold is set to 75%, the program only has to be 75% sure that a point suggestion is correct, and it will create a confirmed annotation. Using the example in step 39, the program is 81% sure that the point is a sponge, which is higher than the hypothetical confidence threshold of 75%, so it will automatically assign the sponge label to the point. This threshold can be edited.

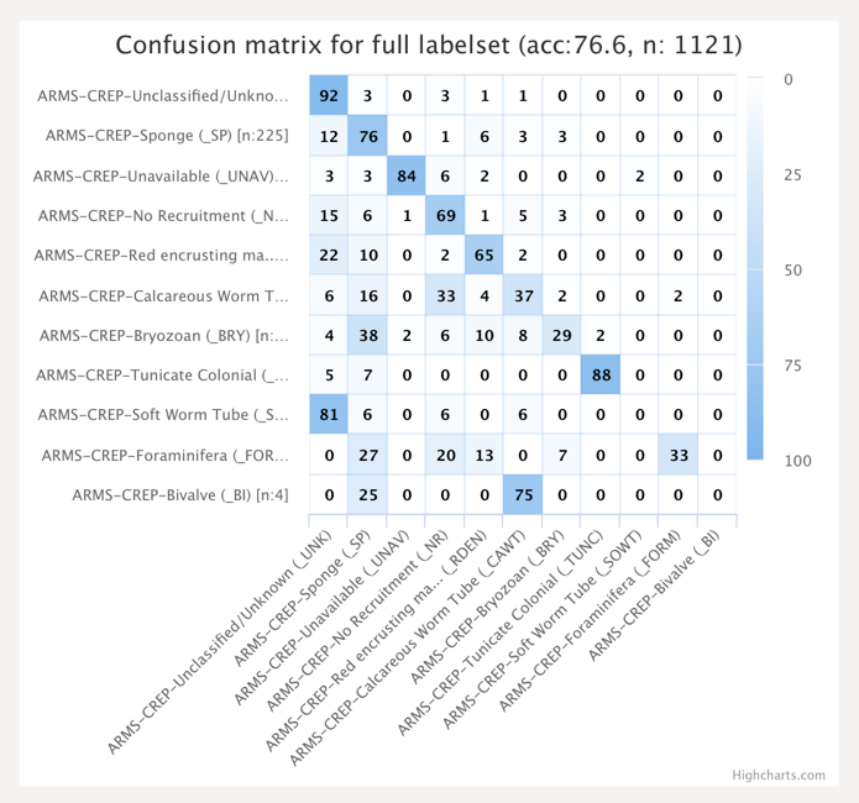


43) Navigate to the "Backend" tab in the main homepage toolbar. Data that is compiled and summarized can be viewed here. These statistical representations are automatically updated with the addition of new data.

The first plot below shows the classifier's current accuracy stats. Classifier accuracy is calculated based on whether you agree with the classifier when reviewing automated suggestions. You can see the % accuracy for labels (blue line), and the % accuracy for functional groups (e.g. coral, other invertebrates, algae; red line). The grey line (fraction above threshold) shows how many points in your data the classifier has assigned to be at or above a certain confidence threshold. So, in the graph below, about 50% of points were identified with 80% or higher confidence. You can see that only 2% of points were classified at or above 98% confidence.



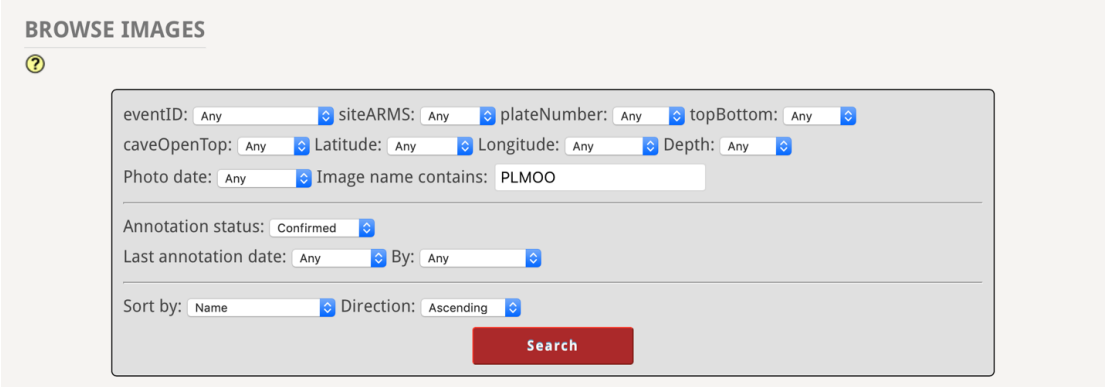
The second main chart, the confusion matrix, is helpful as it organizes and presents the percentage of points that the classifier labels correctly for each category in the labelset, as well as how often a given label is confused for each of the other labels. This matrix, like any of the other visual statistics, can be exported by clicking the "export" option above the matrix or graph.


Confusion matrix for full labelset (acc:76.6, n: 1121)
ARMS-CREP-Unclassified/Unkno... 92 3 0 3 1 1 0 0 0 0 0
ARMS-CREP-Sponge (_SP) [n:225] 12 76 0 1 6 3 3 0 0 0 0
ARMS-CREP-Unavailable (_UNAV)... 3 3 84 6 2 0 0 0 2 0 0
ARMS-CREP-No Recruitment (_N... 15 6 1 69 1 5 3 0 0 0 0
ARMS-CREP-Red encrusting ma..... 22 10 0 2 65 2 0 0 0 0 0
ARMS-CREP-Calcareous Worm T... 6 16 0 33 4 37 2 0 0 2 0
ARMS-CREP-Bryozoan (_BRY) [n:... 4 38 2 6 10 8 29 2 0 0 0
ARMS-CREP-Tunicate Colonial (_... 5 7 0 0 0 0 0 88 0 0 0
ARMS-CREP-Soft Worm Tube (_S... 81 6 0 6 0 6 0 0 0 0 0
ARMS-CREP-Foraminifera (_FOR... 0 27 0 20 13 0 7 0 0 33 0
ARMS-CREP-Bivalve (_BI) [n:4] 0 25 0 0 0 75 0 0 0 0 0
ARMS-CREP-Unclassified/Unknown (_UNK)
ARMS-CREP-Sponge (_SP)
ARMS-CREP-Unavailable (_UNAV)
ARMS-CREP-No Recruitment (_NR)
ARMS-CREP-Red encrusting ma... (_RDEN)
ARMS-CREP-Calcareous Worm Tube (_CAWT)
ARMS-CREP-Bryozoan (_BRY)
ARMS-CREP-Tunicate Colonial (_TUNC)
ARMS-CREP-Soft Worm Tube (_SOWT)
ARMS-CREP-Foraminifera (_FORM)
ARMS-CREP-Bivalve (_BI)
0
25
50
75
100
Highcharts.com

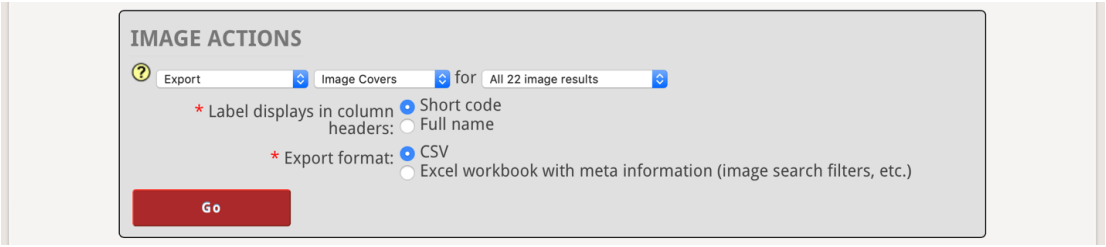
Exporting ARMS Plate CoralNet Annotation Data

Download coverage data

1) After all necessary plates have been annotated, download their percent coverage data. Navigate to the `Images` page of your source project. The easiest way to select specific finished plates is to search based on plate metadata. For example, filter plate images via a prefix and specify annotation status “Confirmed” as pictured below:

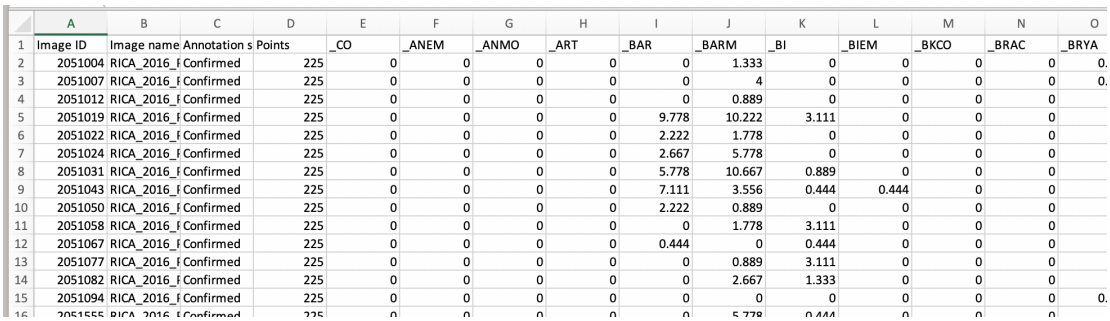


2) Scroll to the bottom of the page to the box labeled “Image Actions”. Select from the drop-down menus the following input: “Export”, “Image Covers” for “All {#} image results”. You will then specify full or short label names as column headers, as well as whether you want the data as a .csv or excel file (the .csv file is sufficient for our needs.) Click the “Go” button to download the % coverage for all specified plates; the output file will be named “percent_covers.csv”. This may take a few moments depending on how many plates must be parsed; do not leave the page.



This “Image Actions” menu box also gives you the option to export “Annotations, CSV”, which provides a spreadsheet listing every point annotation for every plate, as well as the classifier’s call vs. your call. Because of the large number of points per plate, it is best to download this information in subsets, e.g. by sites or by individual ARMS. (We generally do not use this for our primary data analysis, but it may be useful for other types of data exploration.)

3) Your downloaded file should look like this:



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Image ID	Image name	Annotation s	Points	_CO	_ANEM	_ANMO	_ART	_BAR	_BARM	_BI	_BIEM	_BKCO	_BRAC	_BRYA
2	2051004	RICA_2016_F	Confirmed	225	0	0	0	0	0	1.333	0	0	0	0	0.
3	2051007	RICA_2016_F	Confirmed	225	0	0	0	0	0	4	0	0	0	0	0.
4	2051012	RICA_2016_F	Confirmed	225	0	0	0	0	0	0.889	0	0	0	0	
5	2051019	RICA_2016_F	Confirmed	225	0	0	0	0	9.778	10.222	3.111	0	0	0	
6	2051022	RICA_2016_F	Confirmed	225	0	0	0	0	2.222	1.778	0	0	0	0	
7	2051024	RICA_2016_F	Confirmed	225	0	0	0	0	2.667	5.778	0	0	0	0	
8	2051031	RICA_2016_F	Confirmed	225	0	0	0	0	5.778	10.667	0.889	0	0	0	
9	2051043	RICA_2016_F	Confirmed	225	0	0	0	0	7.111	3.556	0.444	0.444	0	0	
10	2051050	RICA_2016_F	Confirmed	225	0	0	0	0	2.222	0.889	0	0	0	0	
11	2051058	RICA_2016_F	Confirmed	225	0	0	0	0	0	1.778	3.111	0	0	0	
12	2051067	RICA_2016_F	Confirmed	225	0	0	0	0	0.444	0	0.444	0	0	0	
13	2051077	RICA_2016_F	Confirmed	225	0	0	0	0	0	0.889	3.111	0	0	0	
14	2051082	RICA_2016_F	Confirmed	225	0	0	0	0	0	2.667	1.333	0	0	0	
15	2051094	RICA_2016_F	Confirmed	225	0	0	0	0	0	0	0	0	0	0	0.
16	2051555	RICA_2016_F	Confirmed	225	0	0	0	0	0	5.778	0.444	0	0	0	

If you like, you may delete column “Annotation Status”. The column “Image ID” is a unique ID CoralNet generates for all photos and should be kept for reference. Column “Points” is also useful to maintain, since it designates the annotation method employed.

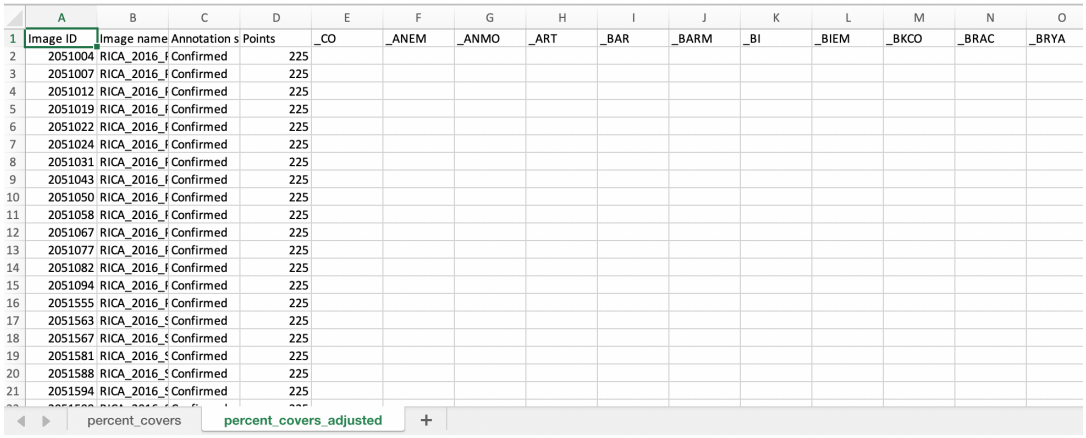
Now that you have your coverage data, you may analyze the data however you see fit (e.g. using R or Matlab). The steps below use Excel for correcting plate coverage percentages to account for space unavailable to recruitment.

Account for unavailable space

4) Next, normalize the data to correct for unavailable space (“_UNAV”) that cannot (by definition) recruit organisms. For example, if the entire plate surface is 1.00 and sponges cover ½ of the plate, sponge coverage is 0.5. However, ARMS cross bars and spacers prevent settlement, so the plate surface available is actually 1.00 - % cover of cross bars / spacers. Accordingly, for a cross bar plate with ½ sponge cover, sponge coverage would be adjusted as 0.5/(1.00-cross bars, spacers).

We need to remove unavailable space from the denominator of each category’s total percentage.

a) Create a new sheet (tab) in your excel workbook and rename it “percent_covers_adjusted”. We will calculate adjusted % cover in this sheet so that you maintain your original data. Copy the first four columns from the previous sheet into this new one, and add all original label columns except “_UNAV”:



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Image ID	Image name	Annotation s	Points	_CO	_ANEM	_ANMO	_ART	_BAR	_BARM	_BI	_BIEM	_BKCO	_BRAC	_BRYA
2	2051004	RICA_2016_I	Confirmed	225											
3	2051007	RICA_2016_I	Confirmed	225											
4	2051012	RICA_2016_I	Confirmed	225											
5	2051019	RICA_2016_I	Confirmed	225											
6	2051022	RICA_2016_I	Confirmed	225											
7	2051024	RICA_2016_I	Confirmed	225											
8	2051031	RICA_2016_I	Confirmed	225											
9	2051043	RICA_2016_I	Confirmed	225											
10	2051050	RICA_2016_I	Confirmed	225											
11	2051058	RICA_2016_I	Confirmed	225											
12	2051067	RICA_2016_I	Confirmed	225											
13	2051077	RICA_2016_I	Confirmed	225											
14	2051082	RICA_2016_I	Confirmed	225											
15	2051094	RICA_2016_I	Confirmed	225											
16	2051555	RICA_2016_I	Confirmed	225											
17	2051563	RICA_2016_S	Confirmed	225											
18	2051567	RICA_2016_S	Confirmed	225											
19	2051581	RICA_2016_S	Confirmed	225											
20	2051588	RICA_2016_S	Confirmed	225											
21	2051594	RICA_2016_S	Confirmed	225											

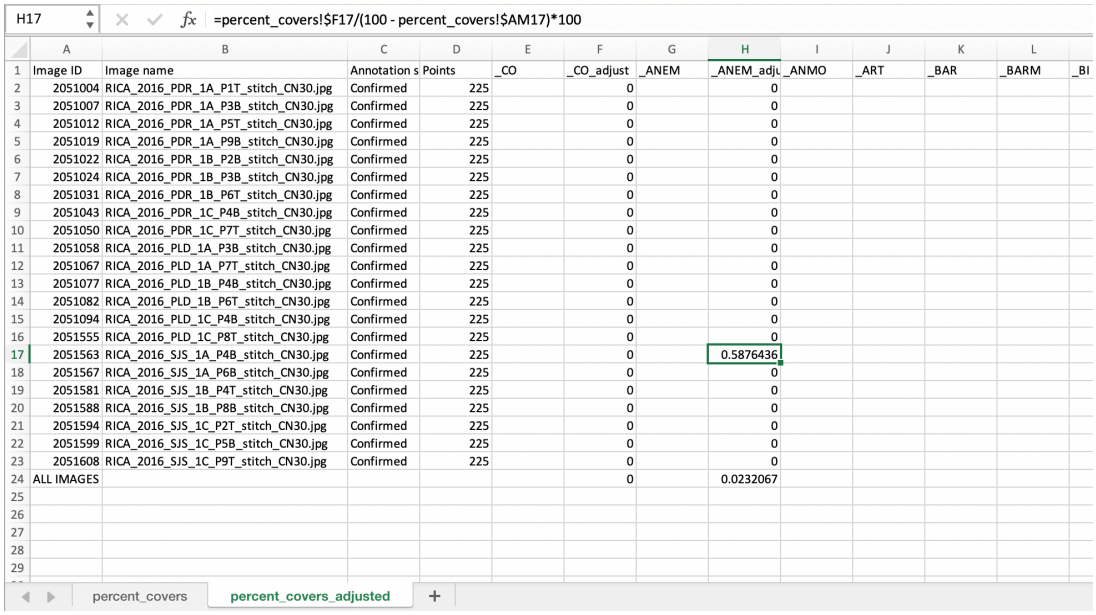
percent_covers | percent_covers_adjusted | +

b) Insert a blank column to the right of your first category (_CO). Name this column something like "_COadjust". In the first cell of this column, enter that row's _CO fraction divided by (100 minus that plate's _UNAV fraction) x 100. This will look like the equation below; note that you are retrieving values from a different sheet (`percent_covers`), so calling a cell follows the syntax `sheet_name!cell`. Your _UNAV column may be different than the one in this equation – be sure to check!

=percent_covers!$E2 / (100 – percent_covers!$AM2) * 100

c) Drag the equation down the entire column. The 0 values will remain 0, but all other values should increase slightly when unavailable space is removed from the denominator.

d) Repeat these steps for each column except _UNAV. See photo below for reference.



H17 | fx | =percent_covers!$F17/(100 - percent_covers!$AM17)*100

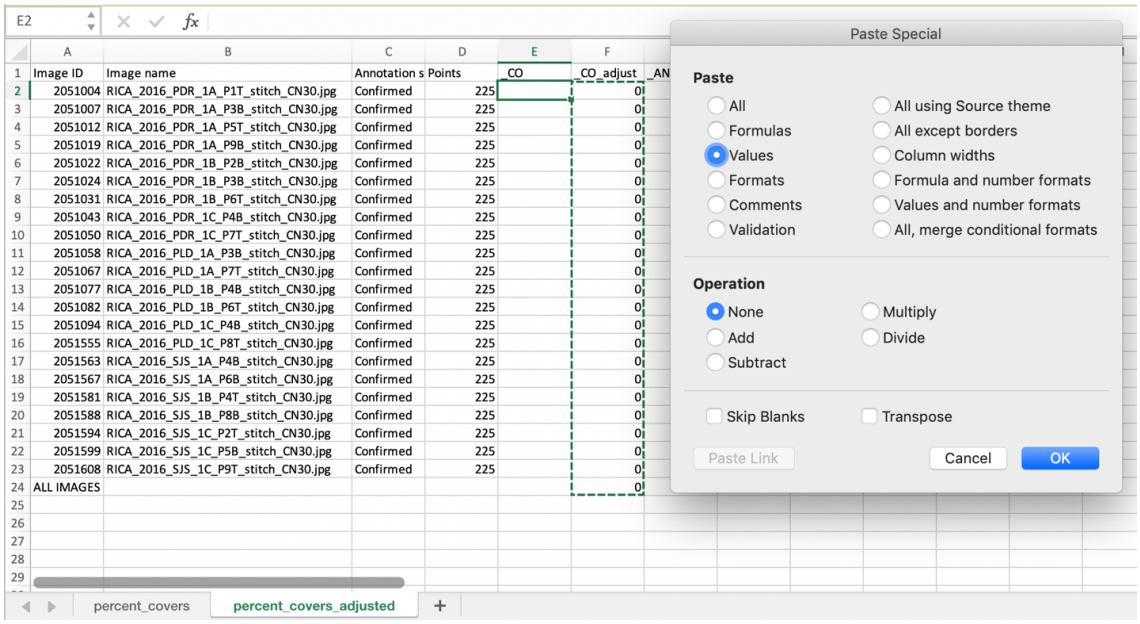
	A	B	C	D	E	F	G	H	I	J	K	L
1	Image ID	Image name	Annotation s	Points	_CO	_CO_adjust	_ANEM	_ANEM_adju	_ANMO	_ART	_BAR	_BARM
2	2051004	RICA_2016_PDR_1A_P1T_stitch_CN30.jpg	Confirmed	225		0		0				
3	2051007	RICA_2016_PDR_1A_P3B_stitch_CN30.jpg	Confirmed	225		0		0				
4	2051012	RICA_2016_PDR_1A_P5T_stitch_CN30.jpg	Confirmed	225		0		0				
5	2051019	RICA_2016_PDR_1A_P9B_stitch_CN30.jpg	Confirmed	225		0		0				
6	2051022	RICA_2016_PDR_1B_P2B_stitch_CN30.jpg	Confirmed	225		0		0				
7	2051024	RICA_2016_PDR_1B_P3B_stitch_CN30.jpg	Confirmed	225		0		0				
8	2051031	RICA_2016_PDR_1B_P6T_stitch_CN30.jpg	Confirmed	225		0		0				
9	2051043	RICA_2016_PDR_1C_P4B_stitch_CN30.jpg	Confirmed	225		0		0				
10	2051050	RICA_2016_PDR_1C_P7T_stitch_CN30.jpg	Confirmed	225		0		0				
11	2051058	RICA_2016_PLD_1A_P3B_stitch_CN30.jpg	Confirmed	225		0		0				
12	2051067	RICA_2016_PLD_1A_P7T_stitch_CN30.jpg	Confirmed	225		0		0				
13	2051077	RICA_2016_PLD_1B_P4B_stitch_CN30.jpg	Confirmed	225		0		0				
14	2051082	RICA_2016_PLD_1B_P6T_stitch_CN30.jpg	Confirmed	225		0		0				
15	2051094	RICA_2016_PLD_1C_P4B_stitch_CN30.jpg	Confirmed	225		0		0				
16	2051555	RICA_2016_PLD_1C_P8T_stitch_CN30.jpg	Confirmed	225		0		0				
17	2051563	RICA_2016_SJS_1A_P4B_stitch_CN30.jpg	Confirmed	225		0		0.5876436				
18	2051567	RICA_2016_SJS_1A_P6B_stitch_CN30.jpg	Confirmed	225		0		0				
19	2051581	RICA_2016_SJS_1B_P4T_stitch_CN30.jpg	Confirmed	225		0		0				
20	2051588	RICA_2016_SJS_1B_P8B_stitch_CN30.jpg	Confirmed	225		0		0				
21	2051594	RICA_2016_SJS_1C_P2T_stitch_CN30.jpg	Confirmed	225		0		0				
22	2051599	RICA_2016_SJS_1C_P5B_stitch_CN30.jpg	Confirmed	225		0		0				
23	2051608	RICA_2016_SJS_1C_P9T_stitch_CN30.jpg	Confirmed	225		0		0				
24	ALL IMAGES					0		0.0232067				
25												
26												
27												
28												
29												

percent_covers | percent_covers_adjusted | +

5) Once you have calculated adjusted coverage percentages for each category, paste these into the original empty columns as static values (rather than equations). This ensures that your calculations are in a format that will not change if, for some reason, cells/rows get shifted.

Copy the contents of your first working column (in the images above and below this is "_COadjust"). Click in the first cell of column "_CO" to the left. Paste your adjusted percentages as values using Paste Special: Edit → Paste Special → Paste Values (or, CTRL + CMD + V, Paste Values) (see below). Do this for each column. Once you have copied your calculations as static values for every label, you may delete your working columns (e.g. "_COadjust") that contain the excel equations.

**Note: If you prefer to keep a record of all calculations done in excel for reference, you could create a third sheet (e.g. "percent_covers_adjusted_clean") and special-paste your columns as values in here. That way, you retain one sheet with the equations you used, and the third sheet contains static values for export. This is helpful if you ever need to re-create your steps.



6) Next we will add our ARMS-specific metadata to the static-value data sheet. Luckily, we prepared this information when we uploaded images to CoralNet.

In sheet "percent_covers_adjusted" (or "percent_covers_adjusted_clean") add five empty columns to the left of your first label column (_CO). Label these columns "eventID", "siteARMS", "plateNumber", "topBottom", and "caveOpenTop". Copy the appropriate metadata from your CoralNet metadata file into your adjusted data

spreadsheet, making sure you are matching your entries with the correct plate image name. See example below:

	A	B	C	D	E	F	G	H	I	J	K	L
1	Image ID	Image name	Annotation s	Points	eventID	siteARMS	plateNumbe	topBottom	caveOpenTo	_CO	_ANEM	_ANMO
2	2051004	RICA_2016_PDR_1A_P1T_stitch_CN30.jpg	Confirmed	225	RICA_2016_I	PDR_1A	1	top	cave	0	0	
3	2051007	RICA_2016_PDR_1A_P3B_stitch_CN30.jpg	Confirmed	225	RICA_2016_I	PDR_1A	3	bottom	open	0	0	
4	2051012	RICA_2016_PDR_1A_P5T_stitch_CN30.jpg	Confirmed	225	RICA_2016_I	PDR_1A	5	top	cave	0	0	
5	2051019	RICA_2016_PDR_1A_P9B_stitch_CN30.jpg	Confirmed	225						0	0	
6	2051022	RICA_2016_PDR_1B_P2B_stitch_CN30.jpg	Confirmed	225						0	0	
7	2051024	RICA_2016_PDR_1B_P3B_stitch_CN30.jpg	Confirmed	225						0	0	

7) When we uploaded our image metadata to CoralNet, we could only add five custom fields. There is one additional field we will want to include before we begin our data analysis – "level". You will recall that two plates comprise one "layer" of the ARMS; e.g. P1T and P2B create a cave layer. We will call this layer a "level", and the first layer of the ARMS, starting at the bottom, is level 1. Add an additional column to the left of column _CO, and name this column "level". Fill in the appropriate level for each image. See the key below for level assignments:

P1T: Level 1	P4T: Level 4	P7T: Level 7
P2B: Level 1	P5B: Level 4	P8B: Level 7
P2T: Level 2	P5T: Level 5	P8T: Level 8
P3B: Level 2	P6B: Level 5	P9B: Level 8
P3T: Level 3	P6T: Level 6	P9T: Level 9
P4B: Level 3	P7B: Level 6	

This is what your file should resemble:

	A	B	C	D	E	F	G	H	I	J	K
1	Image ID	Image name	Points	eventID	siteARMS	plateNumbe	topBottom	caveOpenTo	level	_CO	_ANEM
2	2051004	RICA_2016_PDR_1A_P1T_stitch_CN30.jpg	225	RICA_2016_PDR_1A	PDR_1A	1	top	cave	1	0	0
3	2051007	RICA_2016_PDR_1A_P3B_stitch_CN30.jpg	225	RICA_2016_PDR_1A	PDR_1A	3	bottom	open	2	0	0
4	2051012	RICA_2016_PDR_1A_P5T_stitch_CN30.jpg	225	RICA_2016_PDR_1A	PDR_1A	5	top	cave	5	0	0
5	2051019	RICA_2016_PDR_1A_P9B_stitch_CN30.jpg	225	RICA_2016_PDR_1A	PDR_1A	9	bottom	open	8	0	0
6	2051022	RICA_2016_PDR_1B_P2B_stitch_CN30.jpg	225	RICA_2016_PDR_1B	PDR_1B	2	bottom	cave	1	0	0
7	2051024	RICA_2016_PDR_1B_P3B_stitch_CN30.jpg	225	RICA_2016_PDR_1B	PDR_1B	3	bottom	open	2	0	0
8	2051031	RICA_2016_PDR_1B_P6T_stitch_CN30.jpg	225	RICA_2016_PDR_1B	PDR_1B	6	top	open	6	0	0
9	2051043	RICA_2016_PDR_1C_P4B_stitch_CN30.jpg	225	RICA_2016_PDR_1C	PDR_1C	4	bottom	cave	3	0	0
10	2051050	RICA_2016_PDR_1C_P7T_stitch_CN30.jpg	225	RICA_2016_PDR_1C	PDR_1C	7	top	cave	7	0	0

percent_covers | percent_covers_adjusted | percent_covers_adjusted_clean

8) When you have finished filling in all metadata, save the workbook as an excel file. Then, save the selected sheet (either "percent_covers_adjusted" or "percent_covers_adjusted_clean") as a .csv file.

Be sure to give you files clear names. If your file only contains covers for a single ARMS unit, appropriate names might be "KOU_2A_CN_export.xlsx" and "KOU_2A_percCovAdjusted.csv".

ARMS CoralNet Standard Labelset

Label Name	Code	Short Description	Usage
ARMS-Red algae	_RDAL	Unidentified red algae, various forms	standard
ARMS-CREP-CCA	_CCA	Crustose coralline algae	standard
ARMS-CREP-Peyssonnelia spp	_PESP	*Peyssonnelia* species	optional
ARMS-Green algae	_GRAL	Unidentified green algae, various forms	standard
ARMS-CREP-Halimeda spp	_HALI	*Halimeda* species	optional
ARMS-CREP-Neomeris spp	_NEOM	*Neomeris* species	optional
ARMS-CREP-Caulerpa spp	_CAUL	*Caulerpa* species	optional
ARMS-Brown algae	_BRAL	Unidentified brown algae, various forms	standard
ARMS-CREP-Dictyopteris/Dictyota spp	_DICO	*Dictyopteris* or *Dictyota* species	optional
ARMS-CREP-Lobophora spp	_LOBO	*Lobophora* species.	optional
ARMS-CREP-Blue-green macroalgae	_BGMA	Blue-green macroalgae (cyanobacteria)	standard
ARMS-CREP-Sponge	_SP	Sponges	standard
ARMS-CREP-Coral	_CO	Stony/hard corals, order Scleractinia	standard
ARMS-CREP-Corallimorph	_CMOR	Corallimorphs	optional
ARMS-Black coral	_BKCO	Black corals, order Antipatharia	standard
ARMS-CREP-Zoanthid	_ZO	Zoanthids, order Zoanthidea	optional
ARMS-Anemone	_ANEM	Anemones, order Actiniaria	standard
ARMS-CREP-Octocoral	_OCTO	Octocorals	standard
ARMS-Heliopora spp	_HLIO	Blue corals, order Helioporaea	optional
ARMS-CREP-Hydrozoa	_HYD	Hydroids, class Hydrozoa	standard
ARMS-CREP-Hydrocoral	_HYCO	Non-scleractinian hard corals (e.g. *Stylaster*, *Millepora*, *Distichopora*)	standard
ARMS-Staurozoa	_STAU	Stalked jellyfish, Class Staurozoa	optional
ARMS-Cnidaria other	_CN	Other cnidaria, e.g. polyps of non-hydroid medusozoans	standard
ARMS-CREP-Calcareous worm tube	_CAWT	Annelids that secrete tubes of calcium carbonate, e.g. family Serpulidae	standard
ARMS-CREP-Soft worm tube	_SOWT	Annelids with non-calcified tubes	standard
ARMS-Annelid motile	_ANMO	Motile annelids, such as those in families Syllidae, Nereididae, Polynoidae	optional
ARMS-CREP-Tunicate Colonial	_TUNC	Colonial tunicate	standard

ARMS-CREP-Tunicate Solitary	_TUNS	Solitary tunicate	standard
ARMS-Bryozoa encrusting	_BRYN	Encrusting bryozoans	standard
ARMS-Bryozoa arborescent	_BRYA	Arborescent bryozoa.	standard
ARMS-Entoproct	_ENTO	Entoprocts	standard
ARMS-CREP-Bivalve	_BI	Bivalves	standard
ARMS-CREP-Bivalve empty	_BIEM	Bivalves; shells present but empty	standard
ARMS-CREP-Oyster	_OY	True oysters, family Ostreidae	optional
ARMS-CREP-Gastropod	_GAS	Gastropods	standard
ARMS-CREP-Vermetidae	_VER	Worm snails, family Vermetidae	standard
ARMS-Polyplacophora	_POLY	Chitons	standard
ARMS-Brachiopoda	_BRAC	Lamp shells, phylum Brachiopoda	standard
ARMS-Barnacle	_BAR	Barnacles	standard
ARMS-Barnacle-empty	_BARM	Empty barnacle or barnacle base plate	standard
ARMS-Arthropod motile	_ART	Motile arthropods, e.g. amphipods, tanaids, decapods	standard
ARMS-Echinoderm	_ECH	Echinoderms, e.g. brittle stars, sea stars, urchins, crinoids	standard
ARMS-Platyhelminthes	_PLTY	Flatworms, particularly order Polycladida	standard
ARMS-Pterobranch	_PTRO	Pterobranchs	standard
ARMS-CREP-Foraminifera	_FORM	Foraminifera, including *Homotrema spp.*	standard
ARMS-Ciliophora	_CILI	Ciliates, e.g. *Stentor*, *Campanella*, *Folliculina spp.*	standard
ARMS-CREP-Eggs	_EGG	Egg masses from mobile fauna	standard
ARMS-Biofilm various	_BIOF	Biofilm on plate surface, lacking bound sediment	standard
ARMS-Bound sediment	_BSED	Sediment on plate surface obscuring organisms or empty space	standard
ARMS-CREP-Unclassified/Unknown	_UNK	Use when point falls on area that is obscured, blurry, or cannot be identified with confidence	standard
ARMS-CREP-No recruitment	_NR	No recruitment	standard
ARMS-CREP-Unavailable	_UNAV	Use when point falls in area unavailable for recruitment due to position of cross bars or hardware	standard