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Standard Operating Procedure for developing a sea urchin training dataset in VIAME

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Cover photo: *Diadema spp.* urchins aggregating on a coral reef. Photo credit: NOAA Fisheries / Daniella Escontrella.

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Introduction

Urchins play a complex and critical role in the production and persistence of coral reef habitat, contributing to the ecological processes that both maintain and erode 3D reef structure. As herbivores, grazing urchin taxa help support a coral-dominated reef by reducing macroalgal competition for space and resources (Idjadi et al., 2010; Krimou et al., 2023; Lessios et al., 1984). However, overgrazing can physically damage calcium carbonate reef framework (Bak, 1994; van Woesik & Asner, 2025). Moreover, bioeroding urchin species break down reef structure and, when abundant, can significantly influence the balance between coral reef habitat growth and erosion (i.e., carbonate budget). Monitoring urchin community demographics is therefore essential for understanding and tracking changes in these core ecological processes.

Urchin demographic assessments traditionally have been conducted using in-water surveys. However, diver-based coral reef survey methods are increasingly transitioning towards imagery-based survey techniques—including the use of structure-from-motion (SfM) photogrammetry—as the accuracy and efficiency of these data collection and processing tools have matured. These approaches offer substantial advantages over in-water methods in field efficiency and in the ability to derive multiple data sets from the same set of images or models, although the upfront costs and annotation time can be significant (Barkley et al., 2025; Couch et al., 2021). To reduce bottlenecks, AI-based tools capable of detecting, classifying, and segmenting marine invertebrates are rapidly developing in marine benthic research. Initial results from several different underwater object-detection algorithms and frameworks (e.g., Region-based Convolutional Neural Network [R-CNN], You-Only-Look-Once [YOLO], Single Shot MultiBox Detector [SSD]) have demonstrated the strong potential for imagery-based urchin data collection as part of NOAA's National Coral Reef Monitoring Program (NCRMP) and other long-term monitoring efforts (Barkley et al., 2025; Cai et al., 2025; Hu et al., 2020).

This document provides the standard operating procedure (SOP) for the development of training datasets for urchin detection in NOAA's Video and Image Analytics for Marine Environments (VIAME), an image-recognition AI tool. It includes instructions on how to manually annotate, record species, and size urchins in benthic imagery and automate the calculation of abundance metrics. This SOP workflow includes 1) using ArcGIS Pro to subsample large orthomosaic images and import subsampled areas into VIAME, 2) manually annotating urchins in benthic imagery using the VIAME tool, and 3) confirming urchin species using underlying imagery via Viscore as outlined in the Viscore SOP.

Section I: Sub-sampling Large Orthomosaics in ArcGIS

VIAME can import a variety of single- and multi-camera datasets with common file formats such as JPG, TIFF, and video; enabling urchin annotation on projects where benthic imagery is initially collected in these formats (skip to Section III if your imagery is collected in the acceptable formats mentioned above). However, VIAME cannot currently upload and process SFM 3D orthomosaics—geometrically corrected, high-resolution aerial or underwater images created by stitching together multiple overlapping photos—commonly used for coral reef monitoring. In this section, ArcGIS Pro 3.3.0. will be used to crop six 1 m width x 10 m length belt transects from the existing 3D orthomosaic of an NCRMP fixed-site. Each cropped belt transect will be exported as a JPG image to be uploaded to VIAME for urchin annotation. This step is **optional** and only necessary for projects that require annotating urchins from imagery initially in a 3D format.

1.1 Create and connect geodatabase to ArcGIS project

Once you've opened the 3D orthomosaic in ArcGIS Pro and set the correct coordinate system (Figure 1; Appendix A in Barkley et al., 2023 defines coordinate system), add the geodatabase for the correct region / year to the ArcGIS Project. If a geodatabase has not already been made for your project, create one (Appendix B in Barkley et al., 2023) where all of your project files will be stored (e.g., MARAMP2022_Urchins.gdb).

1. In the Catalog pane (right tab), right click on "Databases", select "Add Database", and then navigate to the geodatabase (e.g., N:\Fixed_Sites_Projects\Urchins\MARAMP2022_Urchins.gdb) (Figure 2).

2. Select "OK." You should now be able to see the geodatabase in the Contents pane under "Databases."

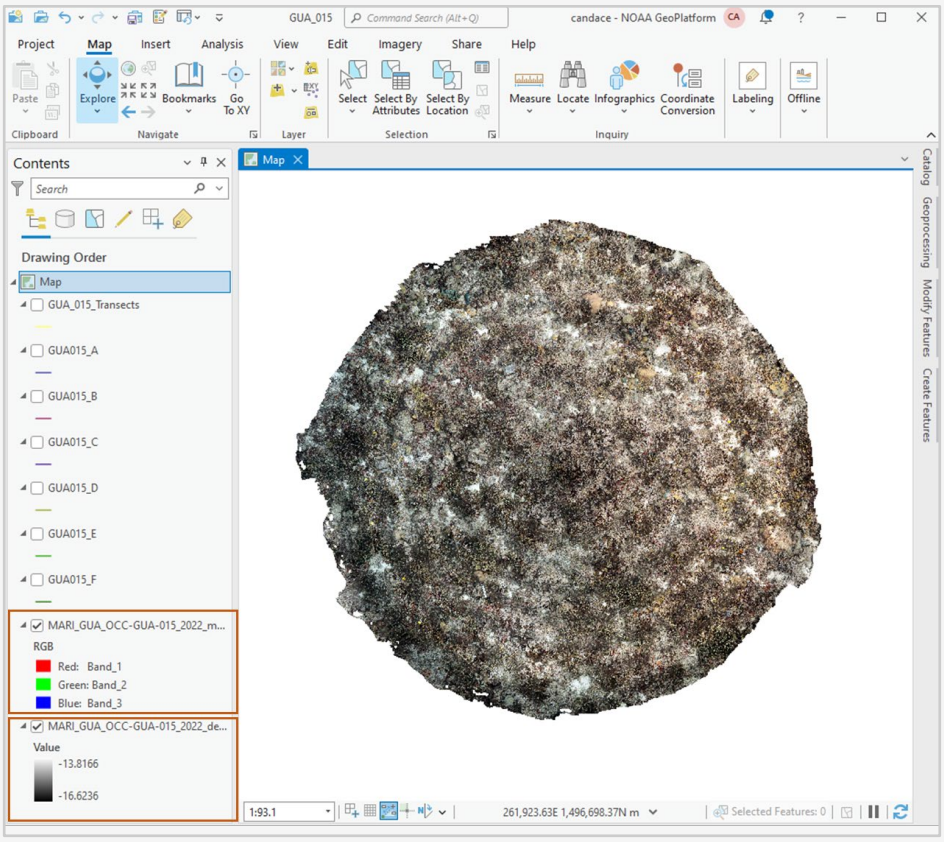

Figure 1. Screenshot from ArcGIS Pro showing an NCRMP fixed-site orthomosaic. Note the orthomosaic and DEM are aligned and can be shown under the Contents pane.

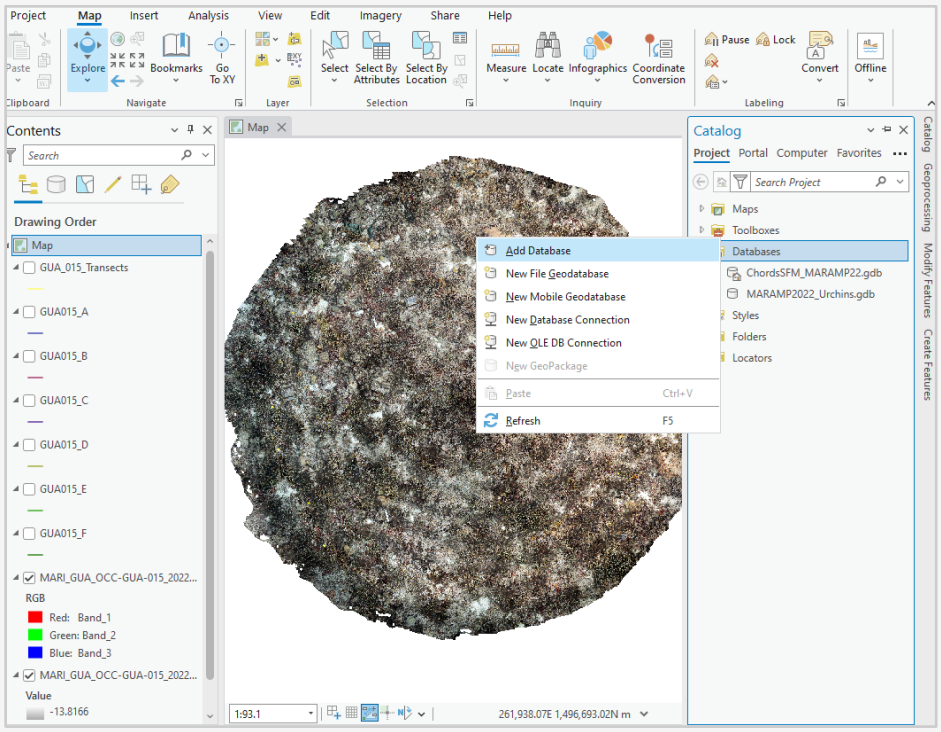

Figure 2. Adding a geodatabase to the current ArcGIS Project where all project files will be stored.

1.2 Creating fixed-site belt transects for urchin annotations

1. Create a new shapefile for transects in the geodatabase

    a. Under “Databases” in the “Contents” pane, right click on the urchin geodatabase (e.g., MARAMP2022_Urchins.gdb), hover over “New,” and select “Feature Class” (Figure 4).

    b. Enter the following:

        Name: SiteName_Transects (e.g., GUA_015_Transects)

        Feature Class Type: select “Line”

        Leave everything else as is and click “Finish”

    c. The feature will show up on the “Contents” pane.

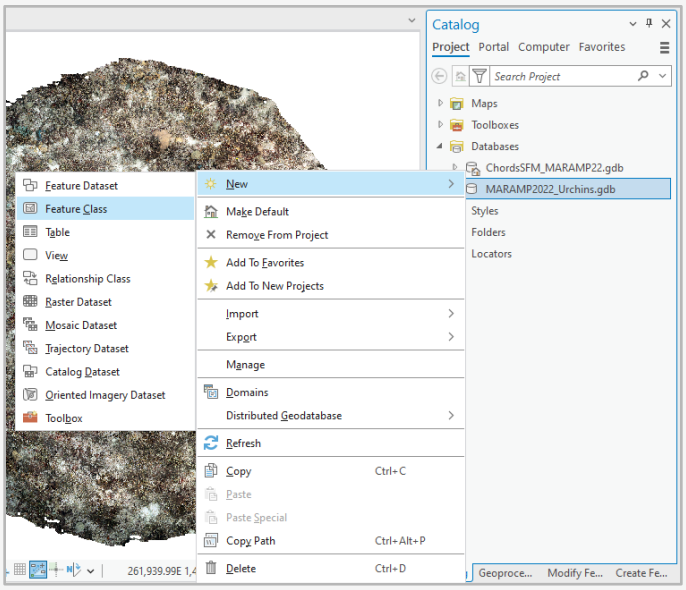

Figure 3. Creating a new feature class within the MARAMP2022 Urchins geodatabase.

2. Drawing Line Transects

    a. Click on the “Edit” tab, select “Create.”

    b. A “Create Features” pane will open. Select the SiteName_Transects file (e.g., GUA_015_Transects) and select “Two-Point Line” drawing feature (Figure 5).

    c. Use the cursor to draw transects by clicking anywhere on the mosaic, then right-click and select “Distance.”

    d. Enter the desired length of the transect in meters (e.g., 10.00 m) and press “Ok”; a line transect will be created.

    e. To reposition a transect, click on the “Edit” tab. A “Tools” box in the upper pane should appear. Scroll down and select “Move” or “Rotate” for each option.

    f. Repeat this process to create the desired number of transects.

    g. Note: To change color and width of line transects, right click on the transects shapefile in the “Contents” pane. The color selection will pop-up on the left pane, and the width selection will be under “Properties” in the “Symbology” pane on the right (Figure 6).

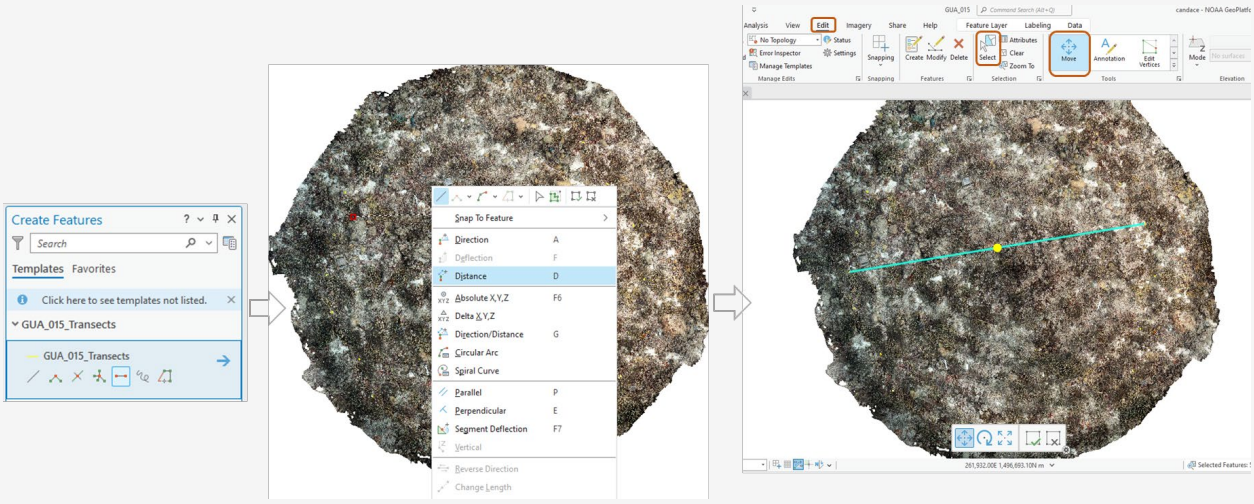

Figure 4. Using the two-point line feature to draw a transect, enter the desired length of the transect by right-clicking to use the Distance feature, and repositioning the desired transect using the Move and / or Rotate Tools.

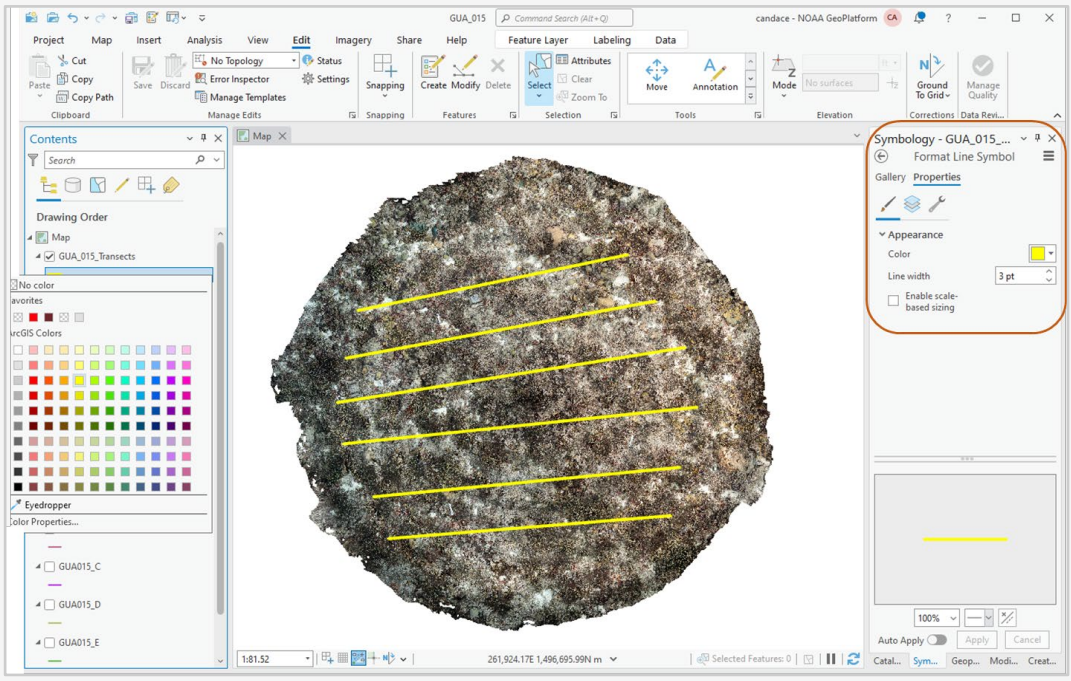

Figure 5. Changing the color and / or width of the six transects.

3. Create transect buffers for 1 m width belt transects

    a. Unhighlight all transects by clicking on “Select” under the “Edit” tab, then click anywhere on the map. This will deselect the highlighted transects.

    b. Navigate to the “Geoprocessing” tab in the bottom right corner.

i. If you can't find the "Geoprocessing" tab, click the "Analysis" tab in the top pane, then select the "Tools" icon and the "Geoprocessing" tab should now appear on the right pane.

c. In the "Geoprocessing" tab, search for "Buffer" (Analysis Tools) and click on it (Figure 7).

d. Enter the following:

Input Features: Site_Transects (e.g., GUA_015_Transects)

Output Feature Class: Navigate to the site geodatabase (e.g., N:\Fixed_Sites_Projects\Urchins\MARAMP2022_Urchins.gdb) and save as Site_Transects_Buffer (e.g., GUA_015_Transects_Buffer)

Distance: 0.5 m (Linear Unit)

Side Type: Full

End Type: Flat

Method: Planar

Dissolve Type: No Dissolve

Make sure all transects are deselected (refer to Step 3a).

e. Click "Run" and the buffer should appear on your Content pane on the left side (change colors as desired).

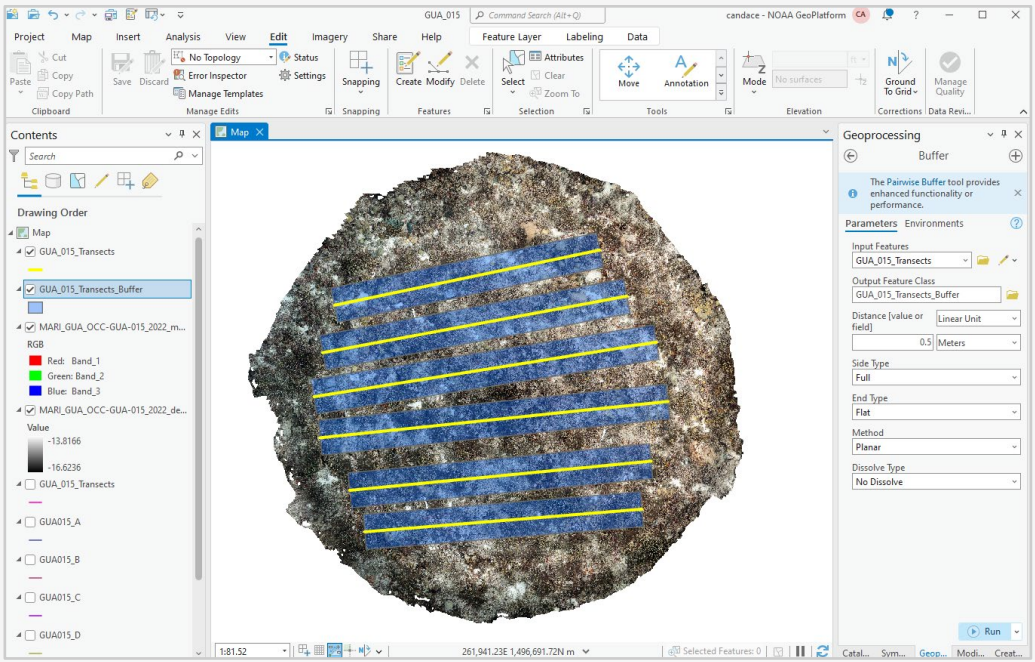

Figure 6. Using the "Buffer Tool" in the "Geoprocessing" tab to create 1 m width (0.5 m width on each side) belt transects for urchin annotation.

4. Clip Raster to Crop Each Belt Transect

    a. Open the Site_Transects_Buffer attribute table by right clicking on Site_Transects_Buffer (e.g., GUA_015_Transects_Buffer) in the "Contents" pane and selecting "Attribute Table."

    b. An "Attribute Table" will pop-up on the bottom pane.

    c. Select the first transect buffer by clicking on the first row in the "Attribute Table" so that only the first transect is highlighted in the map (Figure 8).

    d. In the "Geoprocessing" tab, search for "Clip Raster (Data Management Tools)" and select it.

    e. Enter the following:

        Input Raster: click the drop-down arrow → select the Site_Orthomosaic (e.g. MARI_GUA_OCC-GUA-015_2022_mos.tif)

        Output Extent: Site_Transects_Buffer (e.g., GUA_015_Transects_Buffer)

        Rectangle: This will autofill once output_extent is filled in

        Use Input Features for Clipping Geometry: Check

Output Raster Dataset: Navigate to year/region geodatabase (e.g., N:\Fixed_Sites_Projects\Urchins\MARAMP2022_Urchins.gdb → click on MARAMP2022_Urchins.gdb and save as Site_Transect_Letter (e.g., GUA_015_Transect_A) in the .gdb folder

NoData Value: 256

Maintain Clipping Extent: Uncheck

f. Click “Run” below and the clipped raster will appear in the Contents pane.

g. Repeat for each transect in the map.

h. Note: To check that transect rasters were clipped correctly, in the Contents pane, uncheck all shapefiles except the separate transect shapefiles that were clipped (Figure 9).

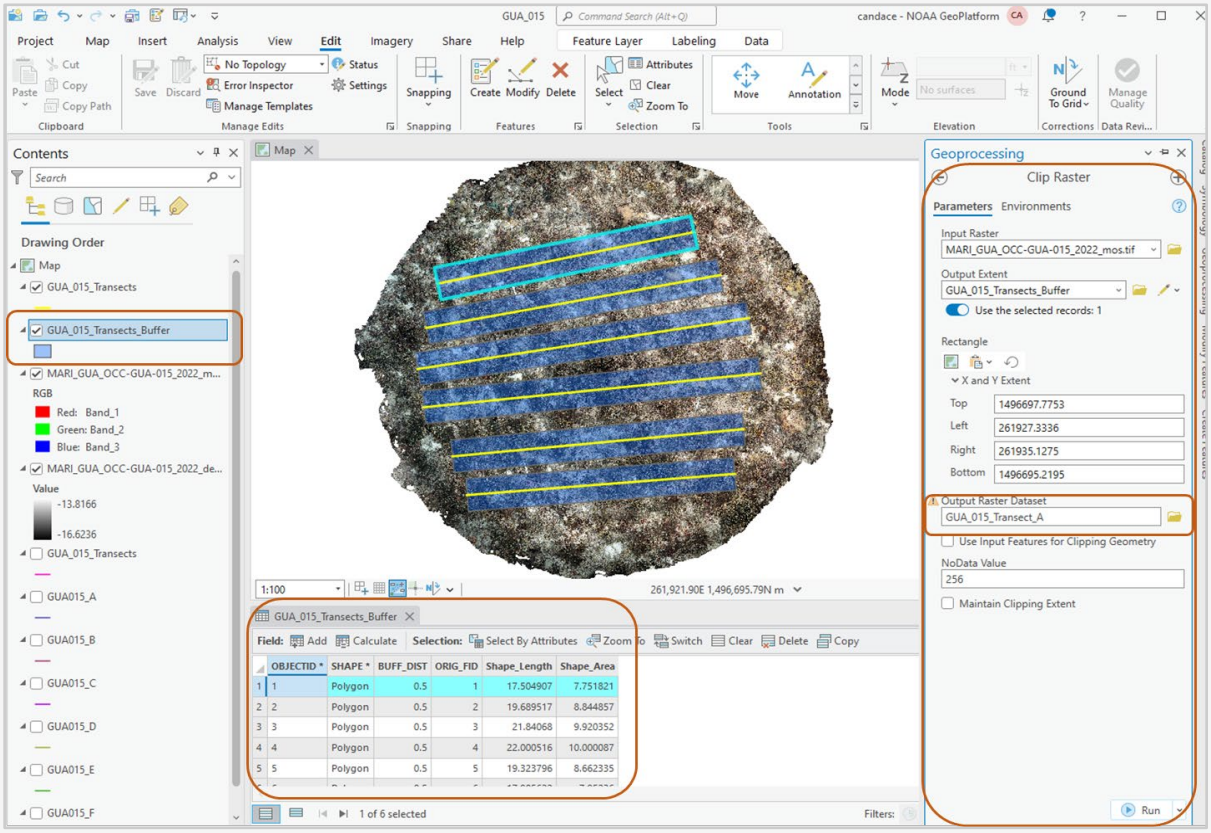

Figure 7. Clipping each individual transect by opening the “Attribute Table” for the “Transect Buffer” shapefile, selecting an individual transect in the “Attribute Table,” and clipping and saving the 1 m wide buffer as an individual raster (e.g., GUA_015_Transect_A).

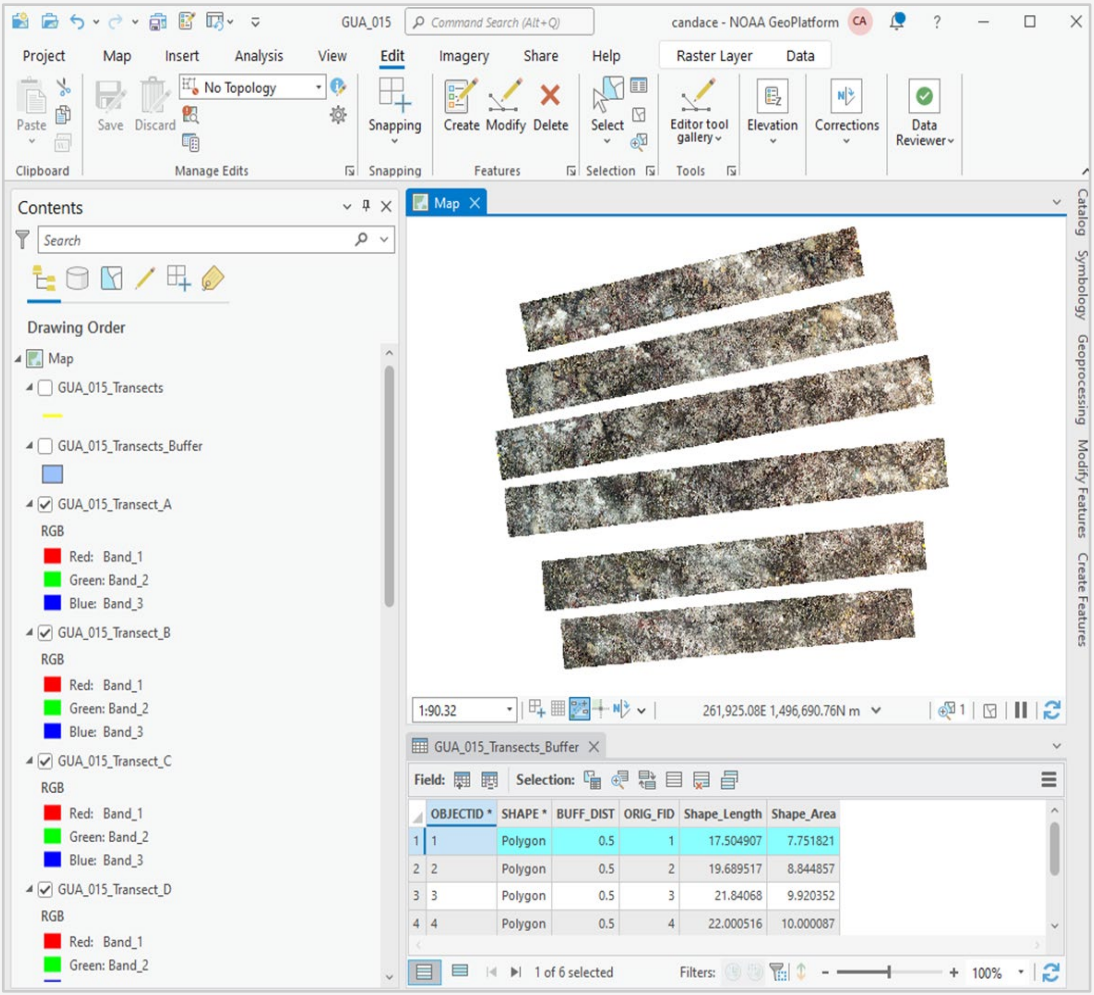

Figure 8. Selecting only the clipped rasters and unselecting all other shapefiles in the Contents pane to check all individual transect rasters (A–F) were clipped correctly.

5. Export Raster as JPG

    a. Right click on an individual transect raster (e.g., GUA_015_Transect_A) in the "Contents" pane, hover over "Data" and select "Export Raster" (Figure 10).

    b. "Export Raster" pane will pop-up. Enter the following:

        Output Raster Dataset: Navigate to desired save location (e.g., N:\Fixed_Sites_Projects\Urchins\2022\OCC-GUA-015\Annotation Imagery\Belts\jpgs) and save as Site_Transect_A (e.g., GUA_015_Transect_A). This location will be where you access all jpg files to be uploaded to VIAME for urchin annotation (Section 2.2.).

Coordinate System: Same as current project (select the orthomosaic and it will set the coordinate system used from the carbonate budgets project)

Geographic Transformations: None

Clipping Geometry: Default

Maintain Clipping Extent: Uncheck

Pixel Type: 8 Bit Unsigned

NoData Value: Blank

Renderer Settings: Uncheck All

Output Format: JPG

Compression Quality: 100

c. Select “Export.”

d. Repeat for each transect in the map.

e. Note: To visually check all 1 m width belt transects were saved correctly as JPG images, navigate to the folder location and click on each jpg image (e.g., GUA_015_Transect_A.jpg) (Figure 11).

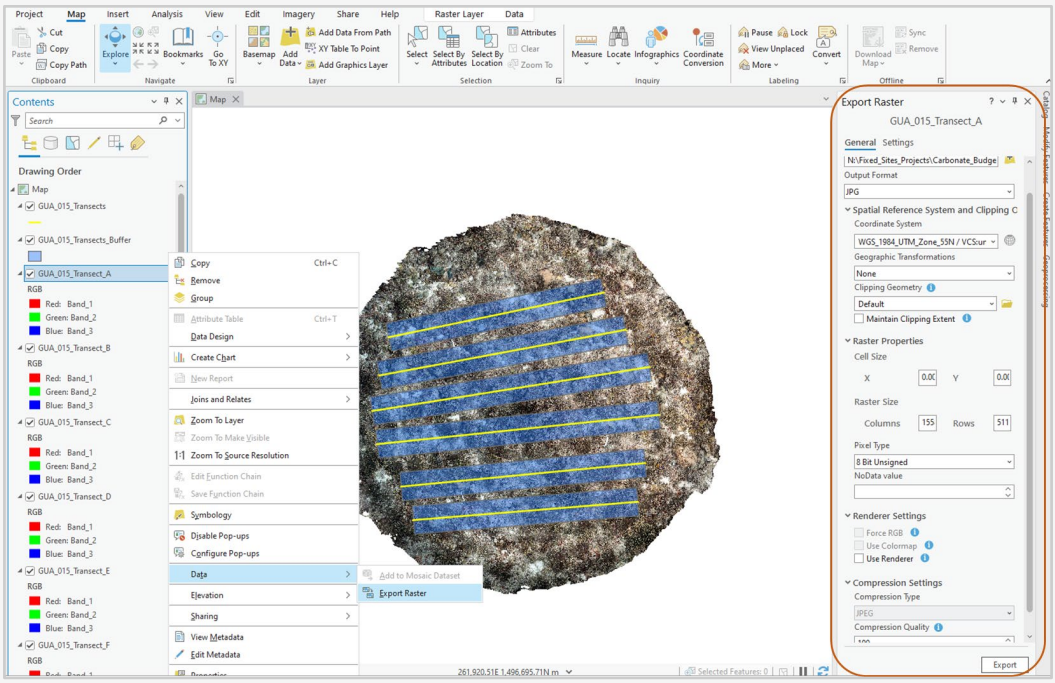

Figure 9. Exporting the individual raster GUA_015_Transect_A (highlighted in blue) as a JPG image.

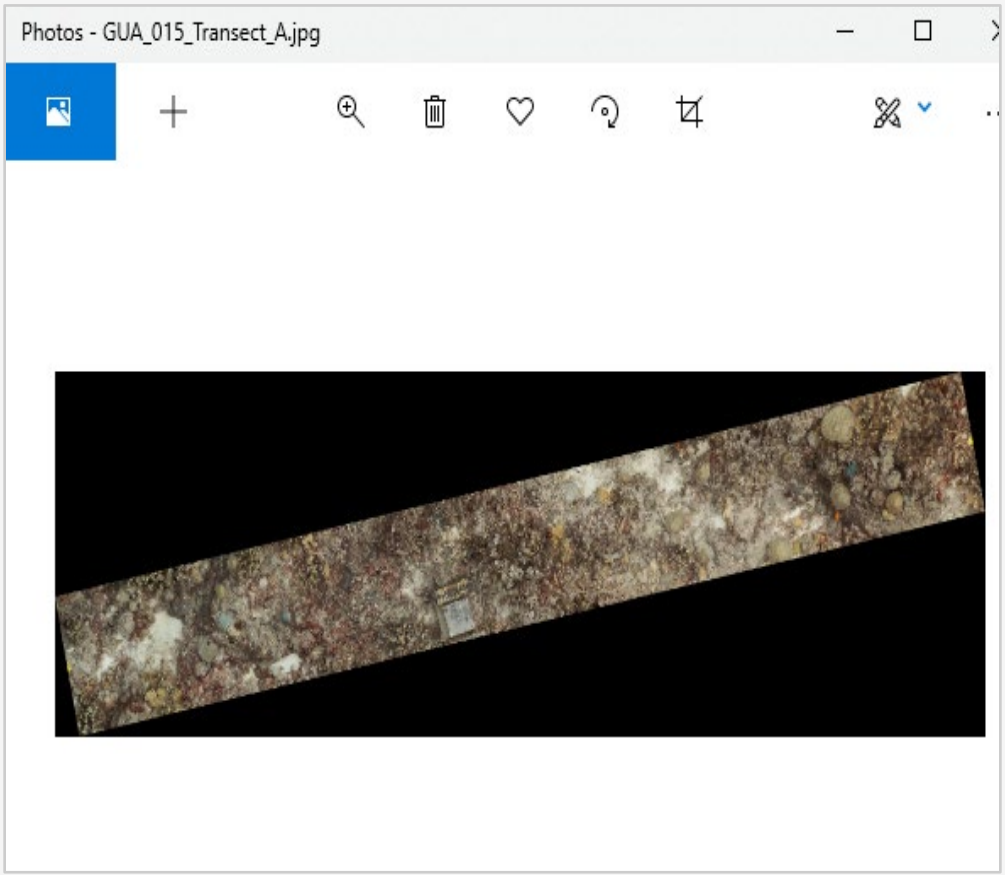

Figure 10. Exported JPG image of belt transect “A” for site OCC-GUA-015.

Section II: Annotating imagery using VIAME

The VIAME annotation tool can be accessed using the DIVE desktop interface or a web-based version. For the purposes of this SOP, we will be using the DIVE desktop interface. For more information and helpful tips go to the "VIAME Annotation Quickstart Guide." While VIAME has a multitude of annotation, object-detection, and classifier capabilities, for the purposes of this SOP, we will only be using manual annotations to identify the genus / species and estimate the abundance and size of urchins in each image.

2.1 Syncing folder locations for access across workstations in DIVE Desktop

The DIVE desktop interface saves each project locally to the workstation it was downloaded on in the DIVE project data storage path. The project data storage path defaults to a subfolder in your local user directory. To access the same project across multiple workstations via a network drive, you can sync folder locations by specifying the project data storage path that is shared across all workstations. It is important to note that the project data storage path and all images and / or videos must be on a shared network drive to maintain accessibility of annotations and imported data across computers / workstations.

1. Open the DIVE application on your desktop and click on the large "Settings" icon on the top of the page (Figure 12).
2. On the right of "Project Data Storage Path," select "Choose" and navigate to the desired location on the shared drive for access to VIAME projects across multiple workstations (e.g., N:\Fixed_Sites_Projects\VIAME_Projects).
3. Select "Save."
4. Select "Sync Recents with Project Data" at the bottom of the page.
5. Repeat this process for all workstations that will be used for VIAME annotation projects.

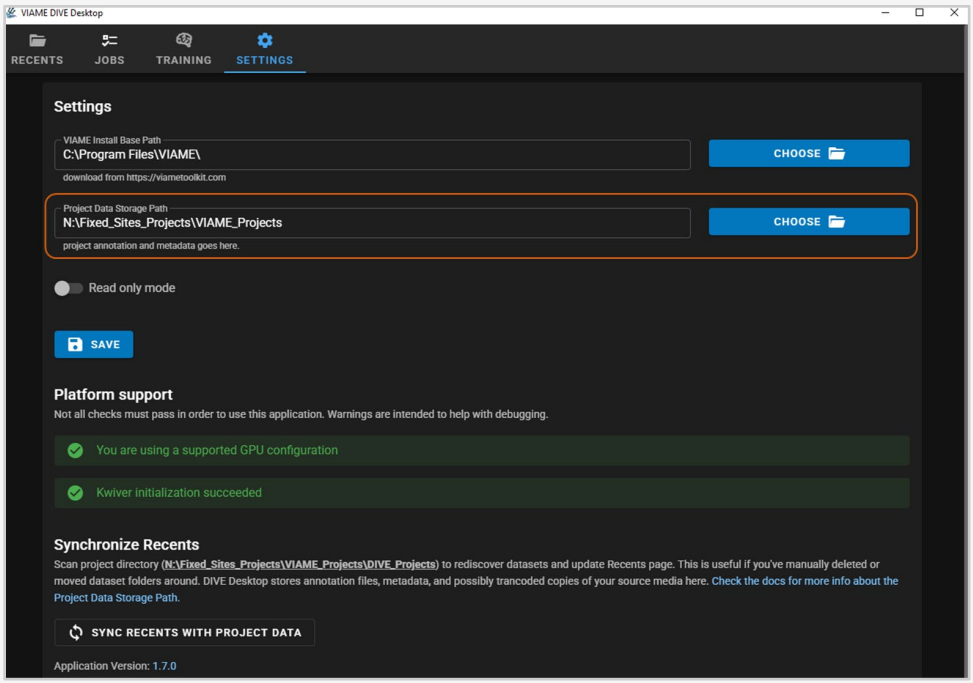

Figure 11. Changing the VIAME DIVE Desktop project data storage path to a desired location on a shared drive for access to VIAME projects across multiple workstations. Note: this will need to be changed to the same project data storage path for each workstation.

2.2 Create an Annotation Project in VIAME

For this SOP, we will be annotating urchins along six 1m-width belt transects in the .jpg format (Refer to Section I on how to create these belt transects in ArcGIS Pro).

1. Uploading imagery (e.g., belt transects) for urchin annotation.

    a. Click on the large “Recents” icon on the top of the page.

    b. Select “Open Image Sequence,” navigate to folder containing images (e.g., N:\Fixed_Sites_Projects\Urchins\2022\OCC-GUA-015\Annotation Imagery\Belts\jpgs), and then “Select Folder” (Figure 13).

    c. An “Import new image sequence” window will pop-up. Enter the following (Figure 13b):

        Name: SiteName_Urchins_YYYY (e.g., OCC-GUA-015_Urchins_2022). It will automatically fill this as the name of the folder selected.

        Annotation FPS: For a set of images (not video) set this as 1 (Video FPS).

d. Select “Finish Import.” Note that the upload may take a moment. The upload progress can be tracked on the “Jobs” tab.

e. All images in the selected folder should now be uploaded and visible. To navigate through all images in the folder, select the forward and backward arrows on the bottom pane.

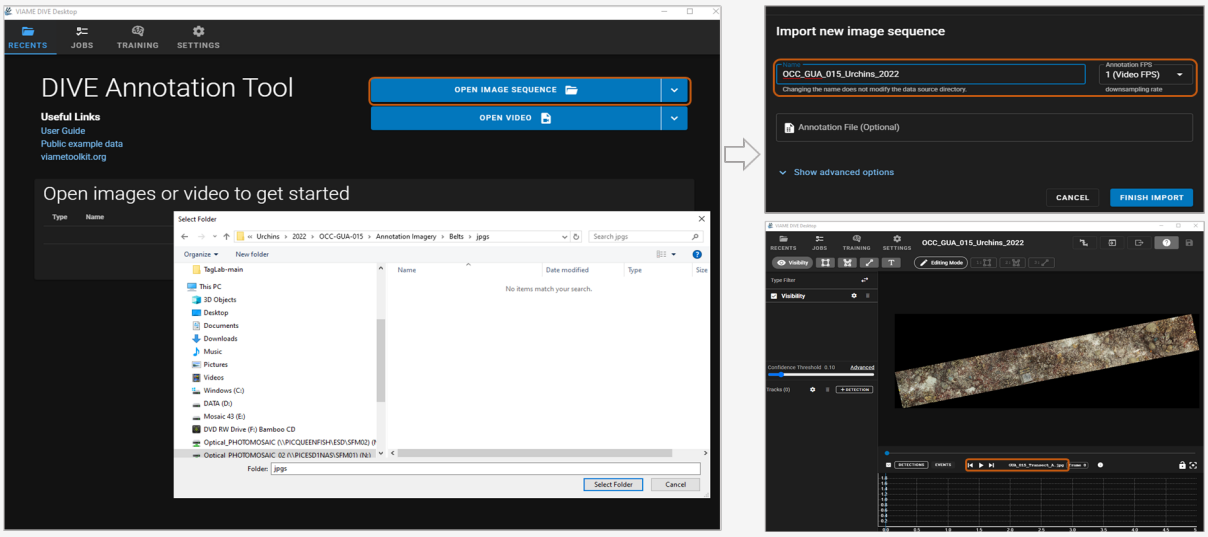

Figure 12. Uploading imagery into VIAME Dive Desktop for annotation by opening the image sequence and selecting the folder with all imagery for the project and / or site, importing all imagery in the folder and renaming project name, and visually checking all images.

2. Creating annotations (detections)

a. To create an annotation, navigate to the “Tracks” pane on the left side of the screen. Click on the small settings icon in the “Tracks” pane. (Note this is not the large settings icon on the top of the screen) (Figure 14).

i. **Note: DIVE desktop does not save edits automatically; therefore, it is good practice to save your project frequently by clicking on the “Save” icon in the top right corner.**

b. A “New Annotation Settings” window will pop-up. Select the following:

Mode: Detection

Type: Desired label for the annotation (e.g., “ECST” for any *Echinostrephus spp.* urchin annotations)

i. Note: It is up to the user’s personal preference whether or not to use “Continuous” mode. This allows the annotator to do continuous

annotations of the same type of annotation without needing to press the detection button for each annotation. This can be helpful when annotating many of the same species in a row (e.g., all “ECST”).

c. To create an annotation (i.e., detection), click on the “+Detection” button.

d. Use the mouse to draw an annotation box around the desired object by clicking on the imagery and dragging the mouse to create a bounding box.

   i. Zoom in / out of the image using the scroll button on your mouse and move the image by clicking your mouse and dragging it.

e. All annotations should appear in the left pane with the correct label of that annotation.

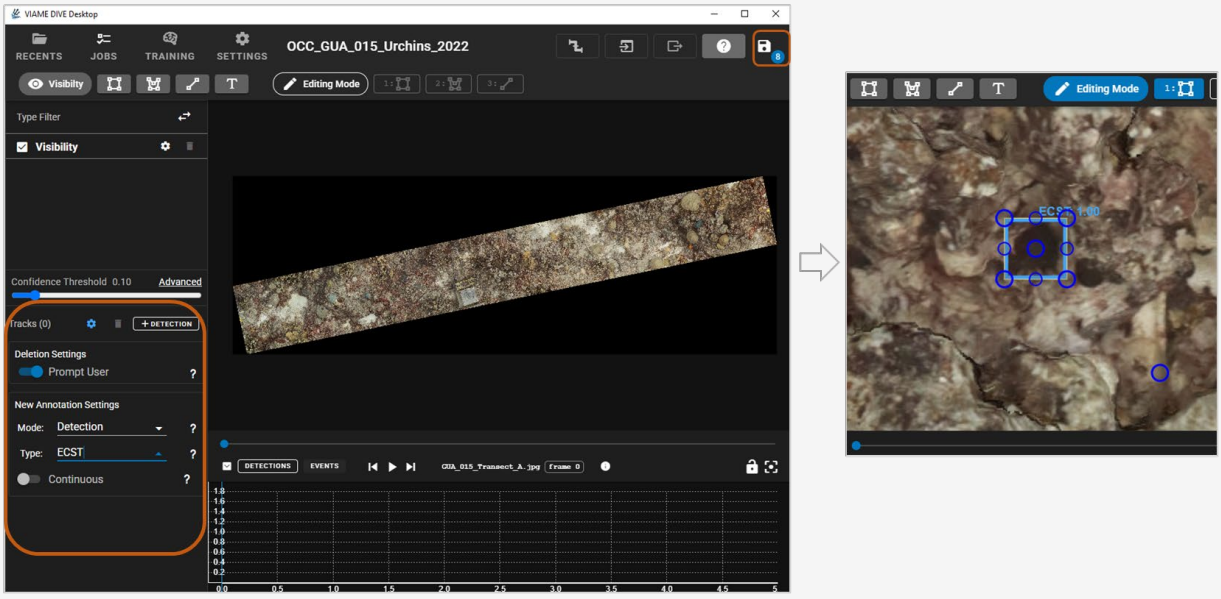

Figure 13. Creating an annotation using the “+Detection” button in the “Tracks” pane and drawing a bounding box around the object (e.g., Echinostrephus spp. [ECST]).

3. Editing the bounding box

   a. Two options:

      i. Hover the mouse over the bounding box and right click. Small circles will appear on the perimeter of the bounding box in blue. You can now use these to adjust the size of the box or move the box (Figure 15).

ii. Click on the annotation you would like to edit. The annotation should be highlighted in blue in the left pane. Select the small pencil icon on the right to edit that annotation.

b. **Note:** It is important to fit the bounding box tightly around the object you are identifying (e.g., urchin). This allows for accurate detection, sizing, and classification of the object and reduces the error of misidentifying objects when training future machine learning models.

   i. For drawing bounding boxes around objects (e.g., urchins) that are only **partially in the field of view,** there are two suggested methods depending on the circumstance of the object.

      1. Part of the object is hidden in the image. For example, burrowing urchins such as ECST with approximately ½ of the body size in the field of view. We suggest drawing a bounding box around the estimated full size of the urchin.

      2. Part of the object is cut off by the image. For example, only ½ of the urchin is captured on the edge of the image. We suggest drawing a bounding box around the ½ of the urchin in the image.

c. To completely remove the annotation, select the pencil icon and a small red trash can icon will appear and this will delete your annotation.

d. After you are done editing the bounding box, use your mouse to click anywhere on the image and the editing box will disappear, only displaying your final annotation bounding box with the correct label.

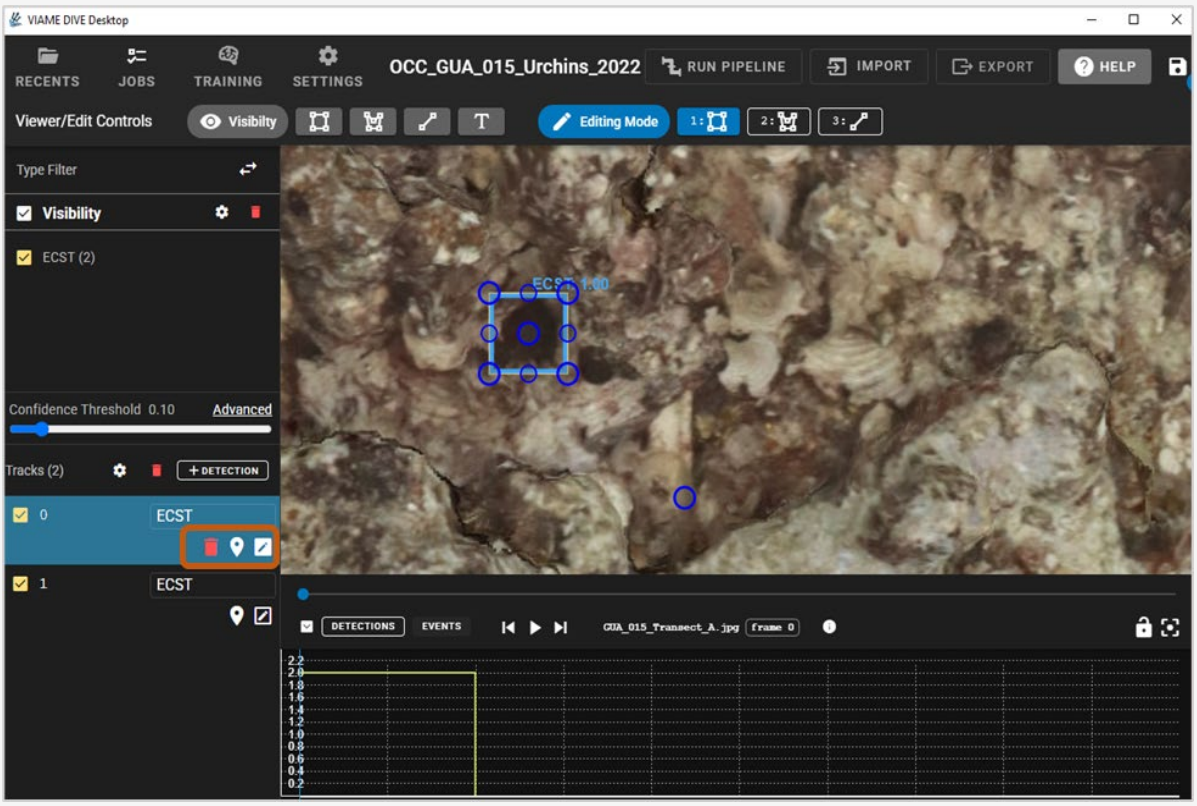

Figure 14. Editing the bounding box for each annotation (detection).

4. Create a new / different annotation label (e.g., ECTH for *Echinothrix spp.*)

    a. Select the small settings icon in the bottom left pane.

    b. Change Type from “unknown” to your new label (e.g., ECTH) (Figure 16).

    c. Select the “+Detection” button and use the mouse to draw another annotation box around the desired object. The new label should appear next to the box and in the left pane.

    d. Note: If you draw a bounding box and the label appears as “unknown,” hover over the label in the left pane and a white arrow with a dropdown menu should appear with all labels previously selected. Another option is to click on the “unknown” label in the left pane, it will appear blank, and fill in with desired label (e.g., “ECTH”).

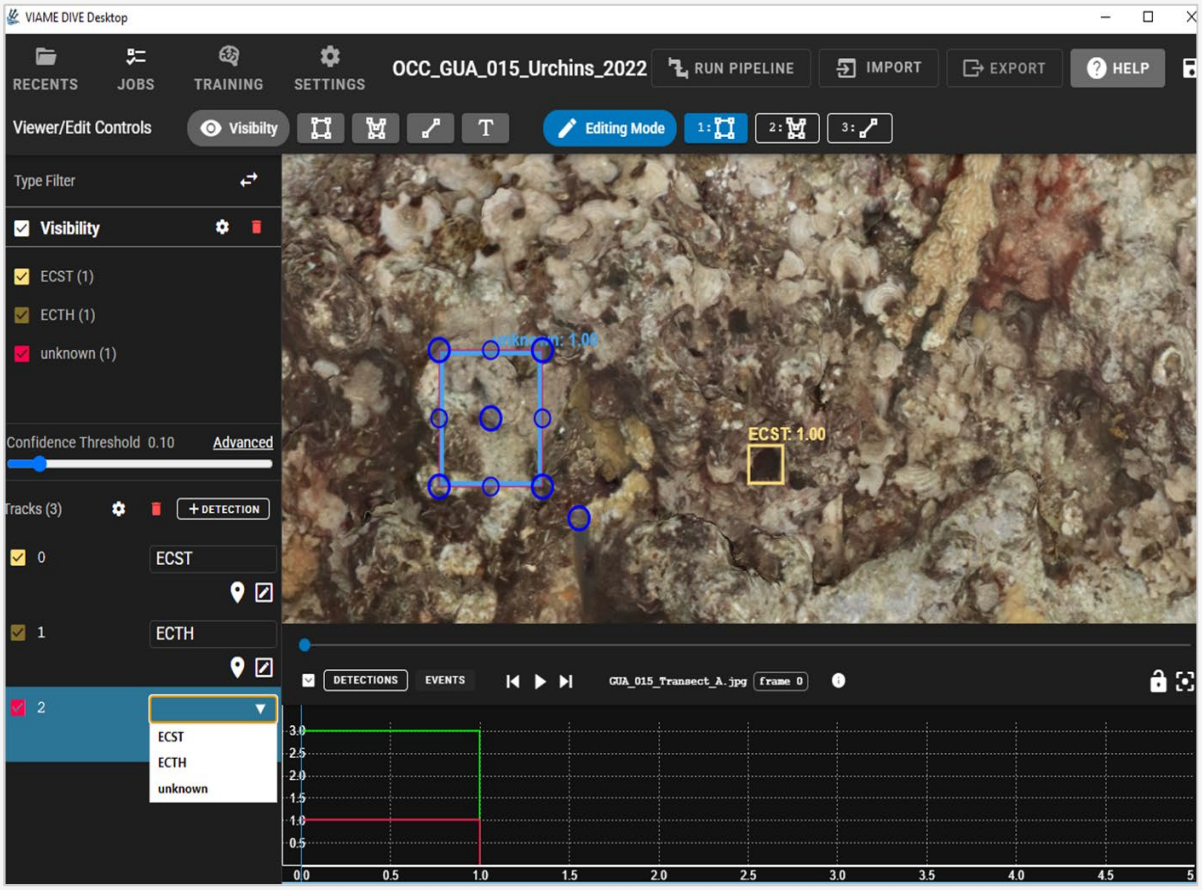

Figure 15. Creating a new / different annotation label (e.g., Echinothrix spp. [ECTH]).

5. When finished with annotations, you will see all labels with the number of annotations for that label in parentheses in the top left pane (Figure 17). Make sure to visually check all annotation bounding boxes and labels are correct on each image.

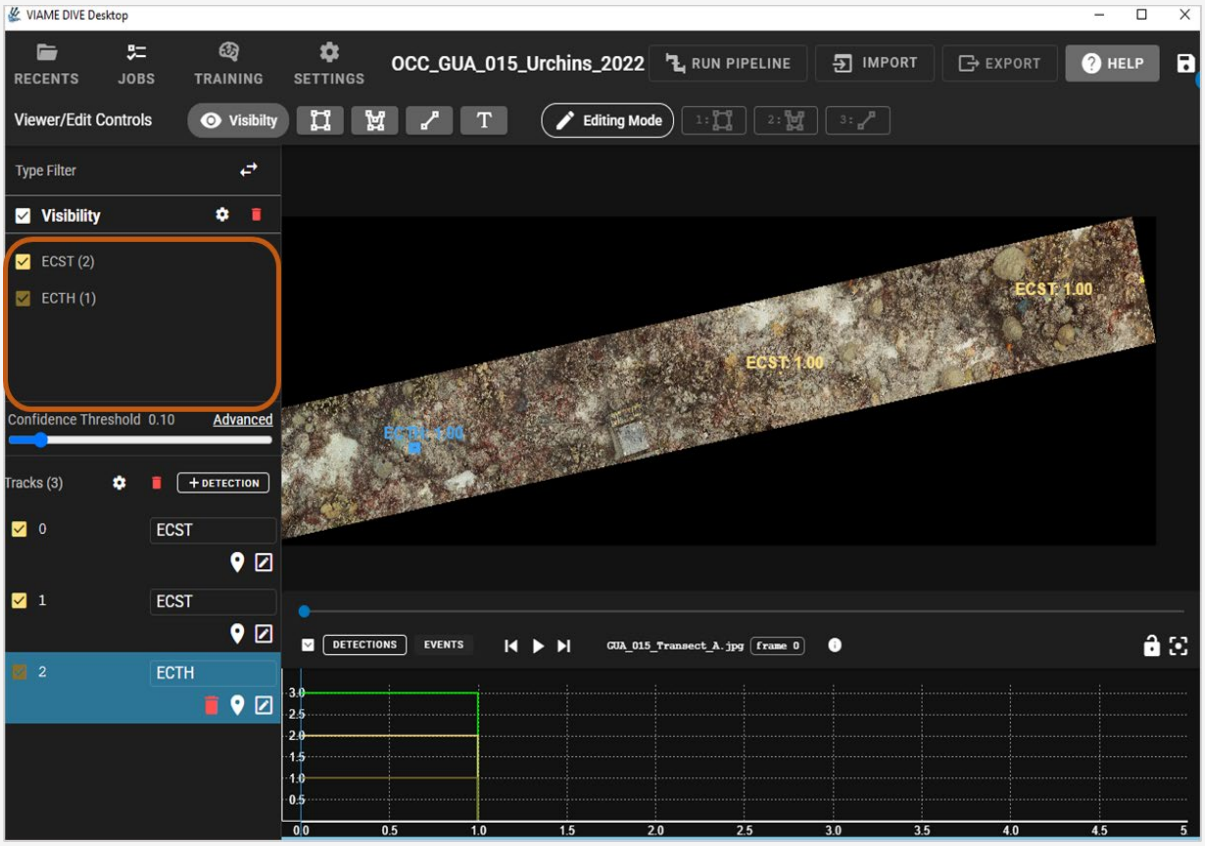

Figure 16. Visually checking all annotation labels and number of annotations for each image in the project.

2.3 Export annotation results in table as .csv

1. To export annotation results for all images in the project as a single csv file, select "Export" in the top right corner of the window (Figure 18).
2. A pop-up window will appear with Export options.
    a. **Exclude tracks below confidence threshold:** check
    b. **Export checked types only:** uncheck
    c. Click on "Export Detections," navigate to the folder you would like to save the csv results table, and rename as desired project name (e.g., N:\Fixed_Sites_Projects\Urchins\2022\OCC-GUA-015\VIAME\OCC_GUA_015_Urchins_2022.csv).
        i. Note: We would recommend keeping the csv results in a folder within the shared network drive (e.g., N:\\PICESD1NAS\SFM01) to access these across multiple workstations.

d. Select “Save” and double-check the .csv was saved in the correct folder.

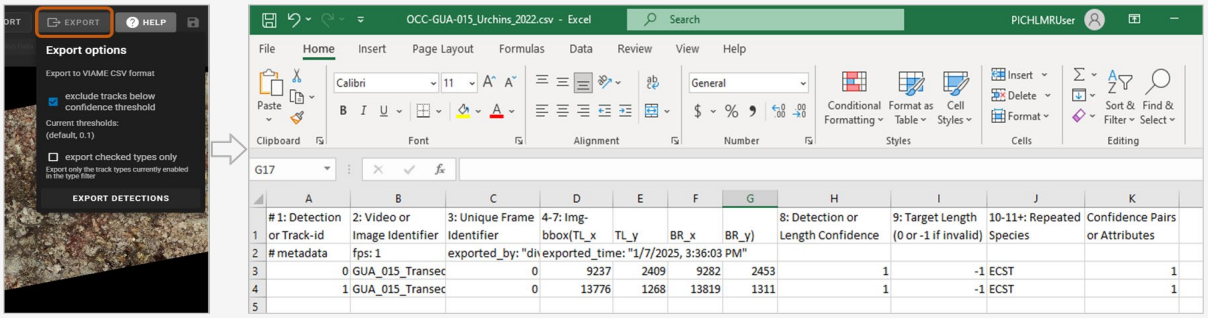

Figure 17. Exporting annotation results for all images in the project file and saving as a .csv.

2.4 Importing existing annotations into DIVE desktop (optional)

If you are working on one specific workstation the entire time, save your project each time before exiting the project. This is to ensure that when reopening your project (on the same workstation), all data and progress should be where you left off. However, if you are working on a new workstation and do *not* have a shared network drive across workstations (i.e., cannot sync the project data path storage), you can re-upload the imagery and import existing annotations .csv results table, and all previous annotations should populate the imagery.

Note: Make sure to export and save the .csv results table each time you make progress on the project (i.e., new annotations) and are going to exit the project. This will allow you to re-import the most recent annotations and start on the project where you left off last.

1. On a new workstation, open DIVE Desktop and upload imagery and create a project (refer to Section 2.2.1).
2. To import your previous annotations on the imagery, select “Import” in the top right corner of the window.
3. Navigate to the folder with the most recent results table and select the .csv.
4. All previous annotations should populate the imagery.

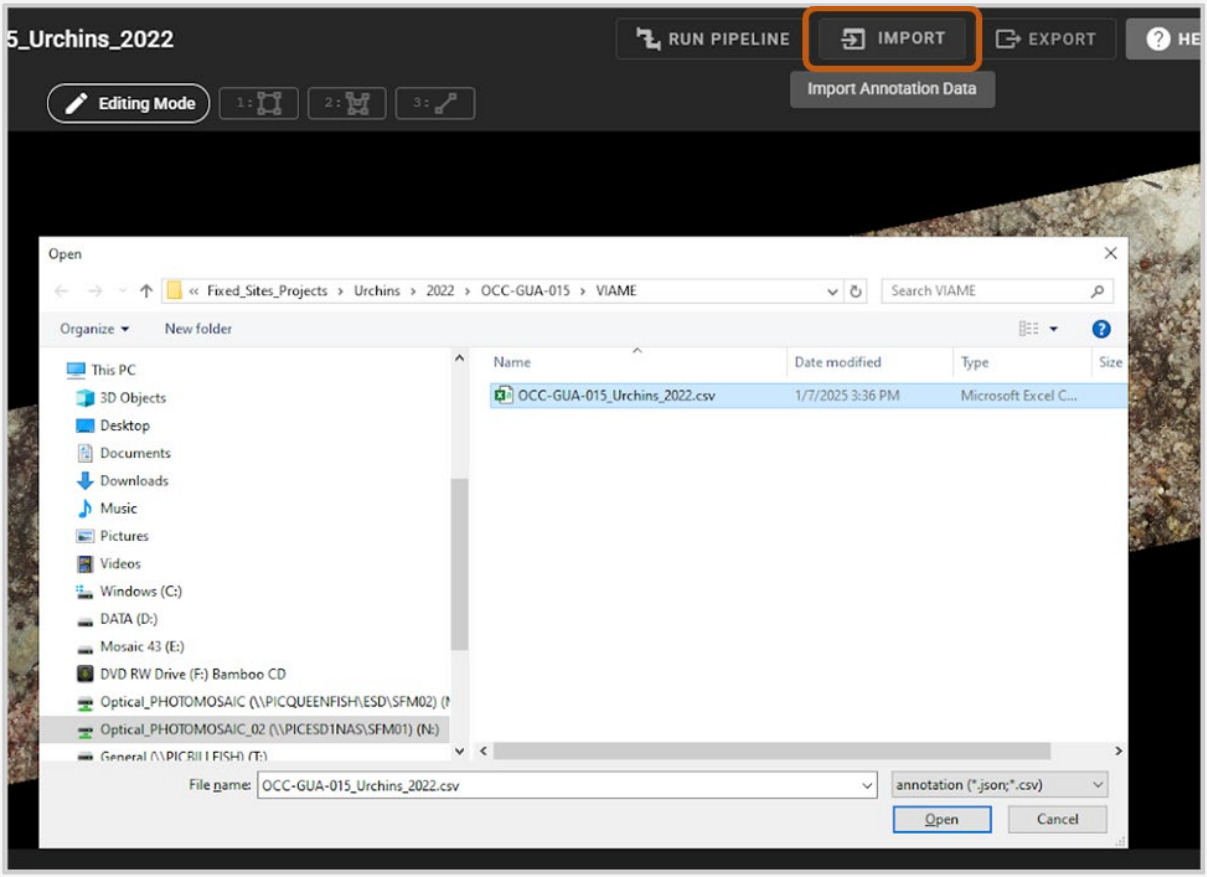

Figure 18. Importing VIAME .csv results table into DIVE desktop to populate imagery with all previous annotations saved for that project.

Section III: Referencing underlying imagery in Viscore to detect cryptic urchins (optional)

Viscore is a software that enables the user to look at underlying raw imagery used to create a 3D orthomosaic of the reef. For more information on how NOAA-NCRMP uses Viscore software, please see Section 5.2 in Torres-Pulliza et al., 2024.

For the purposes of this SOP, this step is **optional** and briefly describes the steps used to reference underlying raw images from dense point cloud models to confirm the presence and identification of cryptic urchins on the reef. While the 1 m width belt transects clipped as JPGs using ArcGIS Pro provide a good starting point to identify urchins in VIAME, the resolution of the image may not be high enough or objects may obscure urchins in the 2D orthomosaic. Therefore, it's best practice to utilize Viscore to look at any raw images (highest resolution) that contain what is suspected to be an urchin, in order to more confidently confirm its presence and identification.

Note, that if your program does not have access to Viscore, a similar image view approach can be conducted in Agisoft Metashape (see Section 5.3 in Torres-Pulliza et al., 2024).

3.1 Opening a fixed-site 3D orthomosaic in Viscore

1. Select the Viscore imagery (.vml file) for your site and double click to open. Find it in the following folder structure (e.g., N:\Fixed_Sites\MARI\GUA\OCC-GUA-015\2022\20220612_OCC-GUA-015_RA2201\Products\2022_0CC-GUA-015.vml).
2. Hover over the right side of the viewer and turn "cams" on.
3. Click on "none" on the left side of the viewer and the site name should appear (e.g., OCC-GUA-015).

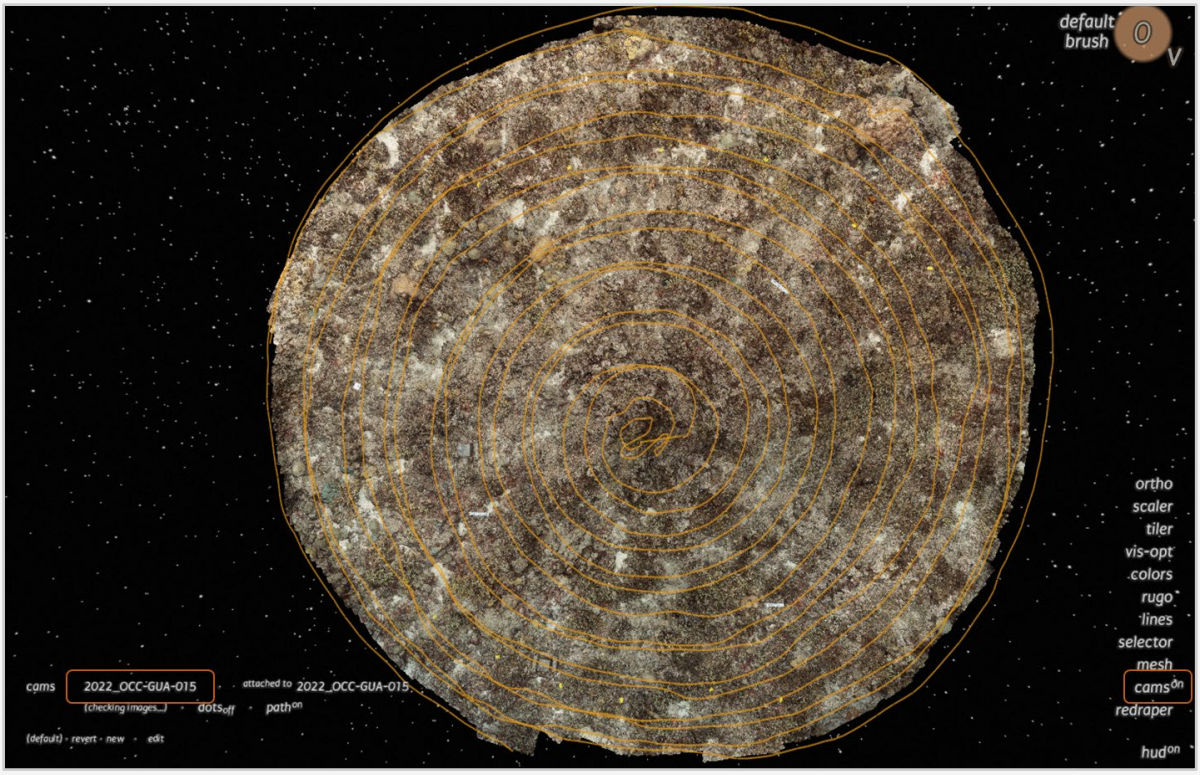

Figure 19. Opening up a fixed-site 3D orthomosaic (e.g., 2022_OCC-GUA-014) in Viscore and turning the cams tool on for the site.

3.2 Using underlying raw imagery in Viscore to confirm object detection

1. Zoom in and make a point on the orthomosaic where you would like to view the underlying imagery by holding down Alt+middle click. This will create a point "A" (Figure 20).

2. Then open up a browser and click on the "iview" tab in the bookmarks bar. This should open up all underlying imagery containing the point "A."

3. Scroll through all the images by clicking on the arrows in the bottom right corner next to the image name (e.g., IMG_2526) or right click + scroll anywhere on the image.

4. When moving on to the next object detection, deselect point "A" by clicking on "A" in the point cloud, then create a new point labeled as "B" in your new location of interest.

    a. Note: You can also move point "A" by double-clicking anywhere on the raw image in the iview browser, and all imagery will shift to where the point is now located.

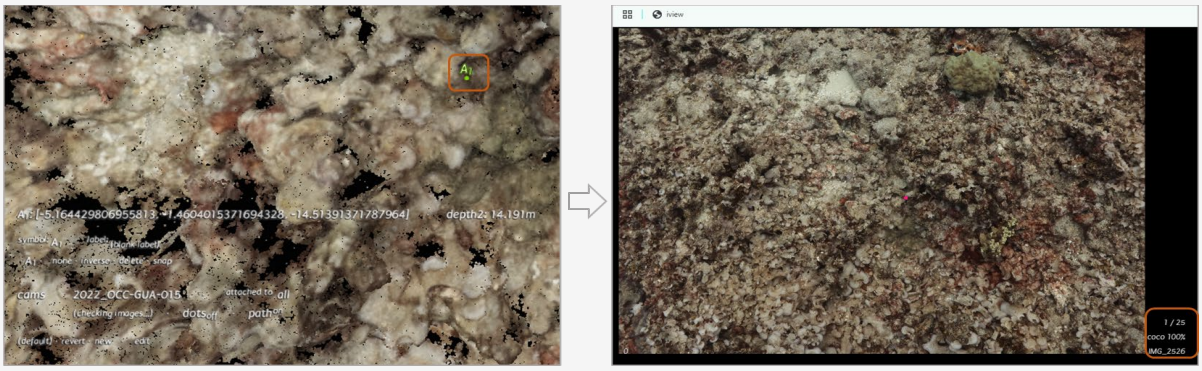

Figure 20. View the underlying raw imagery to confirm the presence and identify the object by creating a point on the dense point cloud in Viscore, and opening up iview in a browser to access all the raw images containing that point.

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