

UC San Diego

Capstone Projects

Title

Using Technology to Improve Conservation: Virtual Environments for Testing Actionable Metrics of Scientific Methodology for Measuring Coral Recruits in the Field

Permalink

<https://escholarship.org/uc/item/6hp3946d>

Author

Giuseffi, Louise

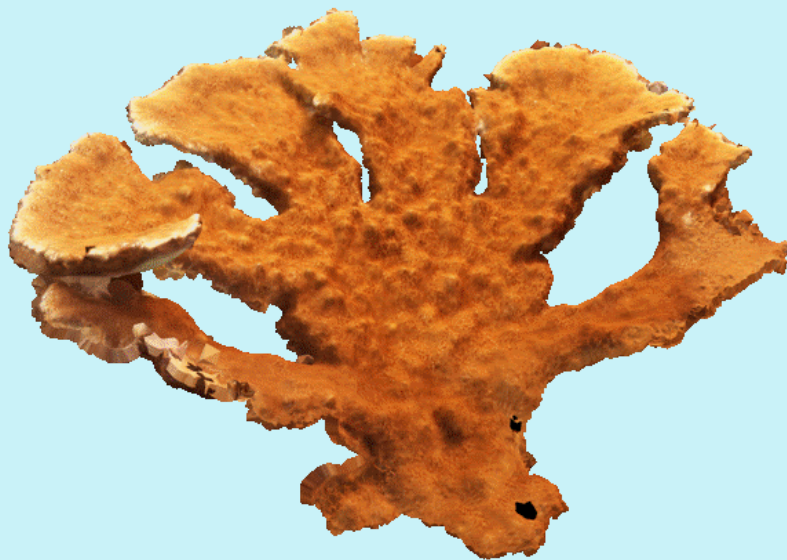
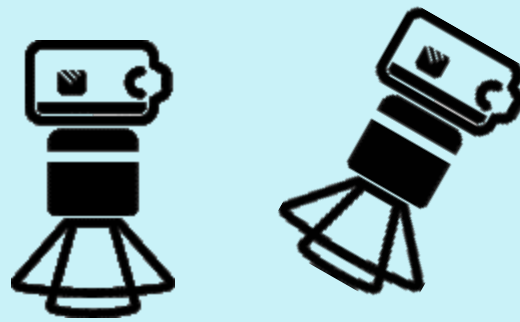
Publication Date

2020-06-01

Using Technology to Improve Conservation:

Virtual environments for testing actionable metrics of scientific methodology for measuring coral recruits in the field

By Louise Giuseffi



Abstract:

As scientists, we have embraced underwater survey and design methods, often with limited time and resources to fully test each step of the work flow to understand which method provides the most robust metrics we are after. In a timely experiment, given this pandemic era of limited field research, I investigated the use of virtual corals and animation of photographic patterns to simulate real life survey methods. These methods use thousands of photographs collected in the field to reconstruct 3D corals reefs, from which we collect 2D metrics of coral growth. Being that this 3D technology is being used to collect 2D metrics, I wanted to investigate if the 3 types of current methodology used for large scale rapid assessments are appropriate for collecting 3D metrics of individual coral colonies. Furthermore, I investigated if changes in the camera angle and photo percent overlap enhanced the collection of data points for reconstructing the reef scene, and tested the accuracy (percent error) for objects reconstructed in the scene for each method. This could serve as an informative metric in the case of experimentation, giving valuation to a damaged reef, and in coral restoration design.



Louise Giuseffi, photo credit: NOAA

Keywords:

Coral, restoration, simulation, 3D, technology, structure from motion, reconstruction, animation

Introduction:

The following manual (Standard Operating Procedures) is a living document and a detailed description of my journey learning and navigating the world of animation to mimic what scientists do in the field. I encountered many technical difficulties along the way; these are not included in the manual, but there may be a short comment occasionally cautioning the user to do or not to do something that will result in an undesired effect. This document will serve as an appendix and will inform the Methods section of a future publication.

I recommend using pre-built 3D coral models, as these will reconstruct the best as a mesh in order to measure volume. The animation freeware I used is Blender 2.82. With this software, I set the stage: the seafloor and corals, the ambient lighting, adjusted the camera settings. The camera settings were matched as closely as possible to PhD. Stuart Sandin's 100 Island Challenge Standard Operating Procedures for field operations. I then built a track to mimic the 3 options of pathways a diver could swim to collect these data: mowing the lawn, the grid and the spiral. Percent overlap between frames was calculated and the number of frames per track were set up to reflect the 90% overlap suggested in the 100 Island Challenge Standard Operating Procedures. The photos were taken and stored outside of Blender. These photos were then imported into Agisoft to recreate the scene and test which methods were most sound.

While the data points generated from the scene reconstruction inform the user which methods obtain the most data, the second goal of comparing object surface area and volume error is in its last stages yet still under construction. This entails importing the recreated scene as a mesh back into Blender to remeasure the geometry of each coral/object. This is crucial to obtaining each object's surface area and volume separately for the comparison, and this work will be published at a later date.

This is a basic model that can expand to incorporate more characteristics, such as lens distortion and turbidity. There are obvious biases, as field work is not perfect and the simulations cannot capture everything that occurs in nature. Biases include: reduction of percent overlap for objects closer in the frame, the inability to adjust some camera settings due to lack of settings in Blender 2.82, and the lack of a realistic environment. This is why I hope to follow up this study with a field comparison of 3D printed corals with known surface area and volume.

I would like to see the trajectory of this work used in the research and development phase of new protocols prior to getting into the field. A field day is a tremendous amount of work to prepare and execute. While I will not discount the tremendous value in comparing methods in

the field, this animation can serve scientists as an initial tool to help suss out small particulars early on.

Standard Operating Procedure

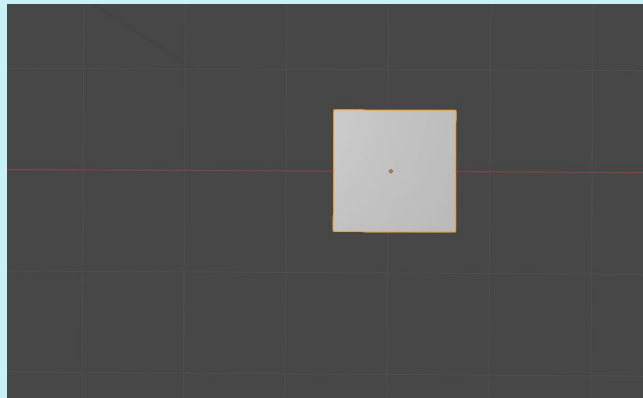
Outline:

- 1) Setting the Stage in Blender 2.82 pg. 4
 - a) Building and importing objects/corals pg. 4
 - b) Lighting: setting up the sunlight pg. 12
 - c) Setting up the field camera pg. 14
 - d) Creating flight paths track pg. 20
 - i) Building Method 1 & 2 pg. 20
 - ii) Building Method 3 (the Spiral) pg. 22
 - iii) Connecting flight path track to the camera pg. 29
 - e) Animating the Camera along the flight path pg. 32
 - f) Building Method 1&2 track by hand if track is non-functional pg. 35
 - g) Render Animation and export photos as jpegs pg. 38
- 2) Reconstructing the objects in Agisoft: pg. 38
 - a) Align photos, generate Dense Point Cloud and Mesh pg. 39
- 3) Import .obj back into Blender pg. 42
 - a) Scale and orient mesh using cube pg. 43
 - b) Remove non-attached data points pg. 45
 - c) Remove base plane and separate objects [Under Construction] pg. 46
 - d) Calculate Surface Area and Volume [Under Construction] pg. 47
- 4) Export .obj of each coral/object into MeshLab to check calculations pg. 47

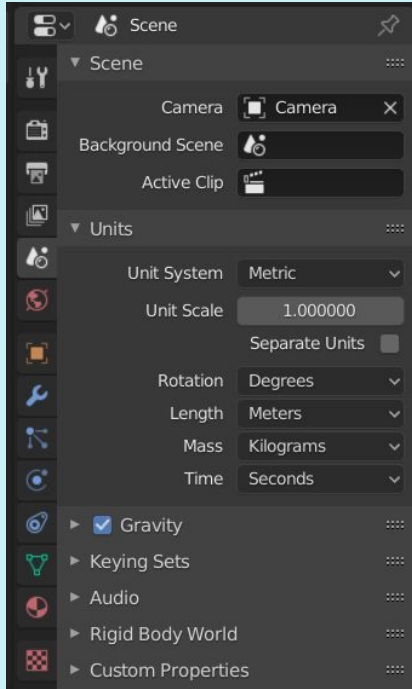
Setting the Stage: Object, Camera, Light, and flight path settings in Blender:

Building and importing objects for scale and corals:

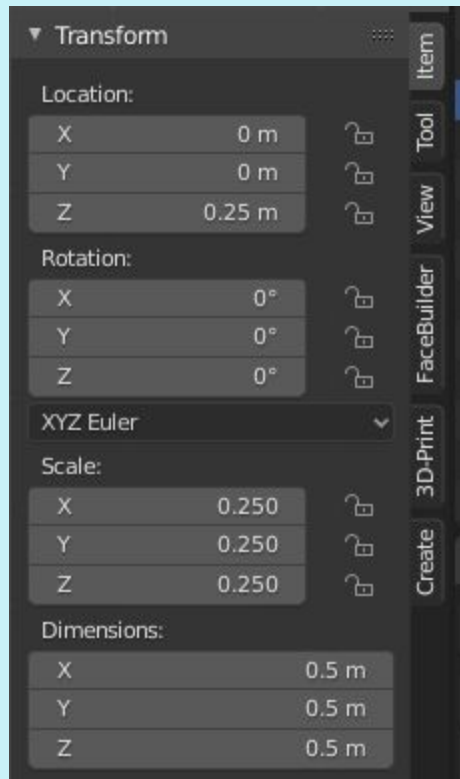
The default grid in Blender 2.82 is a one by one unit of measurement.

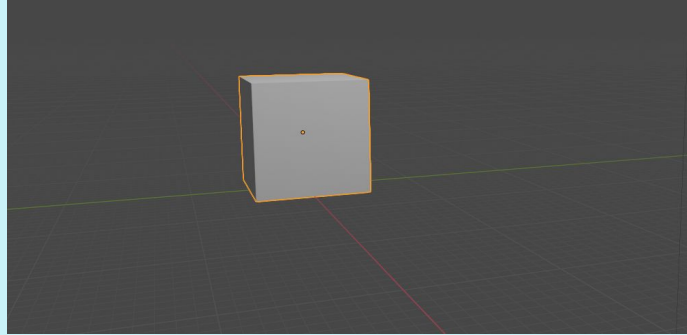


To set this to meters, go to Scene Properties, under Units set: Unit System to Metric, Scale to 1.0, Length to Meters, Rotation to Degrees (if this is not already the default). To create more fine-tuned measurements in order to identify percent-camera-overlap, set the grid to decimeters by going under Overlays, under Guides set scale to 0.1 to break the grid up by 10's.

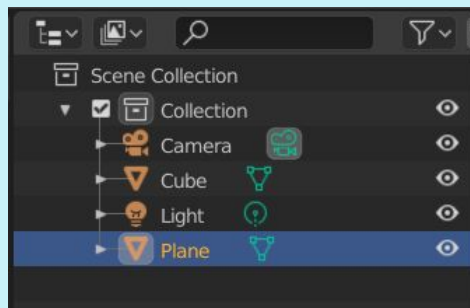


The default cube is set to 2m x 2m x 2m. To rescale to 0.5x0.5m, go into Object mode, select cube so it is highlighted, go to Object Properties, set Scale X = .25, Y = .25 and Z = .25, and set Location of Z to .25. Alternatively, this can be adjusted on the Item tab in Object mode.

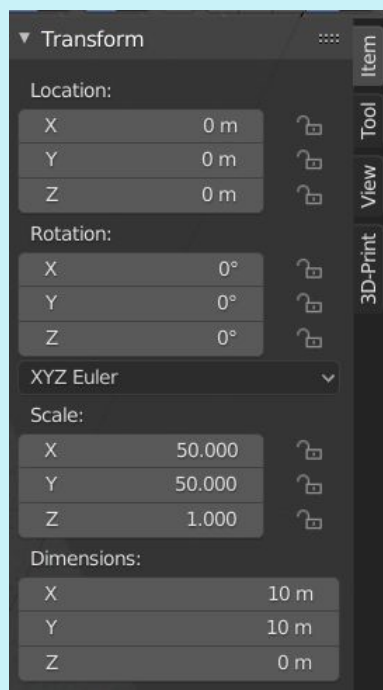




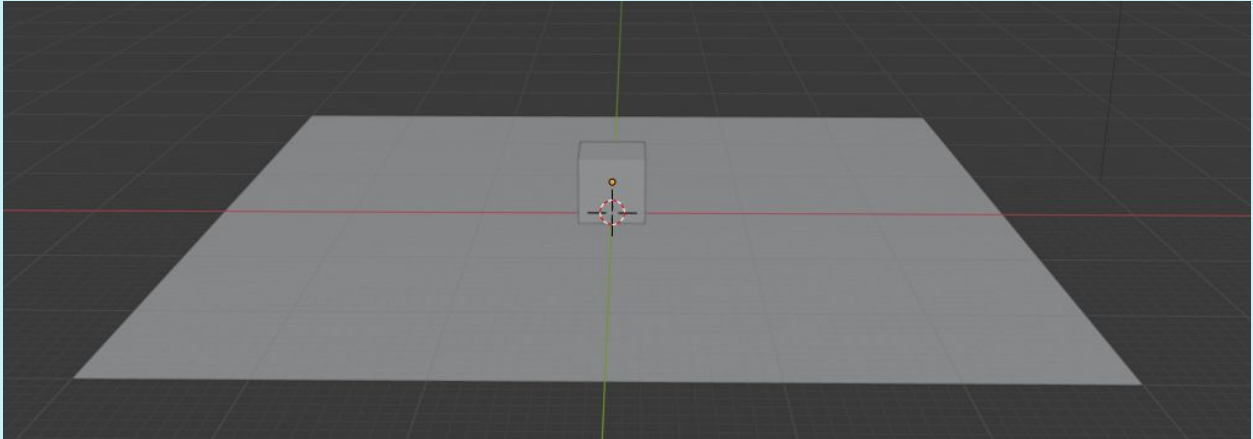
Taking pictures of an object with no ground will not configure correctly when exported to Agisoft, therefore add a plane to serve as the ground, giving the object context. With the cube selected, hit Shift + A, and choose Mesh, then Plane. A plane will appear in the Scene Collection menu on the top right, but you won't see the physical plane because it is hidden under the cube.



Under Item, Transform, go to dimensions and change both X and Y to 10m

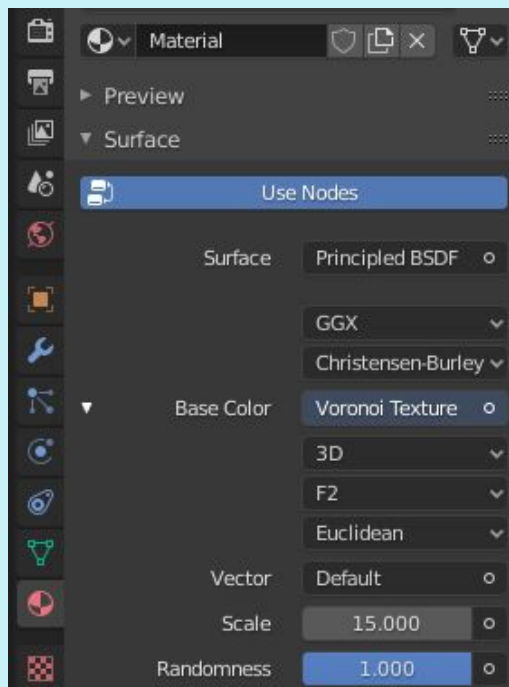


The scene will now look like this:



Hit 7 to go into top orthographic mode, so when you change coordinates, the cube will move to where it's expected to go. Select the cube. Under Item, Transform, change the cube coordinates to X = 0.75 and Y = -0.75, so the corner of the cube rests right at the -1, 1 meter mark. The cube will serve as a frame of reference with a known surface area, but not close enough to the coral samples to cast a shadow on them. Each side is 50x50cm, or 2,500cm square. The bottom will not be calculated/included in surface area, thus the 5 faces of the cube amount to 12,500cm square.

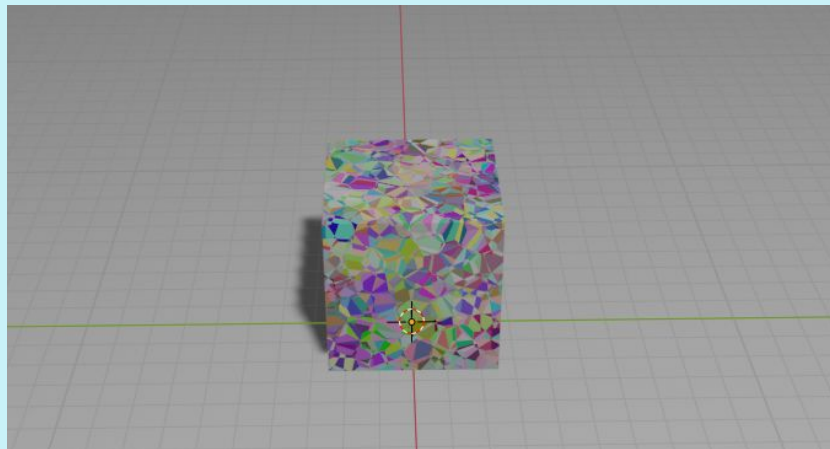
The cube and the plane need a random, non-repetitive texture for the photos to be best reconstructed in Agisoft, and to best represent the random, non-repetitive design of nature. In Object mode, select the cube. In Material Properties, select the circle to the right of the base color to bring up a list. Under texture, select Voronoi Texture. 2 boxes below that setting, change F1 to F2. Change Scale from 5.0 to 15.0.



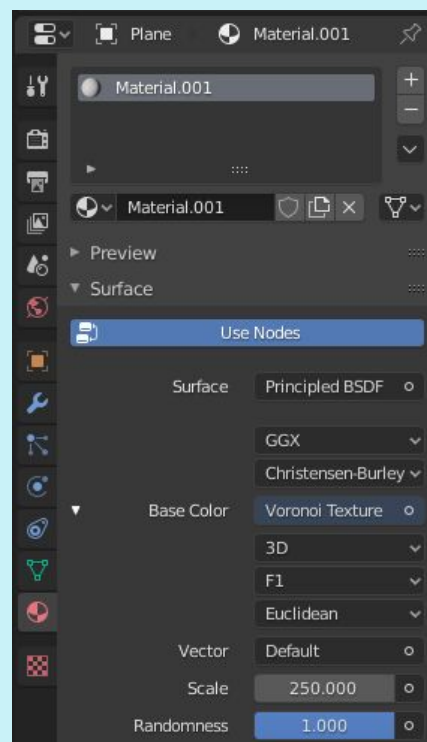
If no color is detected on the cube, the setting likely needs to be changed to Rendered Viewport Shading in the top right.

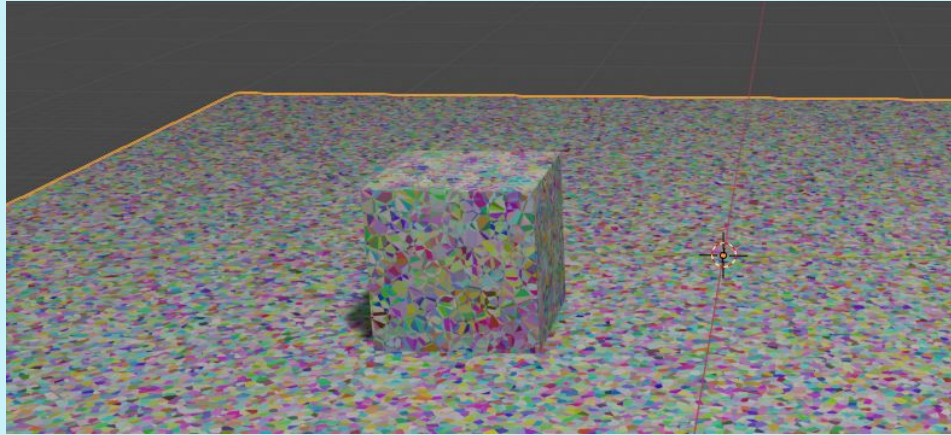


The cube will appear similar to this:

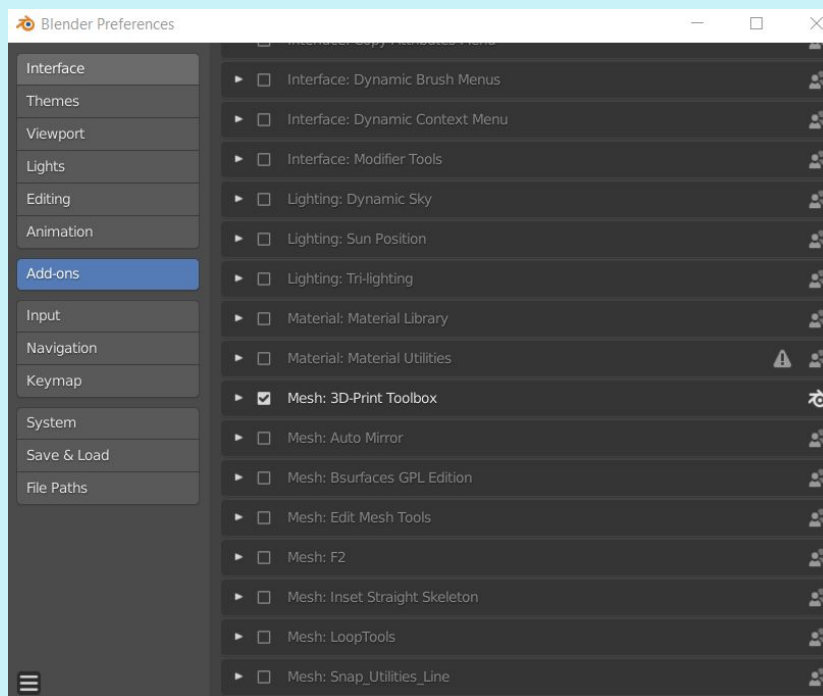


Select the plane. In Material Properties, select New. Pull up the list of options by clicking on the circle to the right of the Base Color. Select Voronoi texture. Make sure F1 is selected, 2 boxes below the Base Color. Change scale from 5 to 250.





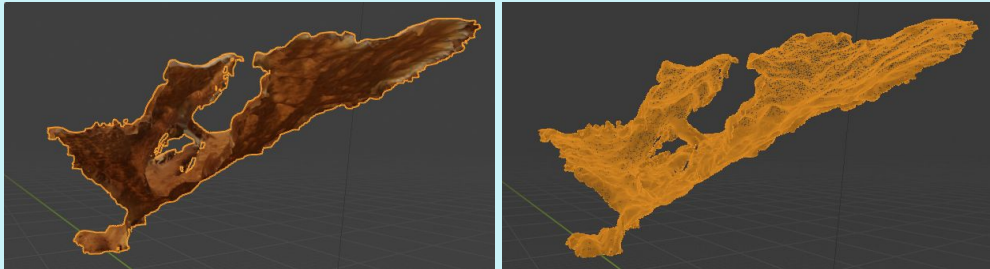
To measure Surface Area and Volume of an object, the 3D Toolkit in Blender 2.82 must be enabled. To do this, go to Edit, Preferences, and under Add-ons, select 'Mesh: 3D-Print Toolbox', go back to top and select Install.



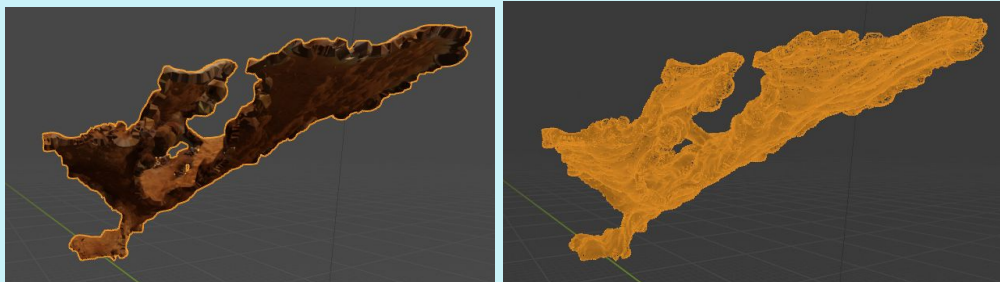
With the cube selected, go to 3D-Print tab and choose volume; volume should be 125,000cm³.

Because the Elkhorn sample was reconstructed and clipped from a point cloud and then a mesh from a Method2 90 degree fly-through, it didn't have great coverage of the underside, leaving the coral paper thin. This is undesirable, because it will not produce a volume if it is one pixel thick. To give this model thickness, I added a modifier. Modifier Properties, add Modifier, Solidify, adjust thickness from 0.01 to 0.1 to get more of an Elkhorn shape, giving it volume to calculate.

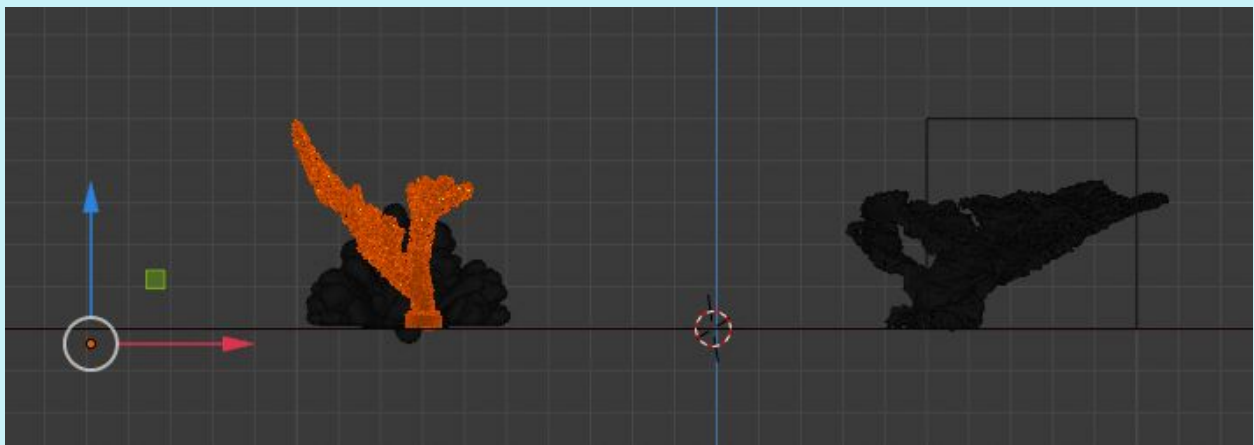
Before:



After:



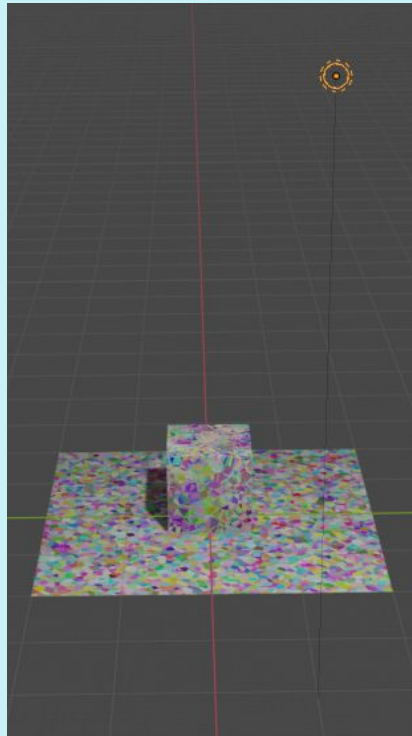
Each coral was adjusted separately and saved as an .obj to be brought into the final scene afterwards. It can also be scaled, sized and rotated in the final scene. Selecting 'Wiring' viewport shading will show just the frames of the object without color, pattern, or texture. Number pad 1 is helpful to see the object from a front orthographic view, facilitating orientation of the model to the floor.



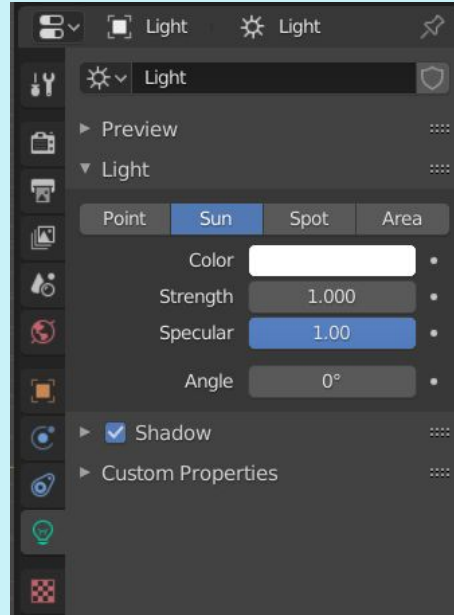
After scaling and sizing are complete, measure surface area and volume of each object and record. These objects should not be altered again for the remainder of the experiment.

Lighting: setting up the sunlight

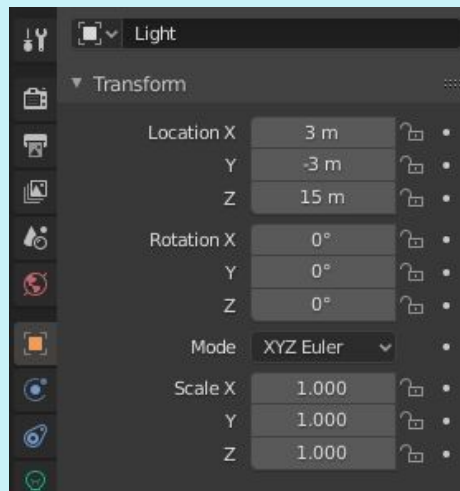
Notice the shadow behind the box. In previous trials, the default 'point' light makes dark shadows that do not reconstruct well in the Agisoft model, leaving large gaps of data points. This can be minimized by mimicking settings closer to what kind of light the sun would provide.



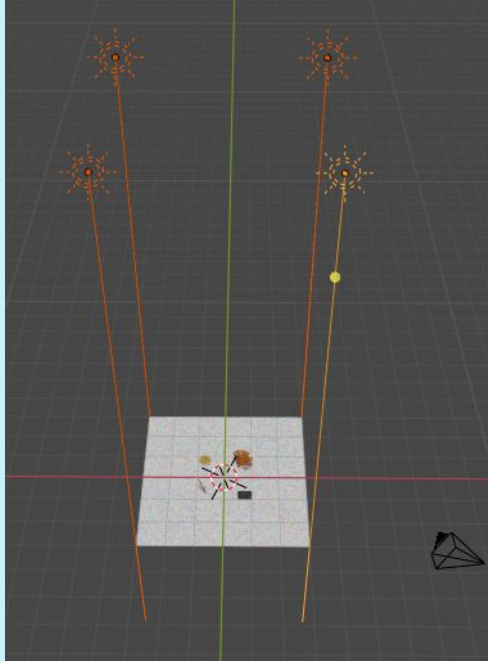
Under Object Data Properties, select Sun, change strength from 1000 to 1, set angle to 0.



Because the sun is very far away and provides a wide distribution of light, double the height of the light by going to Object Properties, Location Z = 15m and Rotation of X, Y and Z to zero. The rest of the default settings may remain.



In Object mode, zoom out and select the light. Shift + D will duplicate the light; make 4 and put them on each corner of the plane.



Camera Settings:

Setting Selections were made to represent the closest possible settings to those of the 100 Island Challenge field cameras (100-IC SOP) and camera properties from 100-IC field photos.

Property	Value
Frame 1	
Path	C:/Users/Igiuseff/Desktop/Louise/Palmyra Restoratio...
Resolution	4928x3264
Colors	3 bands, uint8
Date & time	2016:09:16 04:59:07
Make	NIKON CORPORATION
Model	NIKON D7000
Focal length	18
F-stop	F/8
ISO	400
Shutter	1/250
35mm focal	27

Screen shot from Property metadata

From SIO_Mosaic_SOP_V2:

ISO sensitivity settings:

- a. ISO Sensitivity = **400**
- b. Auto ISO Sensitivity control = **ON**
- c. Maximum sensitivity = **3200**
- d. Min shutter speed= **1/200 s**

Image quality -> **JPEG fine**

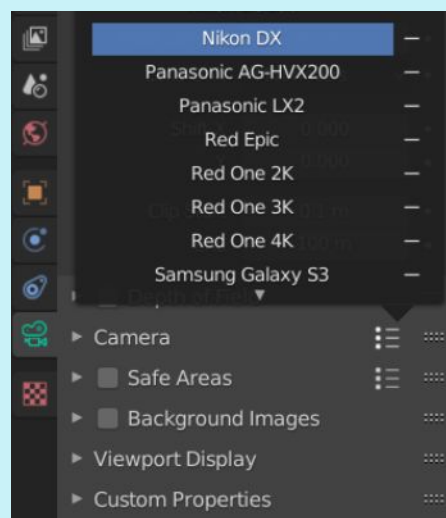
While there is not an apparent way to set ISO, sensitivity and Shutter speed controls, the Image output was Jpeg to match the Sandin SOP.

The Sandin SOP uses the following camera: Nikon D7000 SLR camera and AF-s DX zoom-Nikon ED 18-55mm F3.5-5.6G 11 autofocus lens; Ikelite underwater camera housing for Nikon D7000 including: modular 8-inch dome.

While the camera settings reflect the type of camera used and the focal length, the distortion from the dome could be incorporated into the next version of this manual.

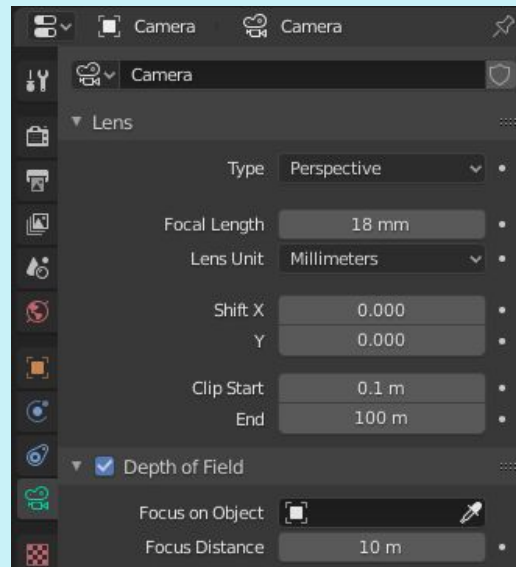
In Blender, match as many of the camera setting properties as possible:

In Object mode, select camera, zoom out to find it if it is not in the frame. In the Camera setting, first select the list next to 'Camera' and select the camera that matches up with the 100 Island Challenge camera Nikon D7000, or 'Nikon DX'. This will automatically set the Sensor fit to 'horizontal', the width to 23.6mm and the height to 15.8mm to match the Nikon DX settings (find this drop-down menu under the arrow left of the word 'Camera').



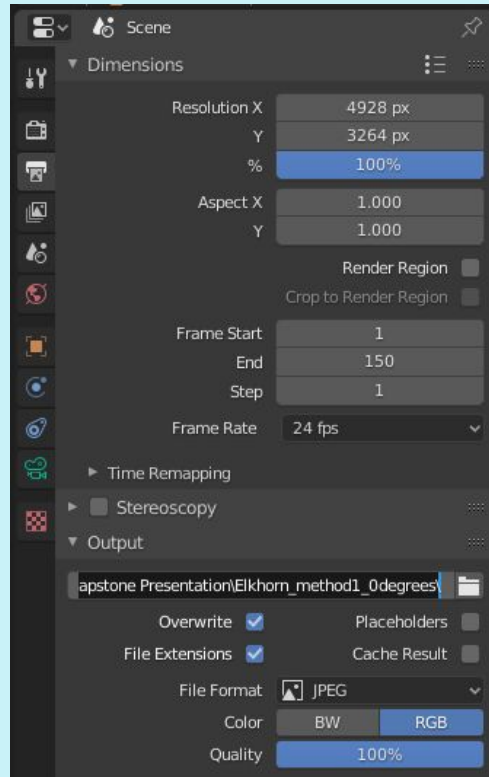
Blender Manual Camera Settings: <https://docs.blender.org/manual/en/latest/render/cameras.html>

The 100 Island Challenge uses cameras with 2 focal lenses, 18mm and 50mm. The 18mm lens view has the widest angle of view for maximum coverage, while the 50mm view represents the narrowest angle of view but yields close-up photos for high-resolution images of coral polyp patterns for taxonomic purposes. For the purposes of the simulation to gather surface area and volume data for use in coral restoration, the 18mm focal lens setting is most appropriate. Under Camera settings, Lens, choose a Focal Length of 18mm. Select 'Depth of Field' and notice that the default focal distance setting of 10m; later, on pg. 19, you will learn to set this to autofocus.



Change photo resolution to 4928 x 3264 pixels to match field camera settings. Go to Properties, Print, and change the resolution. Make sure the resolution is also set to 100%.

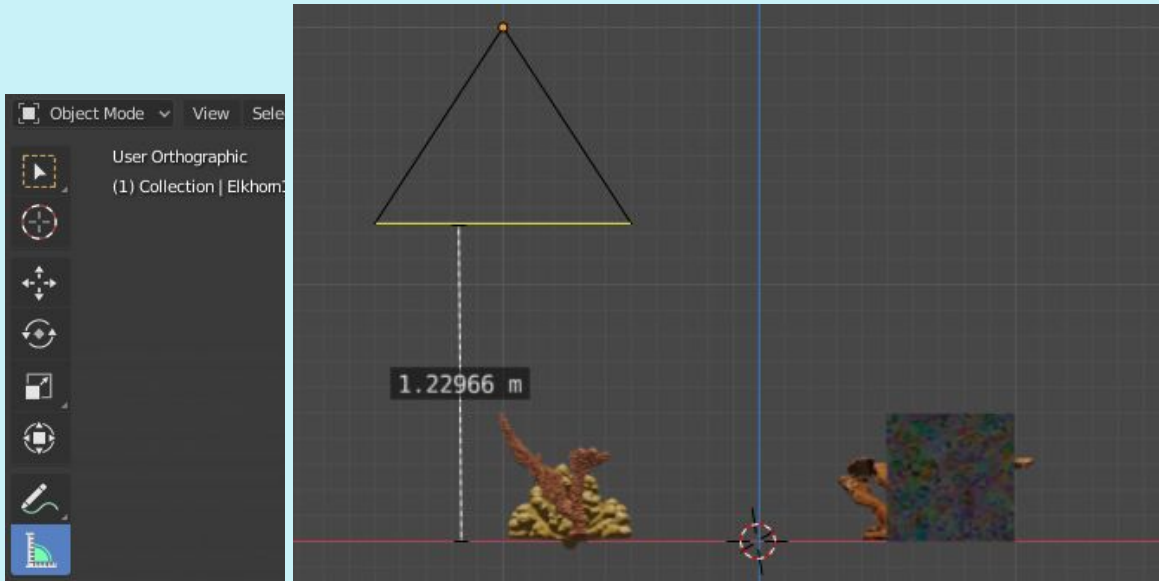
In the 100 Island Challenge SOP camera settings, .jpegs are used at the preferred output file format. Under Output, direct Blender to the folder where the simulated photos will be saved, change the file output format to .jpeg, and change quality to 100%.



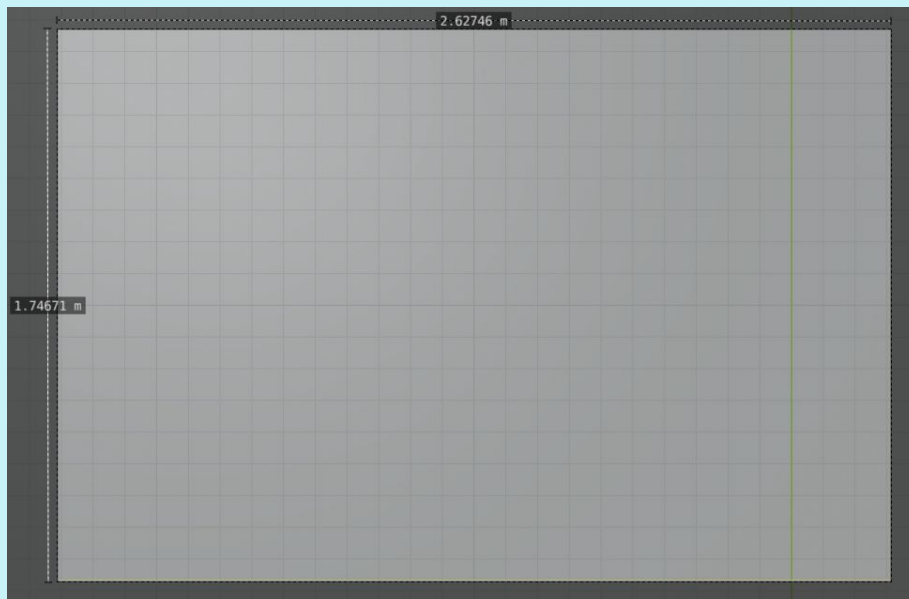
The 100-IC team aims to capture photos 1 to 1.5m from the bottom. Set the vertex of the camera (the sensor origin) to 2m, as the height of the Camera's lens perspective is about .5m deep. To do this, make sure the camera is selected and go to Object Properties, Transform, Z = 2m.



To check that the measurement is between 1 to 1.5m, put the screen into an orthogonal view using the number keypad (2). Click the measurement icon on the left screen, click on the 'ground' and measure upwards towards the camera. If you click on the camera first to measure, it will become selected and change the field of view as you drag down.0



Number pad zero will display the camera's view. Note the dimensions of the field of view for future calculations of % cover between photographs.



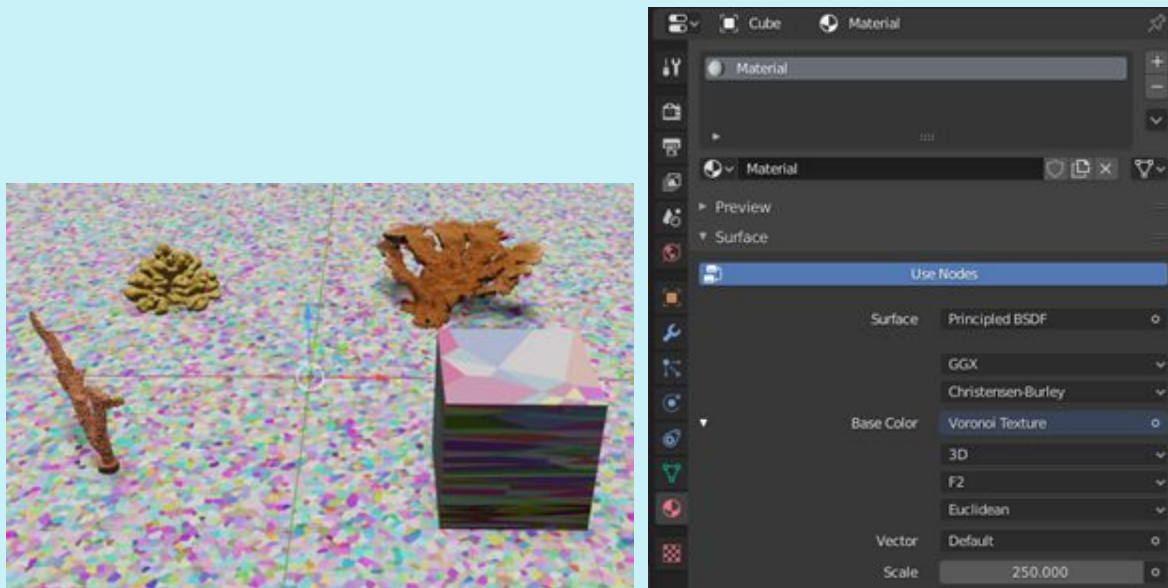
View through the camera lens, each small box is 10cm

With the current settings, the width is approximately 1.75m, while the length is approximately 2.63m. So to find 90% overlap swimming forward, the camera can only move forward 17.5cm at a time. Save this template and open a separate Blender file to build the flight path to import later, ensuring no settings are accidentally changed.

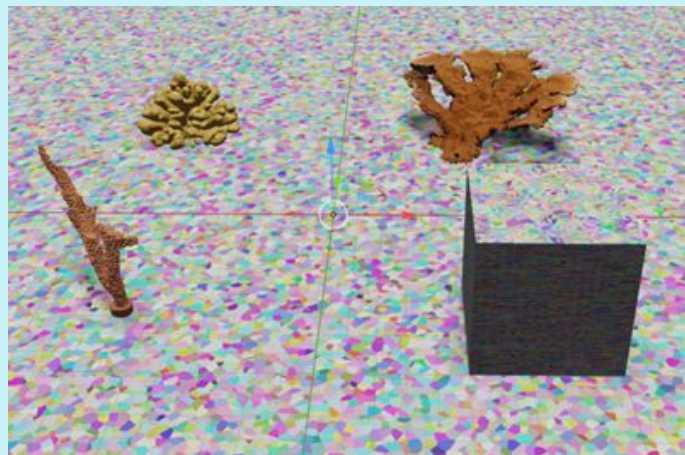
Setting up Autofocus:

The blender default camera does not have autofocus for multiple objects, only one can be chosen to focus on. To work around this, it is possible to combine all objects in the scene as one.

After taking down the surface area and Volume of each object, go into Object Mode. Press shift while selecting the plane, cube and 3 corals. Then hit Ctrl + J to join all meshes as one. Notice that the Voronoi on the cube has changed, and the texture becomes considerably spread out. This is because the scale of voronoi on the plane is 250, while the scale of the voronoi on the cube is 15, creating a formatting issue when they are joined. This can be avoided by changing the scale of the voronoi on the cube to 250 before doing the join. Press Ctrl + Z to go back and fix.



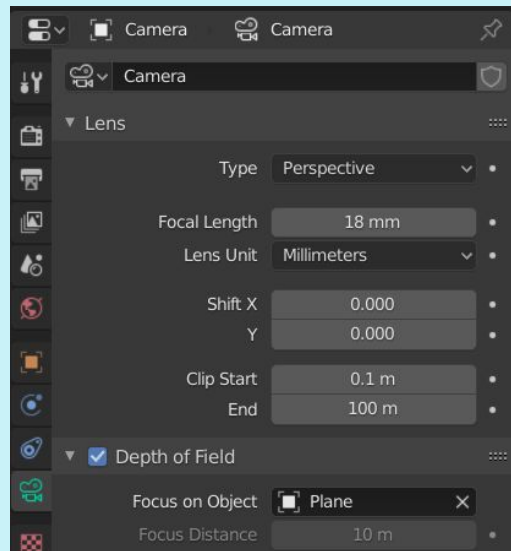
Example of voronoi formatting issue



Voronoi formatting fixed

Notice that rescaling before the join has made the top of the cube appear the same scale it was before, whereas the sides of the cube have become very compressed colors. Also notice that in the scene collection, all objects are now listed under the plane, whereas, they were all separate objects before.

Select the camera and go to Object Data Properties. In the box Focus on Object, select plane; notice that the focus distance box now becomes grayed out. Now this entire object will be focused on, as a work around for the lack of an autofocus option within Blender 2.82. When photographing a reef, the camera doesn't see each coral as a separate object, but rather all as one entity.

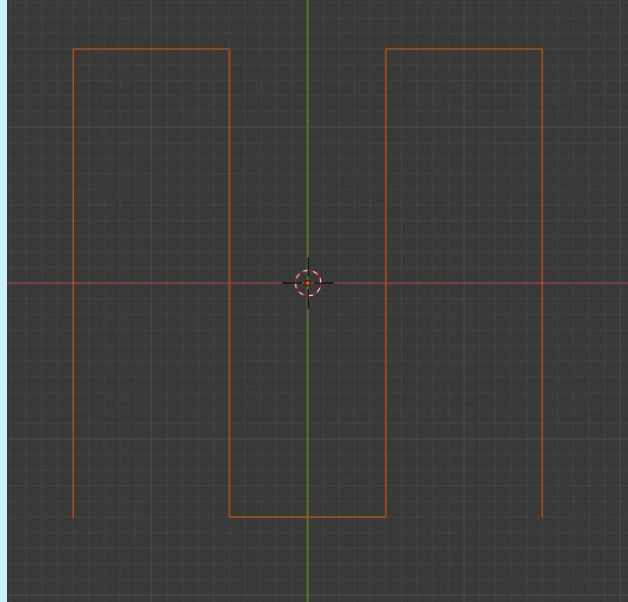


Flight paths:

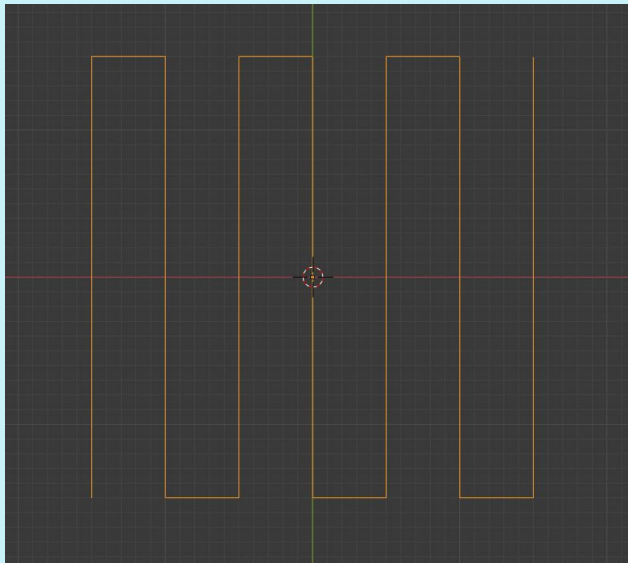
On page 29 of the 100 Island Challenge SOP, divers are instructed to swim 1.5m from the bottom and hold the camera at a level, 90 degree angle (parallel to the substrate). A minimum requirement is one pass (swath per meter), which at 1.5m from the bottom with an 18mm lens results in roughly a 60% horizontal overlap. Instructions follow to maintain a slow swimming speed so that there is at least a 90% overlap vertically between pictures.

Method1 and 2 –

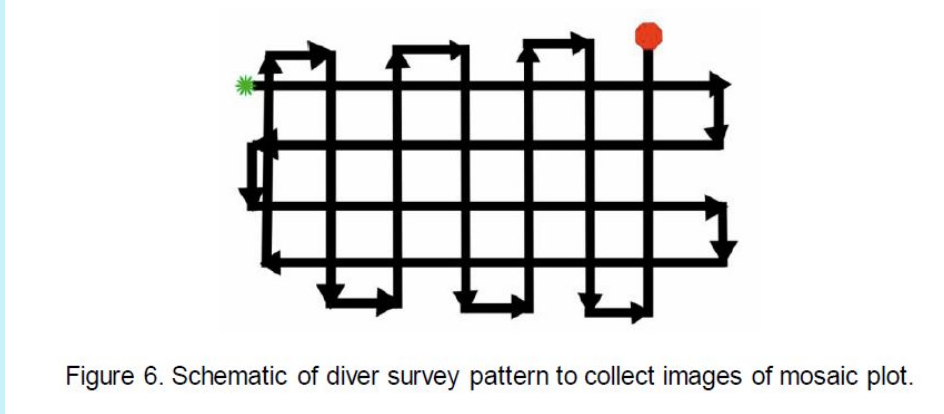
Delete cube. Shift + A, select plane. In edit mode, with the object unselected, hit C for circle select and select 3 of the 4 vertices. Right click off the plane to 'accept'. Then hit X to delete and delete vertices. Click on the one remaining vertices and in Item, change X and Y to -1.5, -1.5. Hit E for extrude and click near -1.5, 1.5. Change the X and Y to be on the exact location. Hit E again and move one meter to the right, make a point at -0.5 and 1.5. Continue this until all areas within a 3m grid have been covered by meter wide flight paths.



Then in Object properties, under Delta Transform, change Z to 2m. The camera sensor will be linked to this pathway 2m above the benthos. Export 'selection only' as a new .obj. Do this same iteration at .5m intervals and export as a new .obj.



Method 2 (from pg. 30, 100 Island Challenge SOP):



pg. 30, 100 Island Challenge SOP

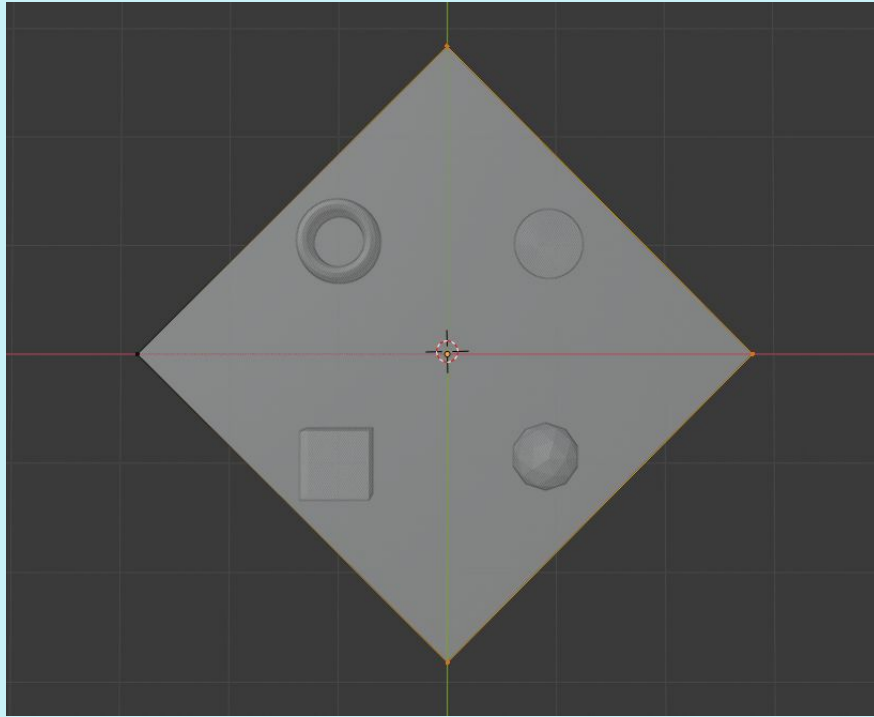
For the purposes of this manual, Method one is replicated in the other direction to create the grid for Method 2, collecting twice the number of photos.

Method3 – spiral flight path; [building a spiral in Blender 2.82](#)

Use a scene with objects of known size for scale. Numbers pad 7, then 5 to go into the top orthographic view. Shift + A, choose Mesh, then Plane. The plane will be 2x2m. Change scale to 4x4m.

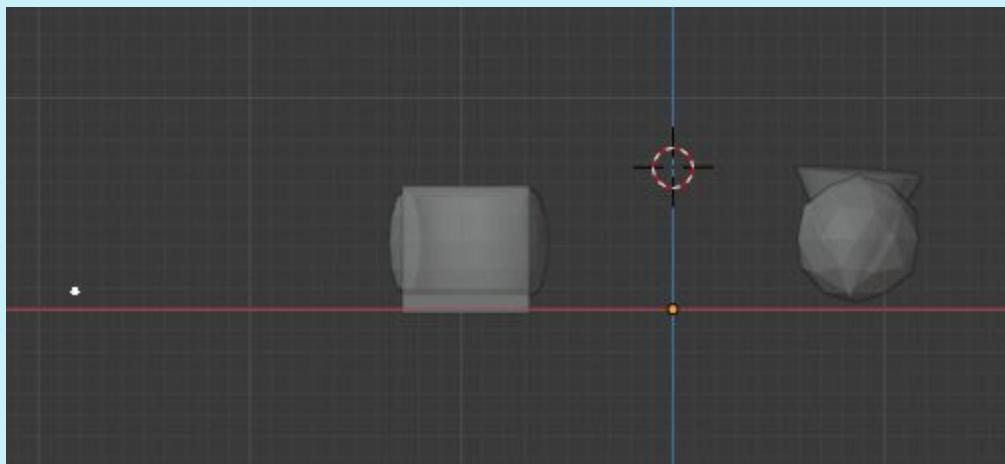


Go to Item, and set Location X, Y and Z all to 0. Make sure the plane is selected in Object mode, click R for rotate, and then 45, followed by a left click, this rotates the plane by 45 degrees.

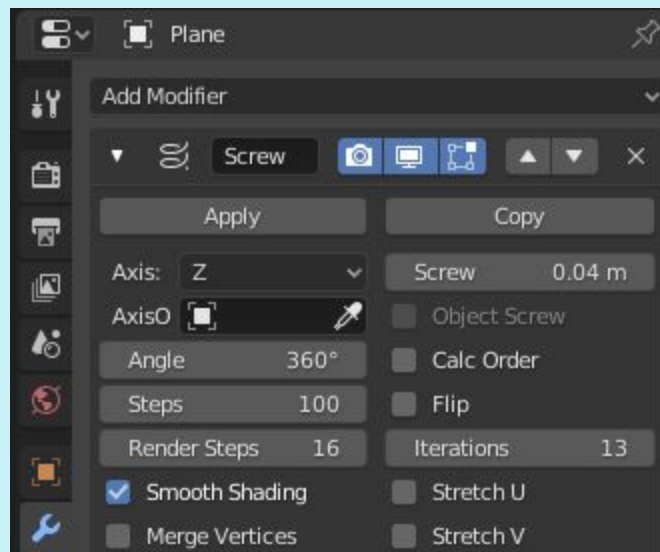


Go into Edit mode, click on a void space to deselect the plane, and then press C to bring up a circle. Click on the top, right and bottom vertices. Right click to 'accept', hit X, then Vertices; all 3 vertices will disappear, leaving one vertex.

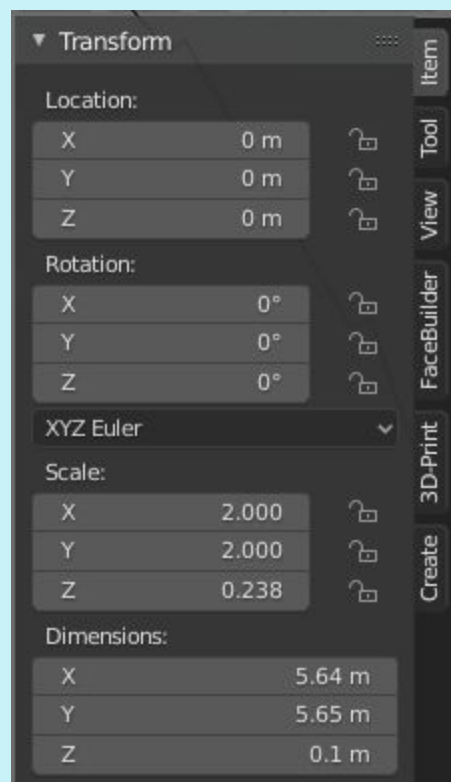
Go into Object mode, hit 1 on the number pad to go into the front orthographic view.



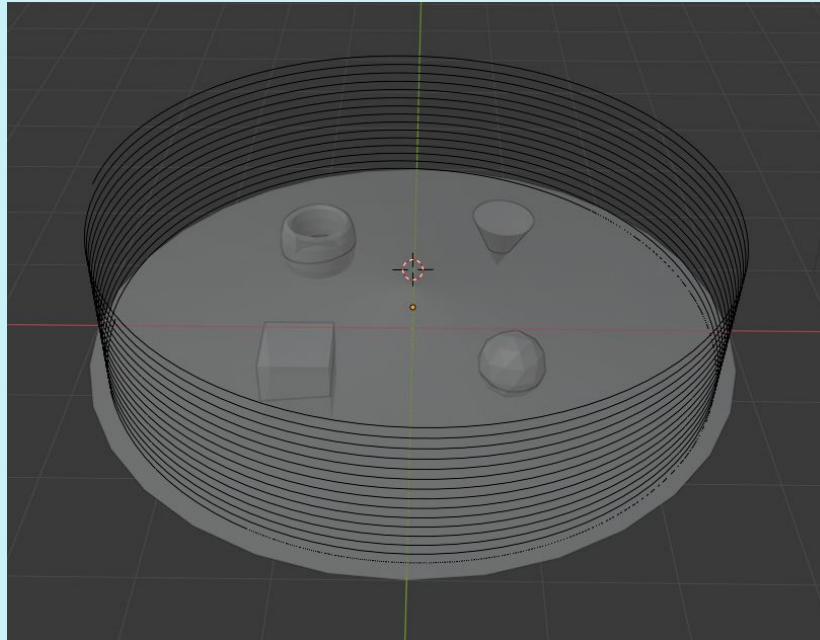
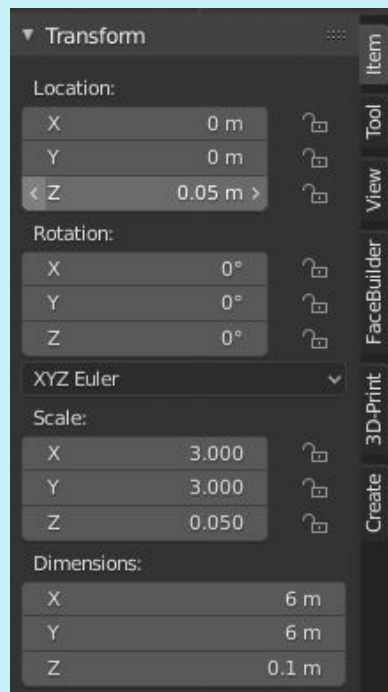
With the vertex selected, go to Modifier Properties (the wrench) and click 'Add Modifier', then select 'screw'. Change screw revolution from 0 to 0.05m. Change steps to 100. Iterations to 13. Select the coiled object in Object mode so it is orange and hit apply.



In Object mode, change screw rotation X, Y and Z to 0.

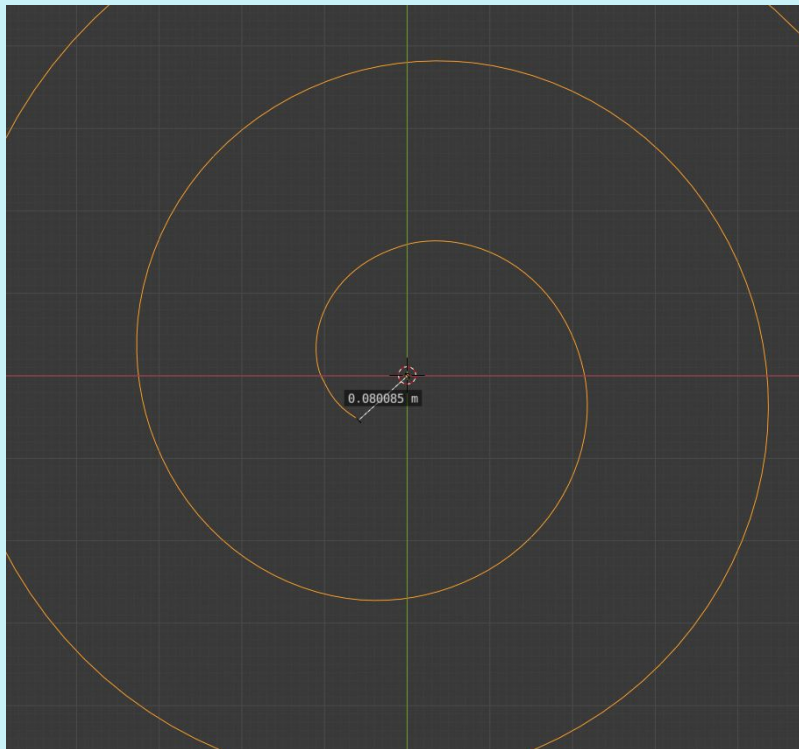
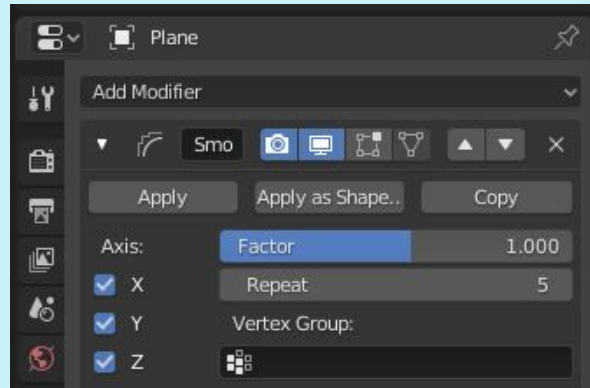


Hold down Shift + A simultaneously, then Mesh, then cone. With the cone selected, go to Item, under Dimensions, change X to 6m, Y to 6m and Z to .1m to flatten and widen the cone. Change Location to 0 for X, Y and to 0.05 for Z.



Still in Object mode, select coil, Modifier Properties, Add Modifier, and select Shrinkwrap. In Target, select the Cone. Select coil and under dimensions, change Z to .487. Select the measuring tool to ensure that the end of the coil to the vertex of the cone is exactly .8, this ensures that the radius of the beginning of the coil matches the 1.6 diameter barrel size indicated in the Pizarro paper. With coil

selected, hit apply under modifiers. To smooth out the coil, go to Modifier Properties with Spiral plane selected. Add the Modifier called 'Smooth', change factor to 1 and Repeat to 5, select 'apply'.



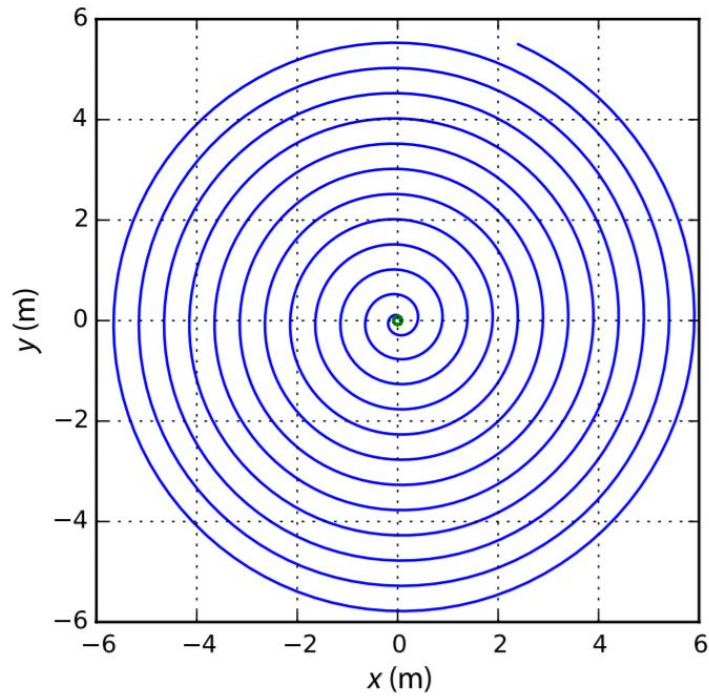
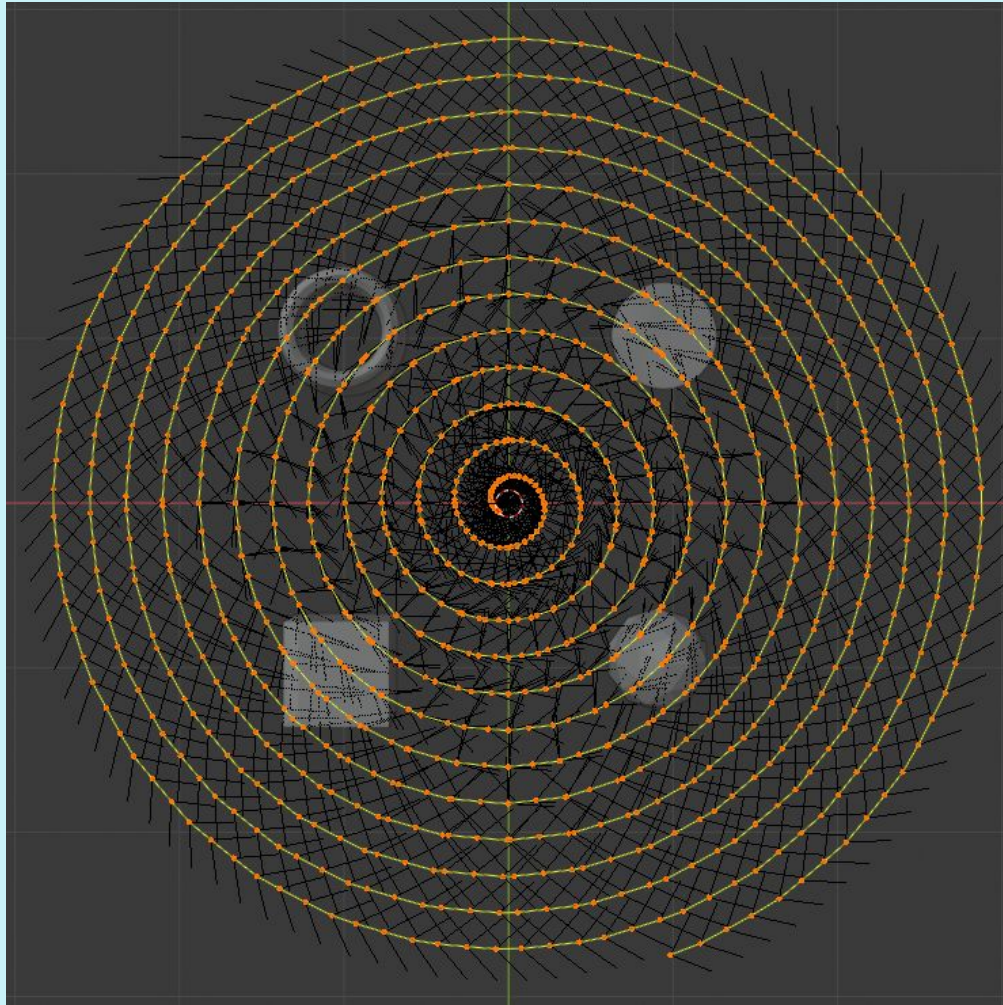


FIGURE 4 X-Y trace made by the involute of a circle of diameter 0.16 m and a 6-m-long line. In practice, the tip of the line will trace this pattern as it unwound around a drum while keeping it in tension.

Then select the Cone and delete. Press 7 on the number pad to go into the top orthographic view. In Object mode, go to Object, Convert to, and select 'Curve from Mesh'. Now the object is an exportable mesh.

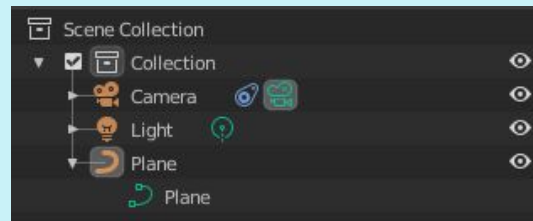
Draw a square around the whole spiral to select all the vertices and go to Edit mode. Go to Delta transform and change Z to 0. If vertices at the end are crooked, remove them with deselect, then C for circle, choose the vertices to be removed, right click to 'accept', then X, then choose the vertices to delete.



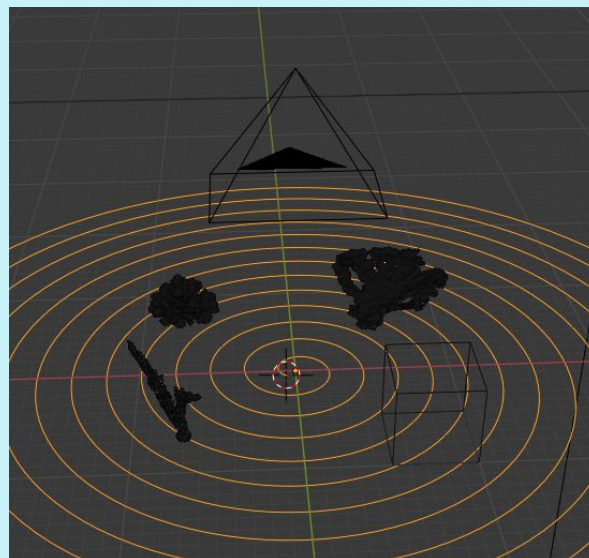
Export as an .obj, with 'selection only' selected.

Clamp Camera to .obj Pathway to create flight path:

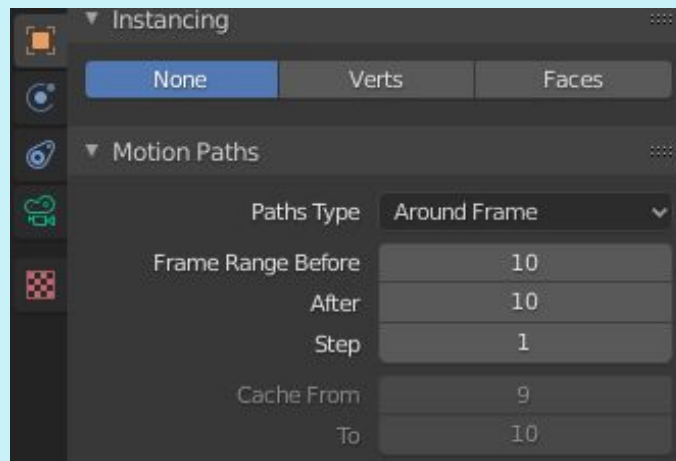
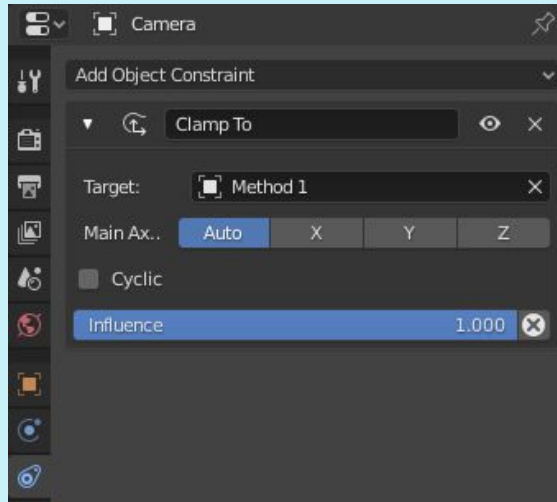
For Method 1, 2 or 3, import .obj flight path to original Blender file with corals. Select flight path, go to Object, Convert to, Curve to Mesh/Text. The plane in the scene collection will then change to this shape:



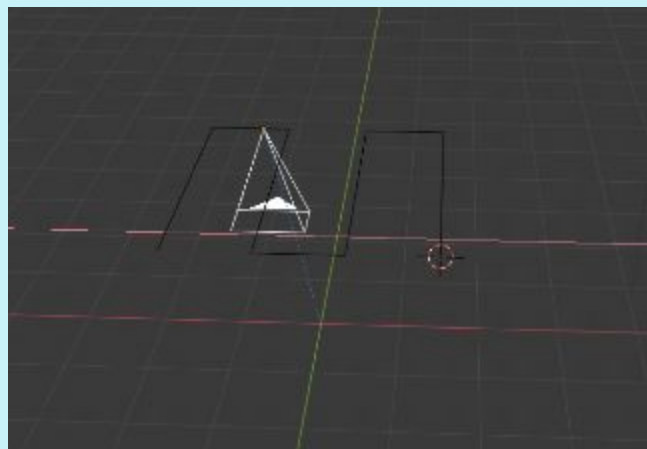
With the Flight path highlighted, change the cursor to rest on one of the end vertices. It's easiest to double click to get it there.



Then use the select arrow, highlight the camera, Go to Object Constraint Properties, Add Object Constraint. Select 'Clamp to', then under Target, choose the Plane. The Main Axis should be set to 'auto'. Under Object Properties, Motion Paths, choose Path type: Around Frame.

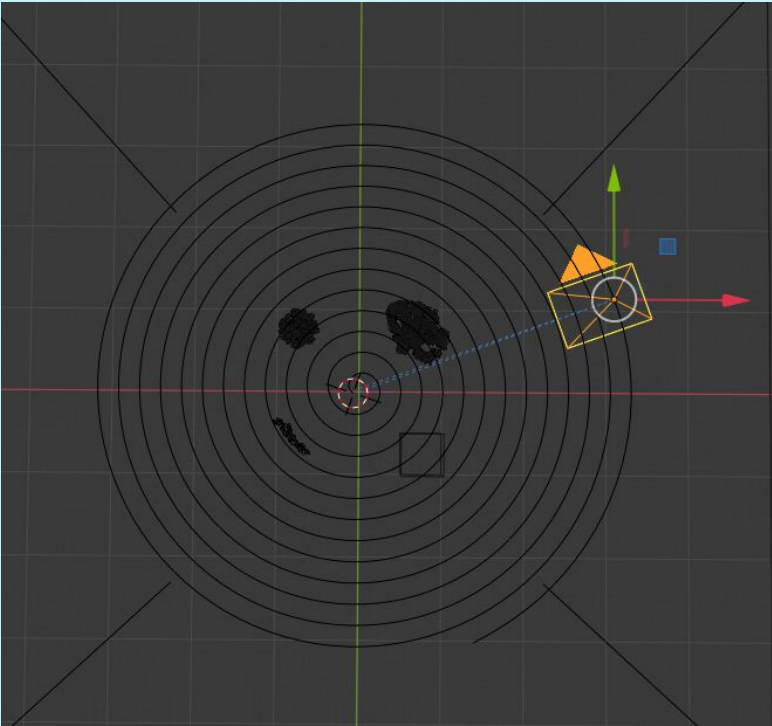
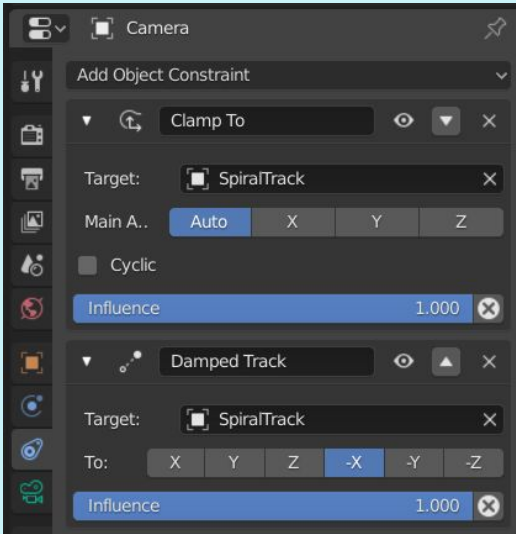


Then in Object mode, with 'Move' selected in the left-hand menu, the camera should move along the track when moved along the x-axis. If it does not, zoom out and try again. If it still doesn't work, with the camera selected, right click and choose Snap, then Select to Cursor. Generally if nothing happens, then with an undo of Ctrl + Z, it snaps to the cursor. Ensure the track's Location of Z is 2m off the bottom.



For Method 3, the spiral track, there is an additional step. The side of the camera is connected by a string that unwraps as the camera spirals away from the drum in the center. The camera is always pointing forward in this case. To make the camera do this in the simulation, there is an additional object constraint to add.

With the camera highlighted, go to Object Constraints, choose Damped Track and choose the spiral track as the target. Choose X and leave the default influence to 1.0. Now the camera is facing the same direction the diver would be swimming with it.



Animating the camera along the flight path:

The objective is to cover a 2x2m area to effectively photograph the corals and the edges of the 2x2m square. The next objective is to create 90% overlap between the photographs while moving forward along the track. Because the width of the field of view is 1.75m, and 90% coverage is desirable, the frame will move forward by only 10% (or 17.5cm), or approximately 24 frames to cover a 2m swath of track.

The overlap between tracks will be different. Following the 100 Island Challenge protocol of 1m distance between tracks at a minimum, and a field of view length of 2.63, moving to the right 1m will result in 1.63m of overlap ($1.63/2.63$), or 62%.

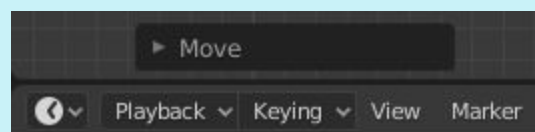


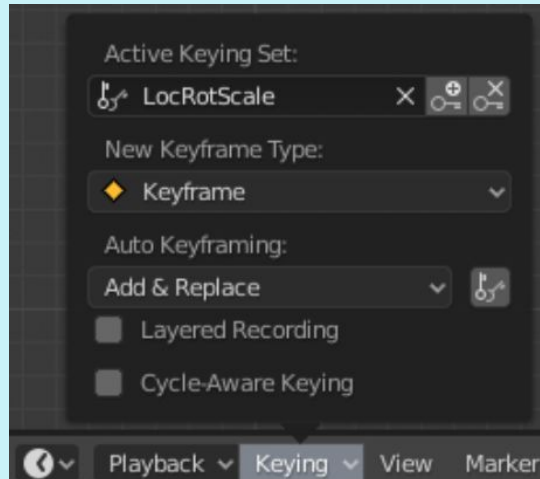
View through the camera lens, each small box is 10cm

By calculation, there will be 24 frames in a 2m track, therefore if the camera is moving on a 2x2m grid, there will be 5 passes ($X = -2, -1, 0, 1, \text{ and } 2$). Therefore, there will be 124 photos in total.

For Method 3, the spiral track, the objective is that the spiral covers the 2x2m area at the very least. When the camera's epicenter has cleared the 4 corners of the 2x2m area, this objective will be considered fulfilled. To keep the methods somewhat comparable, the keyframes will end at 248, because this is where Method2 ends.

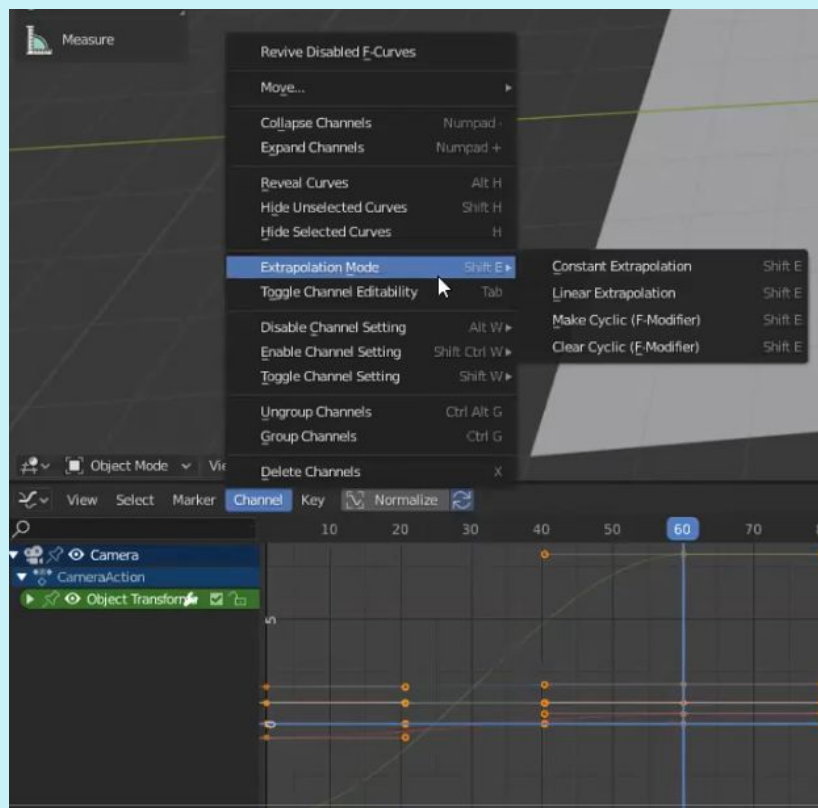
In the bottom animation pane, select Timeline, which looks like a small clock face. Then go to Keying, click the empty box and choose LocRotScale. This will set keyframes for the location, rotation and scale set.

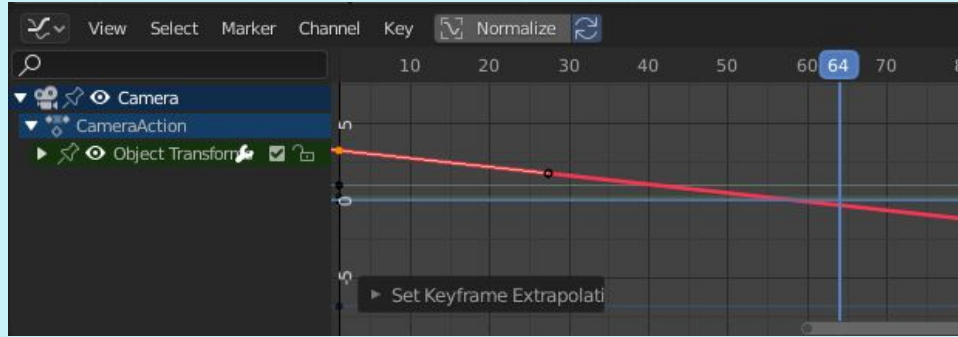




With the camera snapped to the Method1 1-m track flight path, ensure camera is selected and add a keyframe in the first frame. Move the camera all the way to the other end of the flight path and add another keyframe at 24 frames.

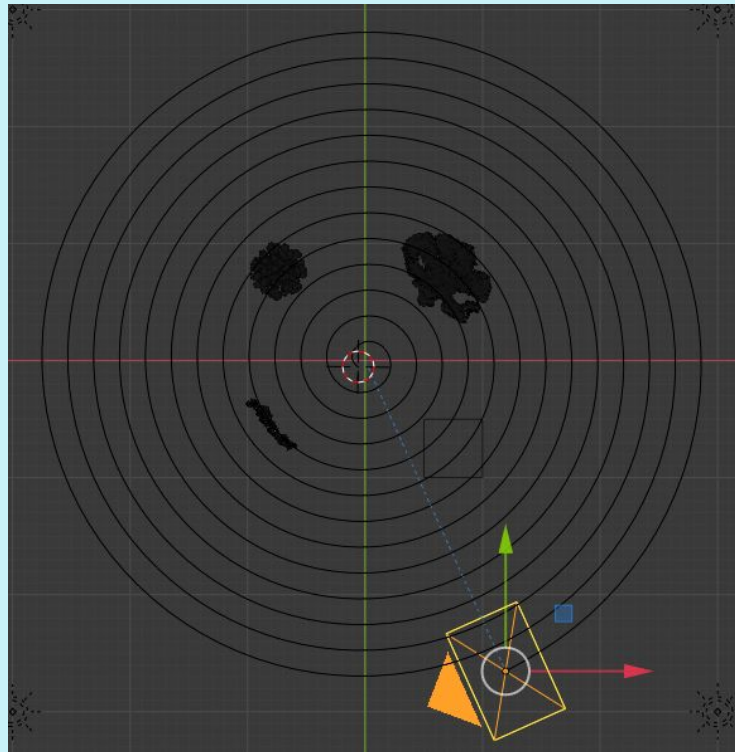
Click on the clock face and choose Graph Editor. The x-axis is highlighted in red on the graph and by default it is non-linear, which affects the rate at which the photos are taken. With the red line selected, select Channel, followed by Extrapolation Mode, followed by Linear Extrapolation. This ensures the photos are taken at the same rate along the flight path.



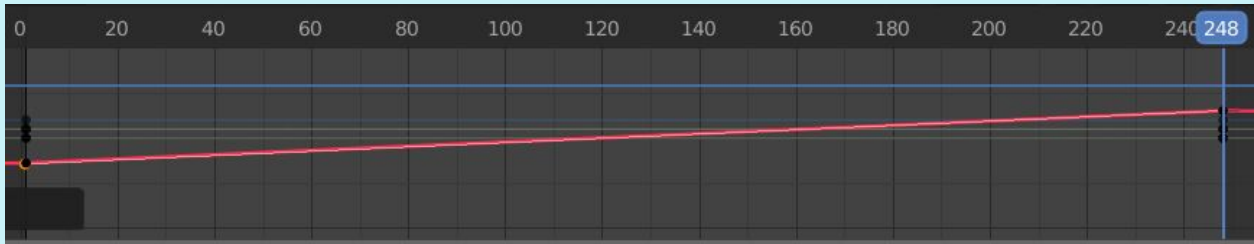
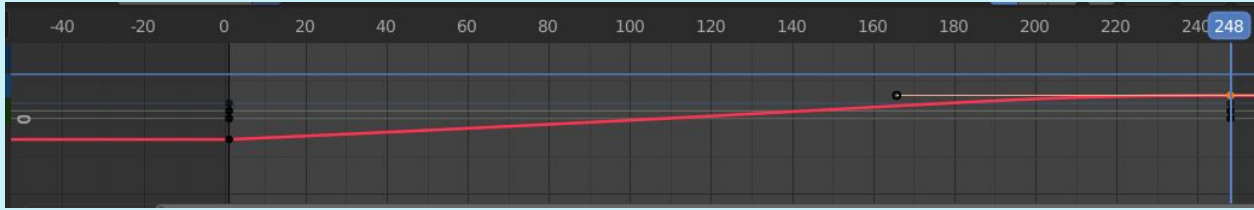


Go back into Timeline mode (clock face) to play the animation.

For Method 3, with the camera at the center, make the first keyframe. At keyframe 248, ensure the camera is at the end of the spiral, just clearing the last of 4 corners of the 4x4m grid.

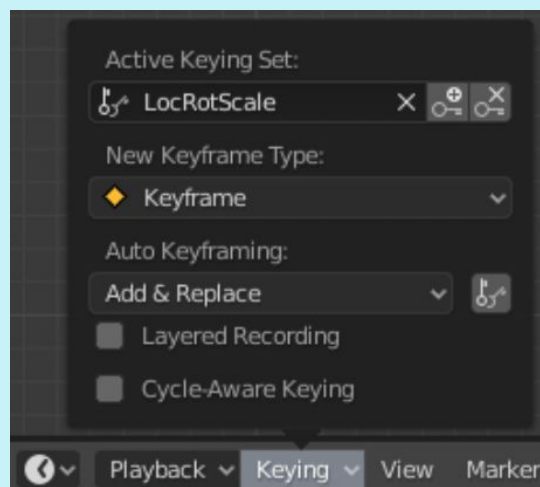
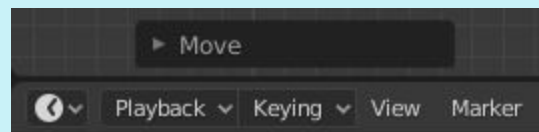


Just as with method 1 and 2, ensure the photos are taken at equal increments by going into the Graphics Editor. Select the black dot on frame 1 and an orange line will appear. Drag the right point to the top of the line at frame 248. Select the black dot on frame 248 and drag the left end of the orange line to frame 1.

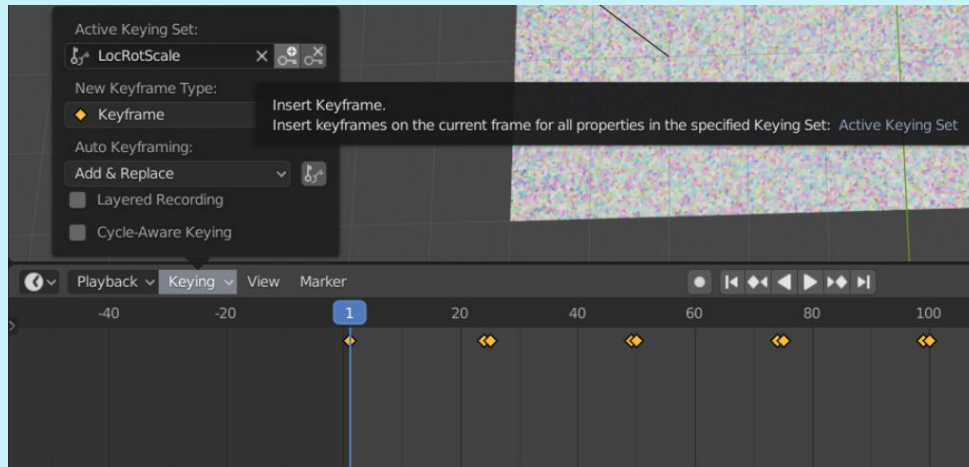


Method 1 and 2 by hand (without track):

In the bottom animation pane, select Timeline, which looks like a small clock face. Then go to Keying, click the empty box and choose LocRotScale. This will set keyframes for the location, rotation and scale set.



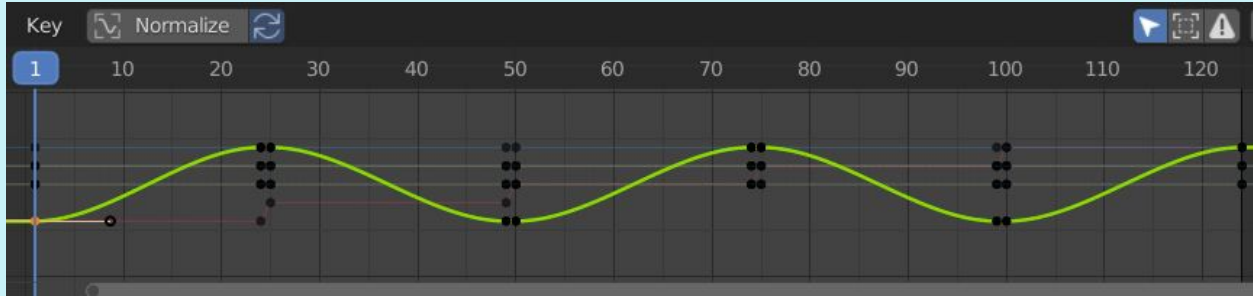
With frame 1 highlighted, in Item/Transform/Location data, set X to -2 and Y to -2, also ensure that Z is still at 2m. Select Keying, then the Insert Keyframe button (the photo of the key with the plus sign).



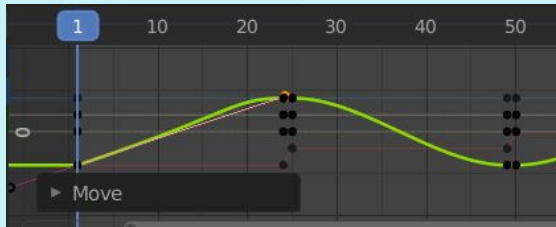
Then go to frame 24 ($X = -2, Y = 2, Z = 2$). Frame 25 will move 1m to the right ($X = -1, Y = 2, Z = 2$). Frame 49 will carry the camera to the end of that row ($X = -1, Y = -2, Z = 2$), and so on.

-200	17.50
-182.5	17.50
-165.0	17.50
-147.5	17.50
-130.0	17.50
-112.5	17.50
-95.0	17.50
-77.5	17.50
-60.0	17.50
-42.5	17.50
-25.0	17.50
-7.5	17.50
10.0	17.50
27.5	17.50
45.0	17.50
62.5	17.50
80.0	17.50
97.5	17.50
115.0	17.50
132.5	17.50
150.0	17.50
167.5	17.50
185.0	17.50
202.5	17.50

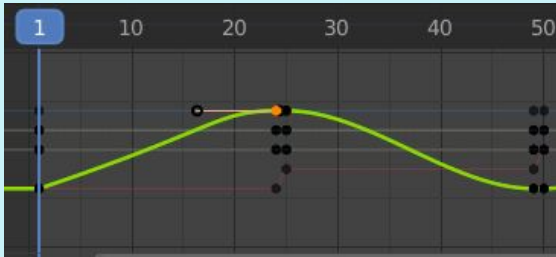
The issue with the default settings is that the rate at which the camera takes pictures is not linear. To change that, go to Editor Type, Graph Editor. The Y axis the camera is moving along is the green line, click on it to highlight it, notice the curved nature of it, this is non-linear. Currently the camera is taking more pictures at the beginning and end of the track with wider spaces between photos in the middle. The middle cursor will zoom in and out on this track line.



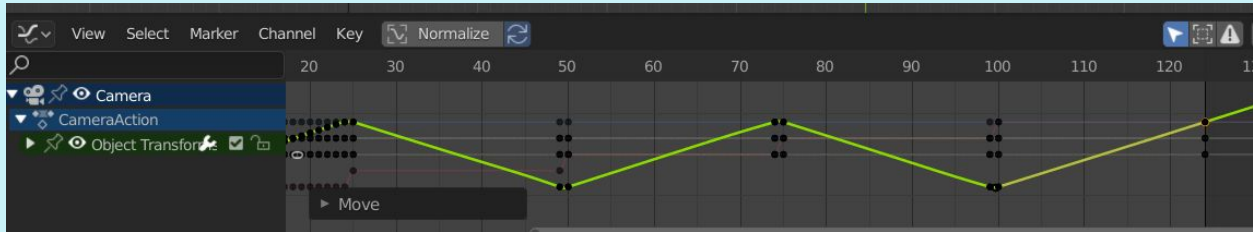
To create a linear rate of photographs, select the line so it is highlighted, and notice the orange bar that appears at one end. Hold and drag the black dot at the end and drag it to the next black dot.



Notice that the first green line (representing photos 1 through 24) is straighter but not completely straight. Now select the black dot you just met with the first line. Another orange line will appear.

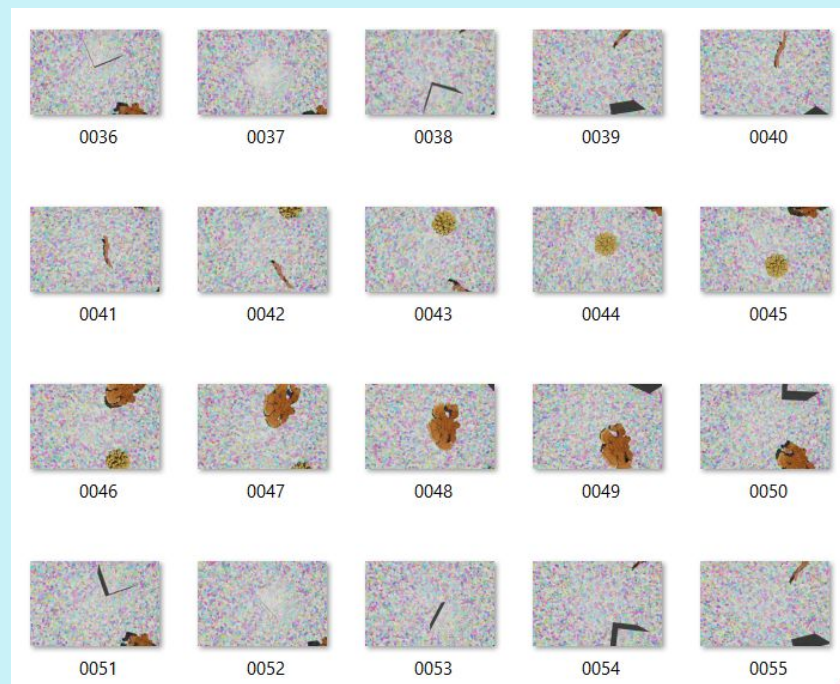


Drag the black dot at the left end of that line back to the initial black dot and notice it becomes linear. Do this for each sequential set of green lines to assure the photos are taken with equal spacing. Click [here](#) to see a video of this process.



Render Animation:

Once the animation is complete, click on Render, then Render Animation. Each photo the camera takes will be uploaded into the folder selected during camera setup. This will take some time, depending on the processing power of the computer it could be 30 mins or more.

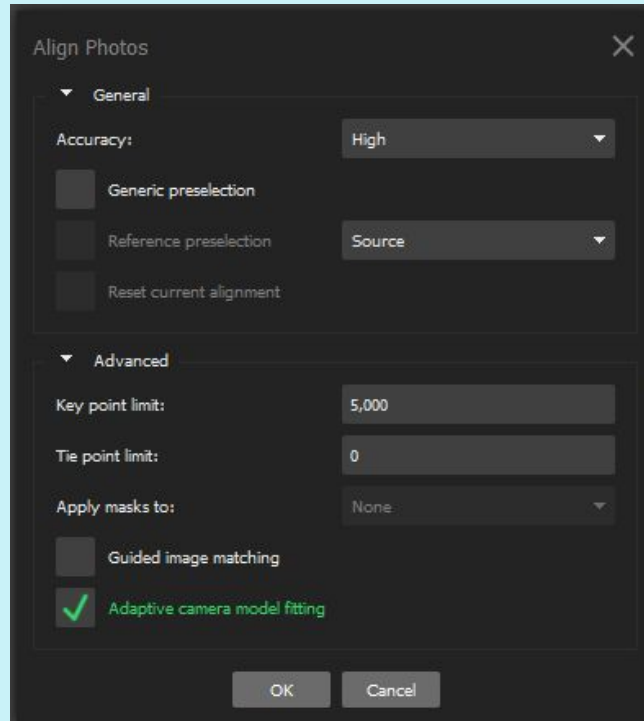


Reconstructing the model in Agisoft:

Using the 100 Island Challenge Agisoft methodology as a framework, reconstruct 3D point clouds and meshes that will be reimported into Blender for final volume and surface area measurements.

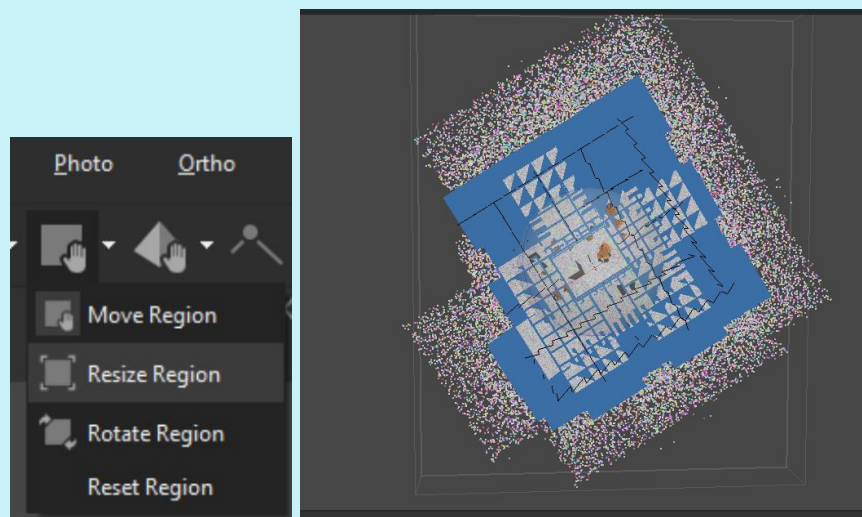
In Agisoft Metashape Professional, go to Workflow, add Photos and direct the program to the folder of photos from Blender and select all of them.

Then in Workflow, select Align Photos and make the following adjustments, press okay.

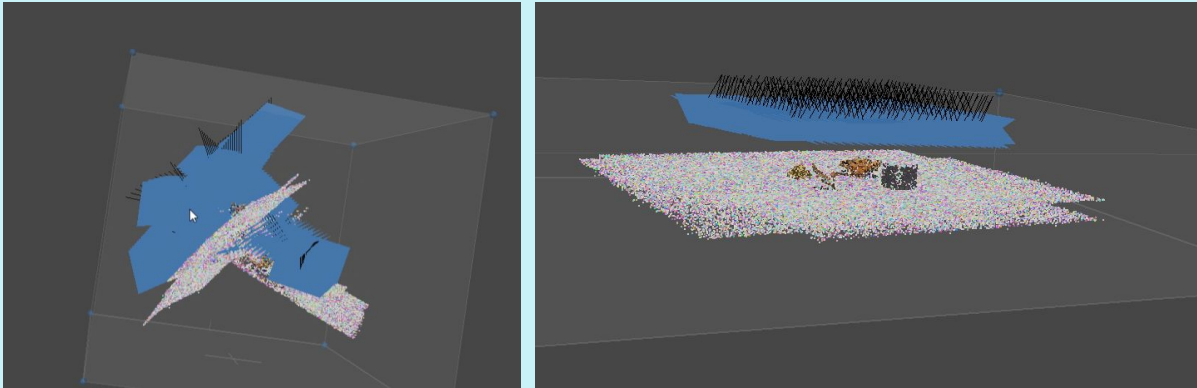


After the photos align, there may be a warning that not all photos have aligned and some points will appear as outliers outside of the bounding box. To change the size of the bounding box, Resize the region, then rerun Align Photos with the same settings, and do NOT select 'Reset Current Alignment', and then hit Okay.

To change the size of the bounding box, Resize the region, then rerun Align Photos with the same settings, and hit Okay.

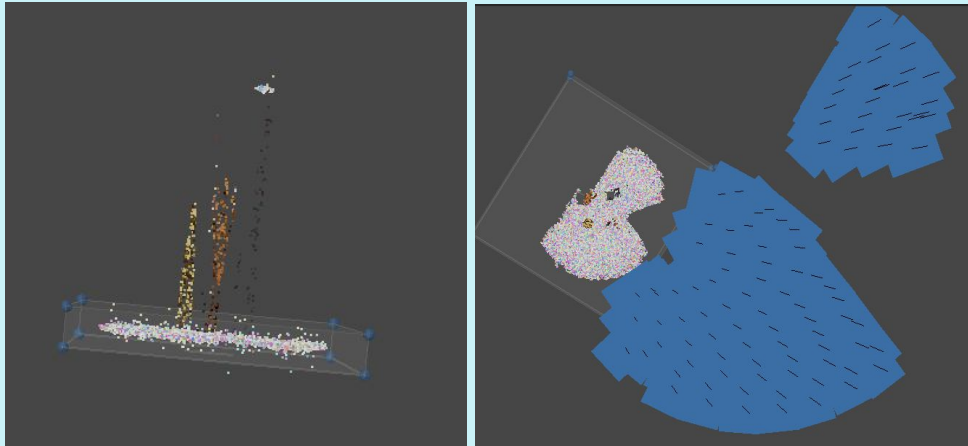


Occasionally the alignment will have obviously malfunctioned, even after altering the bounding box. In this case, realign and select 'Reset Current Alignment'.

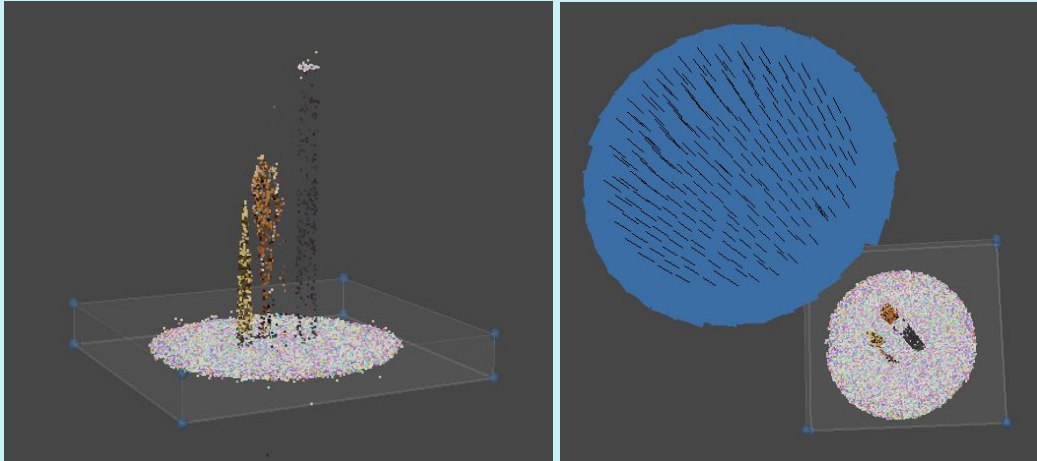


Example from Method2_60degrees, before and after 'reset current alignment'

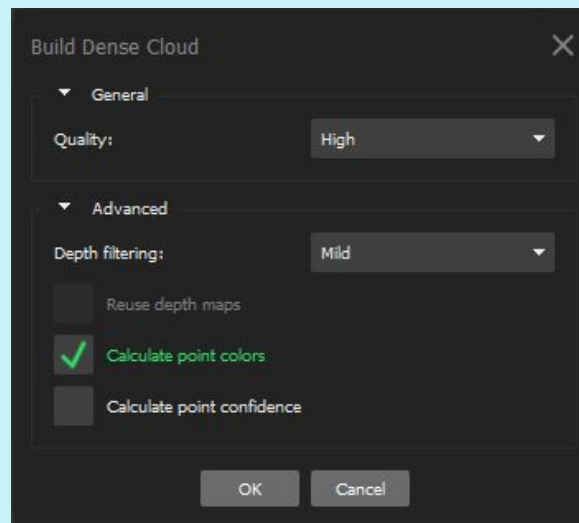
Method 3 had considerable issues aligning and the process had to be repeated many times. After deleting the extraneous points around the top and bottom of the model, the process was repeated (one camera short and came out with improved results (tie points went from 34,614 to 62,562).



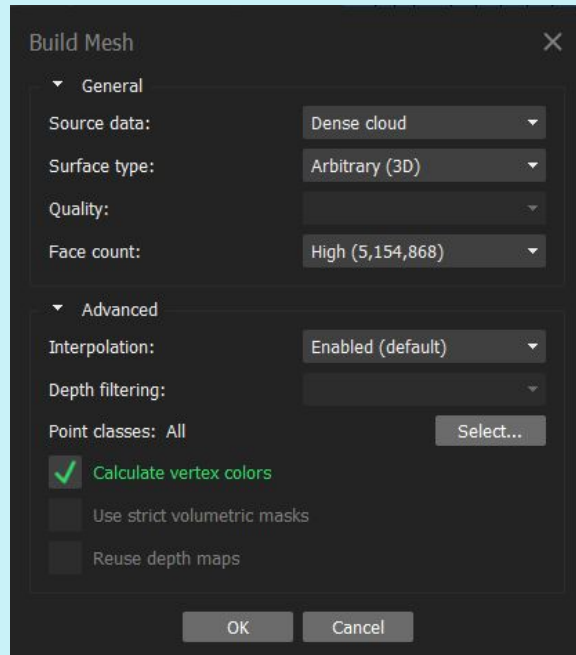
Improved results



Go to Workflow, then select Dense Point Cloud and make the following selections. Processing time could take hours. The Quality is set to high rather than 'ultra high', because of the time involved. To run a model on 'ultra high' takes 10+hrs, whereas a model on 'high' took approximately 2.5hrs.

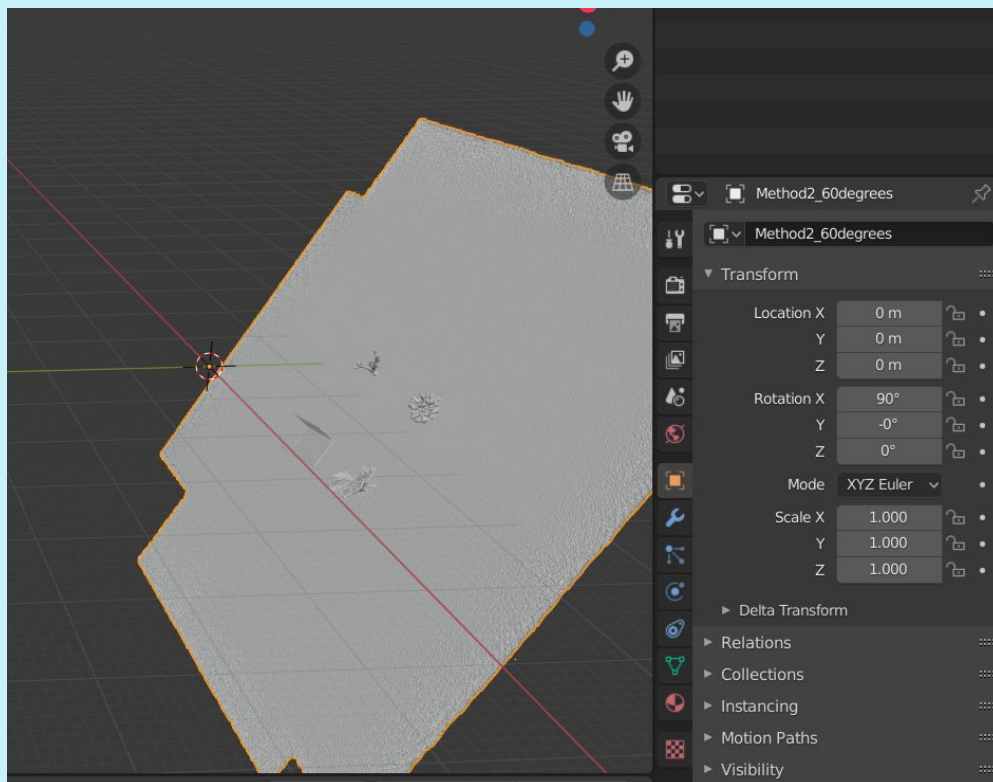


Next, build the mesh with the following selections. Note that if batch processing is done, the face count of the mesh is preselected. It's preferable that the mesh builds in its full capacity from all the point's available. When the Dense Point Cloud is created, the mesh face count setting at High will select the highest number of available points to build the mesh from. This is preferable to get the most accurate surface area and volume when the object is reimported back into Blender 2.82.



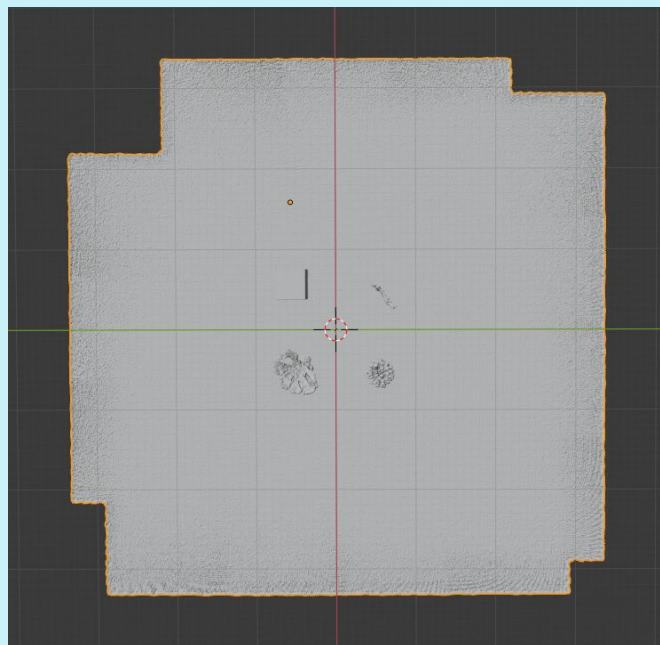
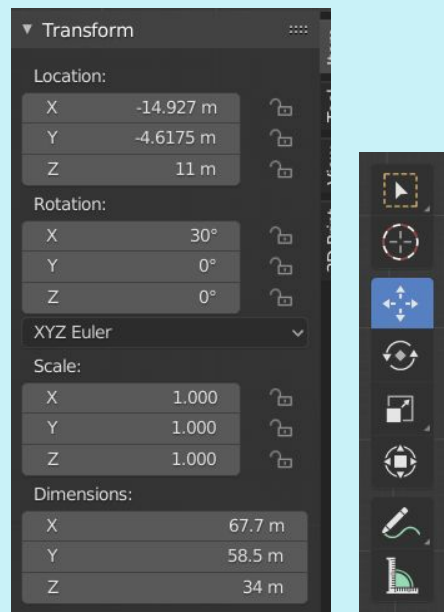
Import .obj back into Blender:

Once the .obj has been imported back into Blender, delete the cube, light and camera to minimize distractions. The object will likely not import on the correct plane.



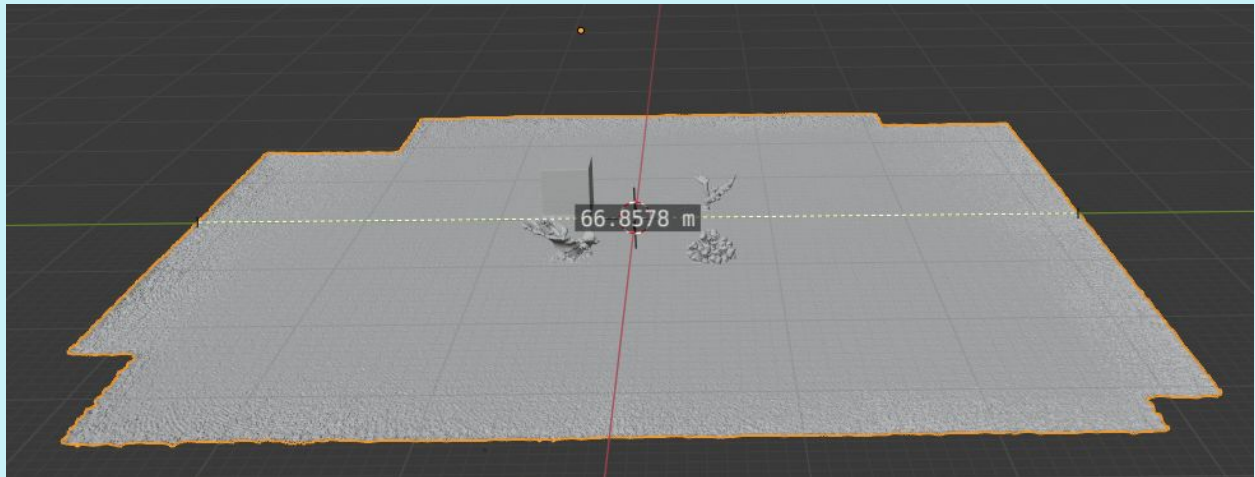
Scale and Orient Object with Cube:

For the object imported from Method2_60degrees, in the Item menu, I changed the rotation of X to 30degrees, and Y and Z to 0 degrees. I positioned the location of Z at 11m and it appeared to lay flush with the grid. With the move arrow on the left pane I centered the cursor between the 4 objects, which altered the location of the X and Y. This is not of consequence, but having the cursor in the center will make it easier to scale the object before separating into individual objects.



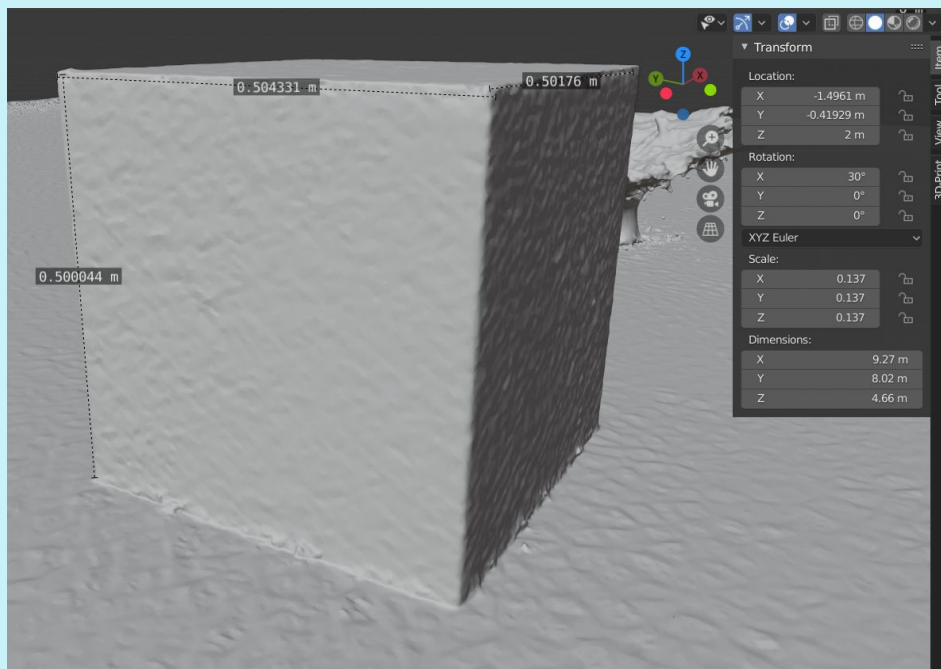
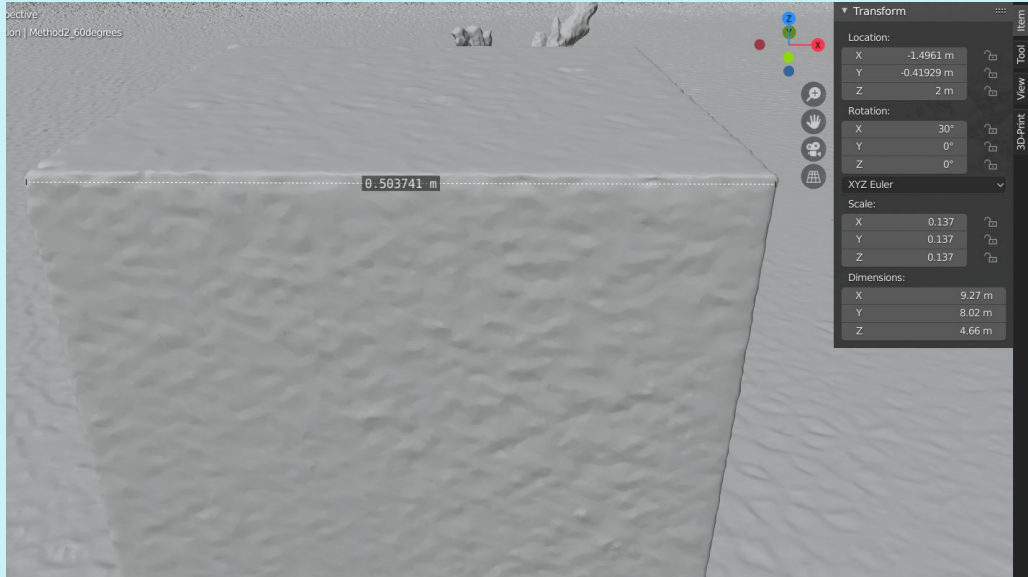
Recall that the original plane was a 10x10m grid. However, the camera did not photograph the entire area, so the plane cannot be used for measurement. The 50x50x50cm cube will be used for scaling.

Currently the object is much bigger than its original size. In this model, one side of the plane to the other is nearly 67m.



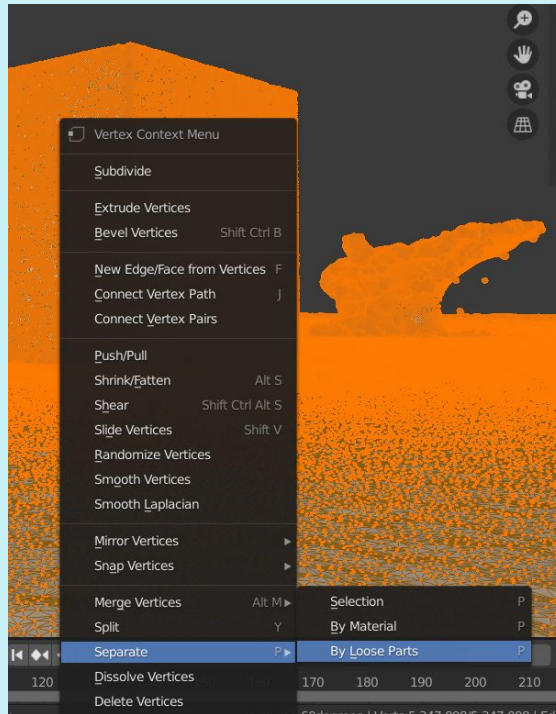
Use number key 7 to go into top orthographic mode. Use the Scale in Menu to scale down until the cube measures 50cm width. Continue to adjust the Location of Z, adjust the X, Y and Z of the scale evenly, and use the Move arrows to redirect towards the center of the grid. Then tilt the plane to view an edge of the box from an angle before measuring, as this will be most precise. Repeat until the edge of the cube is 50cm.



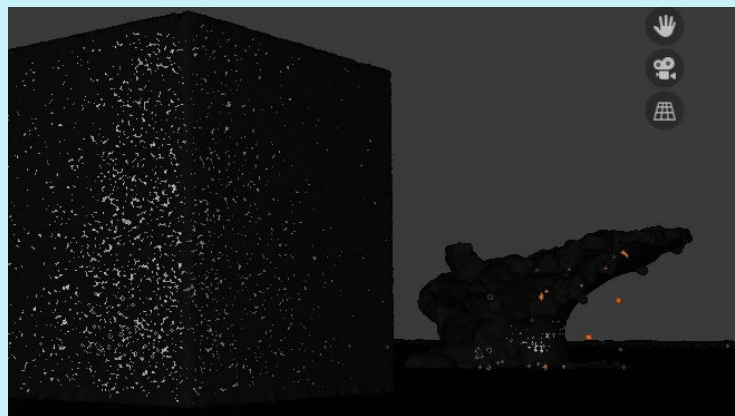


Remove non-attached data points:

Go into Edit mode and all the vertices will turn orange. To remove non-attached data points, first right click and select Separate, then 'by loose parts'.



Those stray points (vertices) will then highlight. Delete them by right clicking and selecting 'delete vertices'

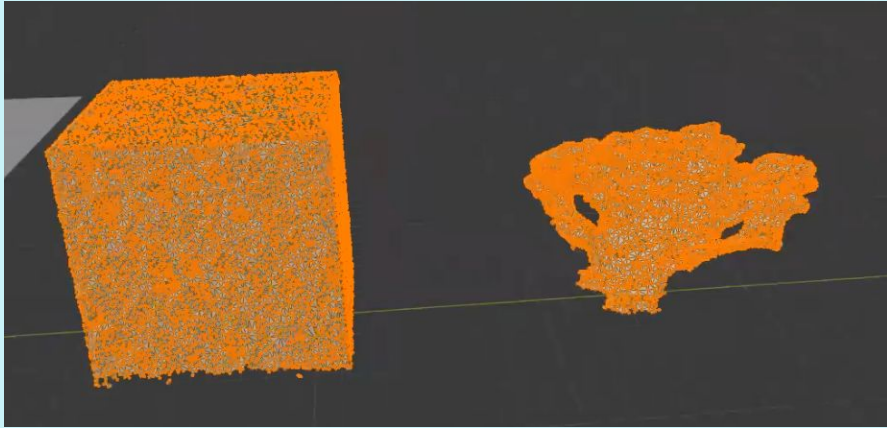


To remove the base plane, hit 1 on the number pad. In Edit mode, choose the Bisect cutting tool on the left and cut down the center of the plane.

Remove base plane and separate objects: [Under Construction]

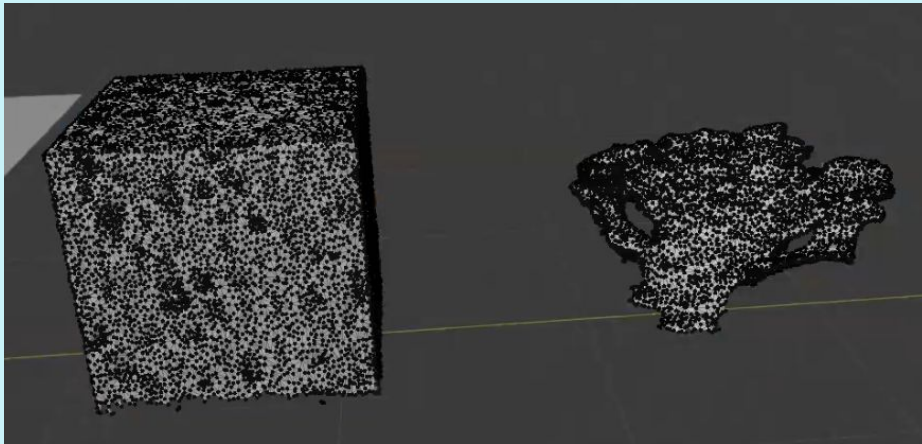
[Currently experimenting with a knife tool to cut away the entire plane at once; this will be more scientifically repeatable between users than going in manually and erasing.]

Select mesh and hit tab; all vertices will be highlighted in orange. The Vertex Context Menu will appear, select



C for circle select; B for box select

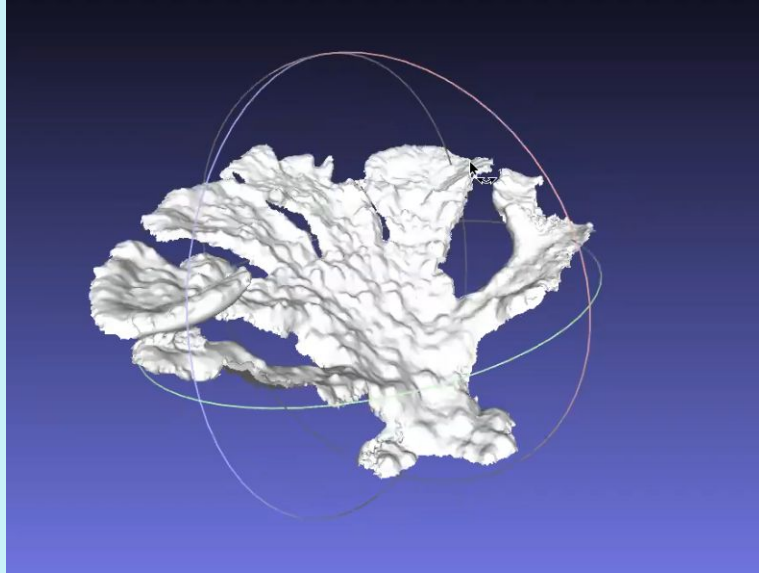
With object selected, double tap AA and vertices unselect



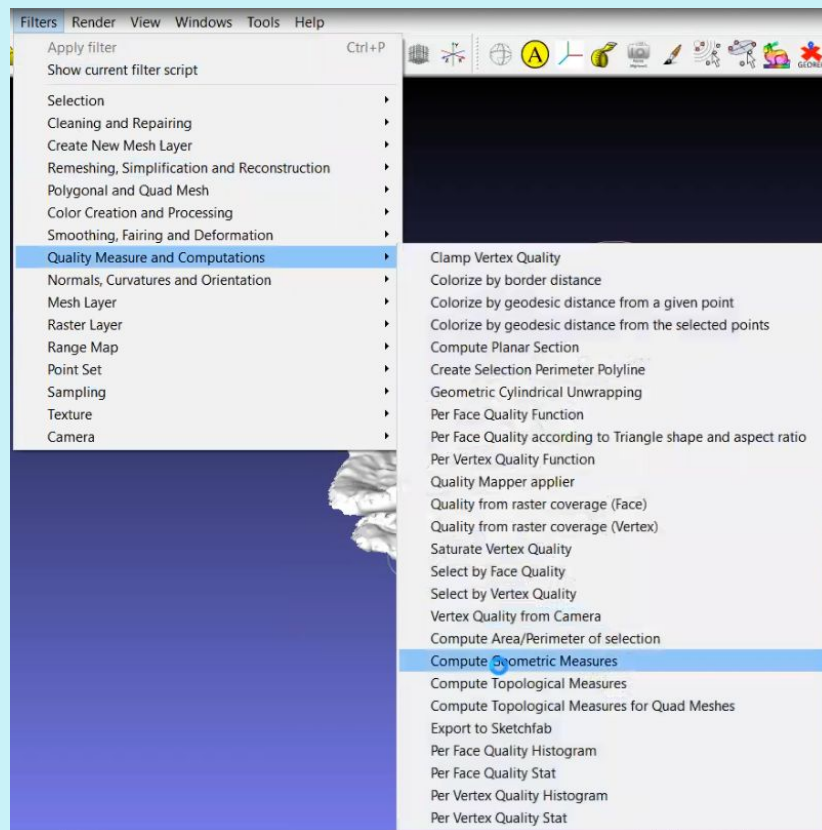
Calculate Surface Area and Volume [Under Construction]:

Export .obj of each coral/object into MeshLab to double check calculations:

Open MeshLab, File, Import Mesh of individual coral reconstructed, pre-cut and exported as an .obj from Blender



Next, select Filters, Quality Measure and Computations, then Compute Geometric Measures.



Then, in the lower right hand corner, the surface area measurements will appear, and volume metrics if they are available. This should match the surface area and volume measurements in Blender 2.82

```
in 742 msec
All files opened in 744 msec
OUT OF SCOPE
Mesh Bounding Box Size 1.267447 0.707832 0.899957
Mesh Bounding Box Diag 1.708032
Mesh Bounding Box min 11.674923 -1.400592 0.945867
Mesh Bounding Box max 12.942370 -0.692760 1.845824
Mesh Surface Area is 1.138671
Mesh Total Len of 237299 Edges is 1043.992676 Avg Len 0.004399
Mesh Total Len of 237299 Edges is 1043.992676 Avg Len 0.004399
(including faux edges)
Thin shell (faces) barycenter: 12.317413 -0.985768 1.408115
Vertices barycenter 12.296538 -0.987606 1.398139
Mesh is not 'watertight', no information on volume, barycenter and inertia
```

Capstone Committee Signatures 6/11/2020:


PhD Stuart Sandin, Scripps Institution of Oceanography (Co-Chair)



Heidi Batchelor, Scripps Institution of Oceanography (Co-Chair)

heidi batchelor

Scott McAvoy, Digital Media Library, UCSD



PhD Jennifer Smith, Scripps Institution of Oceanography

