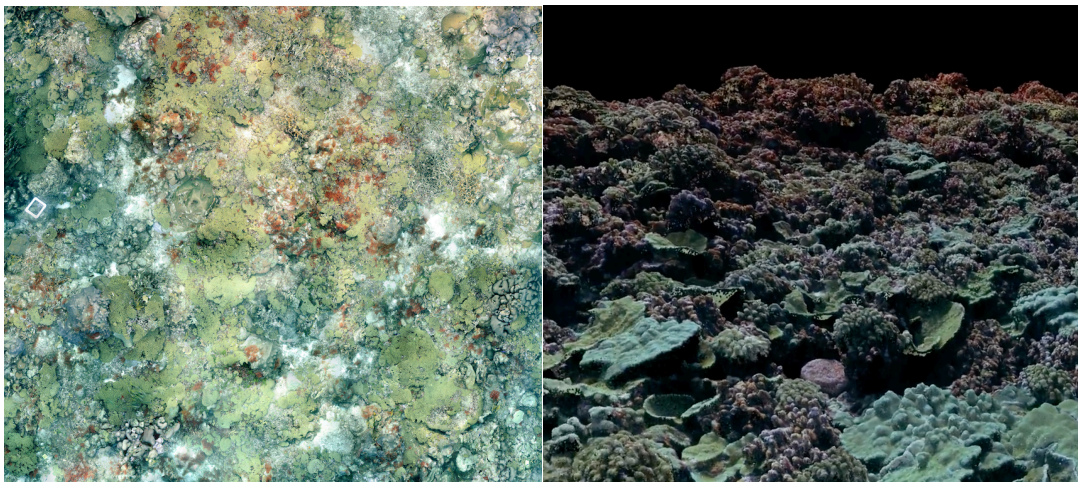
Increasing Ocean Stewardship and Awareness Through the use of Large-Scale Photomosaics



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Abstract

The Sandin Lab has been working with state-of-the-art technology that captures coral reefs as a 3D image at a spatial scale that has never before been captured. The objective of capturing these images on such a large-scale is to monitor the growth of the coral reefs over time and understand their dynamics from a whole ecosystem perspective. I am expanding the audience that this technology currently reaches by using these large-scale 3D models as an education and outreach tool in the hopes that it increases ocean stewardship and awareness. This idea was tested on the island of Curacao with three different user groups: dive shop owners, dive tourists, and the local community. The local community consisted of the Carmabi Marine Education Center and the International School of Curacao. By talking with the different user groups around the island, I gauged general interest in the photomosaics and gathered information on how each user group could find use for the photomosaics. There is potential for the dive shop owners and dive tourists to use the photomosaics in the future once the advancement of technology allows us to hurdle some of the current challenges we face. However, both of these local communities will now be incorporating the 3D photomosaics as an education module into their curriculum.

Introduction

Images are a powerful tool and have the ability to leave lasting impressions with people. The use of images in science can even help people feel more involved and engaged (Balm, 2014). The Sandin lab is using 3D imagery of large sections of coral reefs to monitor the growth of coral reefs and understand how their dynamics are changing over time with the influence of different environmental and human impacts. These large sections that are being monitored are called photomosaics. The process to create a photomosaic is straightforward but requires a special computer program and is time consuming. The photomosaics are a collection of thousands of high-definition images that get "stitched" together to generate a cohesive 2-dimensional and 3-dimensional image, or mosaic. The 2-dimensional mosaic is referred to as an orthoprojection and creates a bird's-eye view of the area of coral reef where the images were taken. We currently use the orthoprojections in Photoshop where students in the lab are trained to identify, trace, and color-code each

individual species of coral. The 3-dimensional mosaic requires special software designed by a colleague that generates an interactive 3D model or a 3D video. The interactive 3D model allows the user to manipulate the image with 360-degree capabilities and with the ability to zoom. This 3D model is used in conjunction with the 2D orthoprojection and again is color-coded by individual coral species. This process can be time consuming, as there can be thousands of coral in one mosaic. Once complete, the color-coded mosaics are run through a mathematical program that will tell us how reef dynamics are changing over time; i.e. what coral species are growing or shrinking year after year. This way of studying coral reef benthic dynamics has never before been captured and is an exciting way to explore changes in coral reefs.

My Capstone project aimed to use this powerful imagery in another capacity that would reach a broader audience outside of the scientific community. I targeted user groups that already had a connection with the ocean in the hopes that this imagery would enhance their connection with the ocean in a way that would also increase their awareness of it. My focus was on the dive industry. As a diver myself, knowing what I am looking at underwater creates a more positive experience for me, therefore, I wanted to explore if my experience would carry through to dive shops and divers. I had the opportunity to test this idea on the island of Curacao, one of the areas where the Sandin lab collects photomosaic images. Curacao is a Caribbean island that lies 12-degrees north of the equator and is approximately 40 miles north of Venezuela. Due to its location and geography, it still has some of the healthiest reefs in the Caribbean. A result of this is a large dive industry. I travelled to Curacao with Stuart Sandin, Clint Edwards, Mikki Dochez and Beverly French and had a total of three weeks on the island from April 11th to May 1st. The first week on the island was dedicated to collecting photomosaics from areas previously visited as well as from new locations. With the help of Mark Vermeij and the Carmabi Foundation, we collected photomosaic images from nine locations around the island. The remaining two weeks were dedicated to showing the photomosaics to dive shops around the island, speaking both with dive shop owners and tourists coming to dive and ultimately discovering potential uses for the photomosaics. During those two weeks, an unexpected user group became the new focus of my Capstone project. As previously mentioned, the Scripps Institution of Oceanography has a close relationship with the Carmabi Foundation

and works together to collect photomosaic images among other research. The Carmabi Foundation recently opened the Carmabi Marine Education Center, which focuses on teaching local school kids about the ocean. Mikki Dochez and I spoke with the education coordinator for the Marine Education Center and arranged a date to present the photomosaics to a school group that would be coming to visit. This opportunity opened the door to use the photomosaic images for education and outreach with the local community.

The Dive Industry

I.

The initial idea for my Capstone project was to show the photomosaics to people in the dive industry. The reasoning behind this was that the use of the images could be an advantageous tool that would excite both dive shop owners and customers and move them in a direction that would create more ocean stewardship and awareness. What I wanted to find out was how the dive industry could use the images and technology in a way that would enhance their underwater experience and ultimately create a movement of ocean stewardship by people who rely on the ocean and coral reefs for their profession. The photomosaics were shown in two different forms: a 3D video that plays on loop and an interactive 3D model that allows the user to manipulate the image with 360 degree capabilities and with the ability to zoom.

II. Dive Shop Owners

I showed the photomosaic images to eight different dive shop owners around the island and asked them what they thought, how they would use it, and what would they like to see that isn't there. Every owner that I spoke to be fascinated by the images and technology but had slightly different ideas of how to use them was depending on how they ran their dive shop. Of the eight owners, six of them wanted to have 3D videos of their dive sites either on their website or playing in their dive shop. The remaining two wanted to use the interactive 3D model for either underwater navigation or to monitor a coral restoration project they were involved in. There was an overall motivation to have 3D videos of the dive sites they frequented and to use them for shop promotion on their website or in their shop if they had access to a television. Furthermore, when looking at the 3D photomosaics

it is difficult to get a sense of the area it covers; therefore there was a general consensus to add some frame of reference that would allow the viewer to gauge scale.

III. Dive Tourists

Among speaking with dive shop owners, I also showed the 3D photomosaics to a small amount of tourists coming to dive. Inevitably, a shop owner and a customer will have different motivations. I wanted to know from a tourist's point of view, how they could see themselves using the 3D photomosaics and what they would like to see included. Though the sample size was limited, I was able to gain some insight as to what a customer would want out of the photomosaics. There was a great amount of attraction to the images and people were eager to think of ways to use it to their benefit. I received suggestions on using the interactive 3D model for fish and coral identification, and again for underwater navigation. The coral and fish identification would allow the customers to virtually move through their dive site with the ability to click on a coral or fish species and have a window pop up that gives them information about what it is that they saw. This feedback shows an initiative and desire to learn. With the capability to incorporate fish and coral identification, it increases the chance for more awareness and stewardship.

Carmabi Marine Education Center

I.

The Caribbean Research and Management of Biodiversity (CARMABI) Foundation is a marine research institute that has receives upwards of 70 scientists and graduate student per year. It has become one of the leading marine research stations in the Caribbean and has an average of 25 scholarly publications released annually with the combined research of local staff and visiting scientists. The Carmabi Marine Education Center is a fairly new addition to the CARMABI Foundation. In June of 2015, Curacao's governor inaugurated the new Marine Education Center into the CARMABI Foundation. The Marine Education Center incorporates lessons in a classroom setting about marine life, as well as a high quality museum that showcases some local marine life found around Curacao. The Marine Education Center is part of a broader Marine Education Program "designed specifically for the schools on Curacao" (IUCN, 2015). Significant portions of the lessons they teach school children are focused on the importance of coral reefs in the area (IUCN, 2015).

II.

During my time on Curacao I was given the opportunity to present information about the photomosaics to a group of high school kids from the International School of Curacao. The group was brought in specifically to hear a presentation about the photomosaics that are being collected around the island. This was intended to be a way to introduce local kids to relevant, accessible, and exciting science. I gave a fifteen-minute presentation that went over who I am, the objective of the photomosaics, how they are collected, and the outcomes that can come of it. The presentation also included the work that Mikki Dochez and The Sirenas Group are using the photomosaics for: a marine drug discovery database. The presentation received much praise and interest and opened the door to have a presentation about the photomosaics included into their education program along with 3D videos of sites from around the island. I was asked to put together a PowerPoint presentation that can be given to the Carmabi Marine Education Center that gives information on the following: general information about Scripps Institution of Oceanography, the objective of making the photomosaics, the different target groups that can make use of the photomosaics, the process/steps of making the photomosaics, pictures of the equipment and materials used, and 3D photomosaic videos. The addition of the photomosaics into the Marine Education Center will begin in September of 2016 and will be a great fit with their existing education initiatives as well as follow along with their motto to "Get to know Curacao's sea life without getting your feet wet!" The PowerPoint slides can be seen in Appendix A.

International School of Curacao

I.

The International School of Curacao (ISC) has provided education for both expatriate and local families for nearly 50 years, teaching kids from pre-K up to high school levels. The ISC offers lessons in many languages including English, Spanish, Dutch, and the local language of Papiamentu. I was introduced to the International School of Curacao via the Carmabi Marine Education Center. The purpose of the Carmabi Marine Education Center is to bring in school groups from around the island and introduce them to local marine life and give them the opportunity to explore what is below the ocean surface with

the ease of a classroom setting. As a result of a meeting with the education coordinator of the Marine Education Center, a high school group from the ISC was brought to the Carmabi Marine Education Center to experience what they teach, but also as a way to trial how the addition of the photomosaics would fare. The group started with the short presentation mentioned above about the photomosaics and continued afterwards with the normal tour of the Carmabi Marine Education Center.

II.

The presentation received positive feedback from both the students as well as the teacher. It introduced students to the many species of corals that surround the island and opened their eyes to ways they can be involved in ocean science without having to be in the water themselves. Their teacher, Lisa Cook, and I have discussed ways in which her students can use the photomosaics as a way to involve them in local and accessible science. We have determined the photomosaics will be used as lab exercise during a unit where the students focus on marine ecosystems. The exercise will be incorporated in September of 2016, during their fall semester. The high school group consists of fifteen students that will be broken up into small groups to work with the photomosaics. They will receive a 2-dimensional orthoprojection of five of the nine locations that we collected photomosaic images from. Five locations have been chosen in order to evenly break up the fifteen students into groups. The choice of the locations is somewhat random but with the intention of getting different biodiversity around the island. Each group of students will work together to identify and color-code individual species of corals using the Photoshop application used in the Sandin lab, shown in Appendix B. In order to help students identify species of corals, they will be prompted to use the Coral Identification for Curacaoan coral species (Coral IDC) page on the CARMABI research station website: (http://www.researchstationcarmabi.org/research-station-carmabi/publications/coral-idc-montastraea/)

In addition to the coral ID guide, students will receive a guide I have made on how to use Photoshop to color-code the coral species. The teacher will be receiving a completed key to each orthoprojection site so that she can easily compare the student's work with the correct and complete color-coded orthoprojection (shown in Appendix B). Once the students have finished identifying and color-coding all of the coral species, they will run a

diversity index with each site. Once the students have determined the biodiversity of each site, they will compare their results with each other and determine if the biodiversity of coral species varies around the island. At this point, each group will do a research project that will require them to research different human and environmental impacts around the island to see why biodiversity might vary. The use of the photomosaics in this manner is an opportunity for students to explore local science in an engaging and interactive way.

Girls in Ocean Science Conference

I.

Earlier in the year an opportunity presented itself to test how exciting and engaging the photomosaics could be to an audience outside of the Scripps community. Every year, the Ocean Institute in Dana Point, CA, holds a "Girls in Ocean Science Teen Conference" event. The event serves to inspire young women to pursue careers in the sciences. The event invites eight female scientists from around the country to come and work with the girls in a series of hands-on workshops. I was asked to participate in the February event as one of the eight visiting scientists to work with the girls.

II.

With the help of Clint Edwards and Yoan Eynaud, I was able to have a hands-on activity for the girls to participate in that introduced them to studying coral reef ecology with the use of the photomosaics. The activity required: Microsoft Surface tablets and track pads provided by the Ocean Institute, Photoshop, and a statistical computing program titled R. On a day-to-day basis, we use Photoshop to trace and color corals, which requires many color options for many different coral species in one picture. However, the activity for each group of girls was to last approximately thirty minutes. Because of the limited amount of time to work with Photoshop, we used a simplified version that only allowed for two color choices and to focus on only three coral species. The purpose of the activity was to create a competition between the groups of girls to see which group could trace the most amounts of corals the most accurately within the allotted thirty minutes. Each group was given a sheet of paper I created with directions on how to use Photoshop on the Surface tablets and a cheat sheet of what each target coral species looked like (seen in Appendix C). Once the thirty minutes was up, their results were uploaded into R, which would compute

which group was the most accurate, thus creating a winner. The activity was a big hit and even received praise in the local newspaper, *The Orange County Register*. A link to the article is included in Appendix C.

Discussion

Seeing a 3D video of an actual coral reef that was created from images people took themselves is nothing short of amazing, at least to me it's not. The inspiration I felt when I first saw that 3D photomosaic video was the driving force behind my Capstone project. That image was powerful to me and I was determined to be involved in that project in some way or another. What I wanted was to carry that experience with me in the hopes that others would react in a similar way and also want to be involved.

The Dive Industry

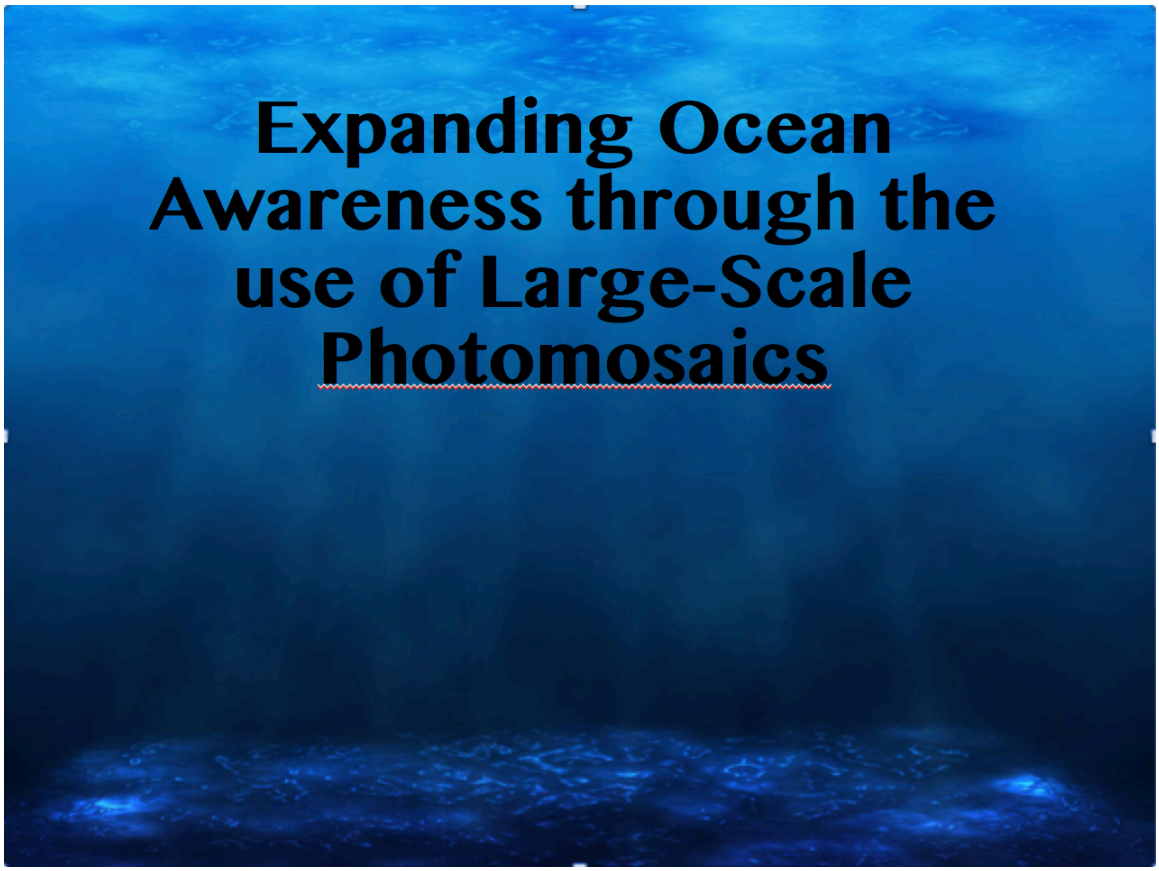
My initial idea was to bring this technology and imagery to a group of people that already have a relationship with the ocean and with coral reefs, and to use this imagery in a way that would reignite the reason they become involved with the ocean in the first place. The dive industry appeared to be a perfect target group. They are a group of people who by nature are natural historians that see the reef and witness its transformations over the years. From the small sample of dive shops I was able to interact with, I found that the dive shop owners found interest in using the photomosaics for the benefit of their shop. There was a stronger business mindset than there was a conservation mindset. There was also concern that the photomosaics had the potential to take away business. If dive shop owners had 3D photomosaic videos of their local dive sites on their website, some feared it would turn away business if customers were unimpressed with how the reef looked. Dive customers also found great interest in the photomosaics and offered helpful suggestions for ways they could benefit from it. The desire from the customer's perspective was to interact with the photomosaics in a way that would teach them about what they are seeing on their dives. This showed a desire to learn and presented an opportunity to create more awareness and stewardship through learning. The limitations that presented itself however, was creating the products they wanted with what is available to us right now. As is, a 100 square meter plot that shows only coral requires a high performance computer that can store and process images holding up to one billion points of information.

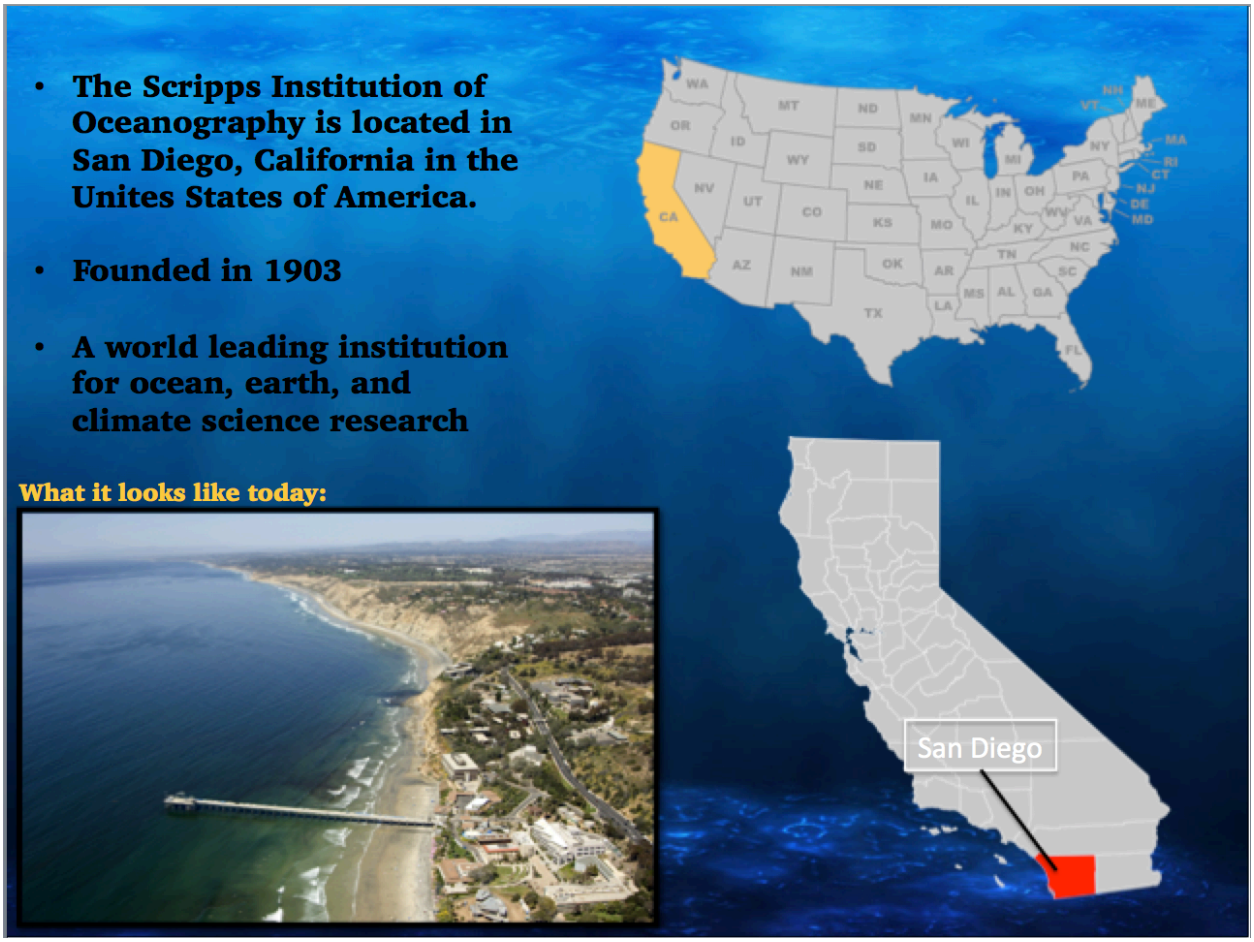
Moreover, it is a time intensive procedure. The amount of time it currently takes to process the images from a 100 square meter plot is one to two weeks. The computer and software available to us now does not have the capability to store the amount of information that would be required of a plot the size of an entire dive site, the addition of fish and coral identification tools, or the addition of navigational tools. Furthermore, the creation of these products was not possible within the time frame allotted for my Capstone.

The Local Community

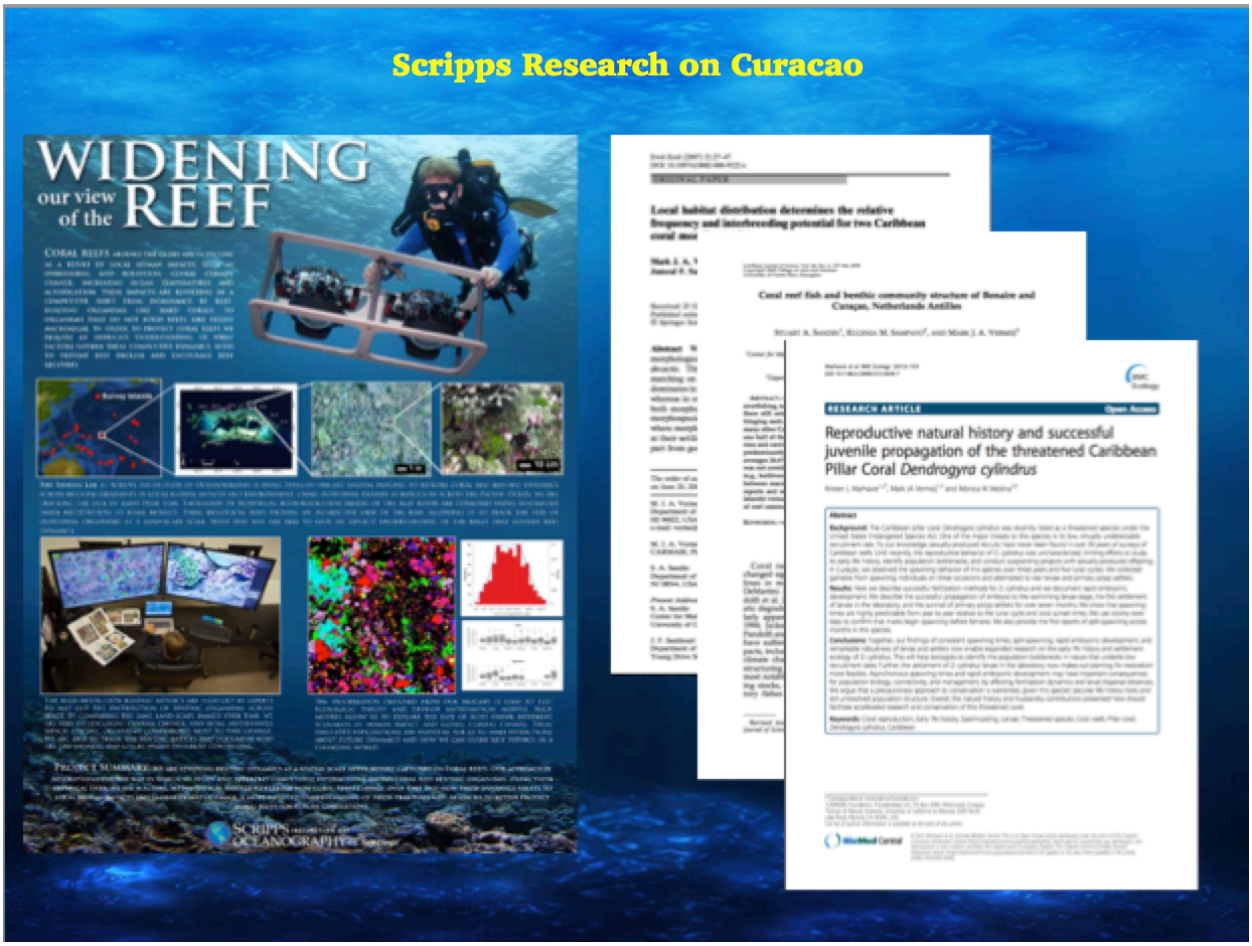
While in Curacao, I learned there was a great opportunity to show the photomosaics to local school kids. Though this was not the direction I intended for my Capstone, it turned out to be a beneficial area of focus. Given that my goal was for the photomosaics to be used in a way that would increase ocean stewardship and awareness, having them be used for education and outreach is a better approach than being used in the dive industry. In any part of the world, kids "hold the key to the future" and the most change will come from the younger generations. I realized that I was approaching this project with an idea of how the photomosaics would be useful to Curacao without getting to know Curacao. It took spending some time there, albeit a short amount of time, to understand where there was a greater need and where the photomosaics could be the most beneficial. In addition to there being a greater need, there were no limitations in order to move this direction. The 3D photomosaic videos and 2D orthoprojections are readily available tools and have the ability to be used in other capacities such as for education and outreach. The Carmabi Marine Education Center is an incredible resource for the local community. Thousands of kids come through the Carmabi Foundation each year to learn about the local environment. With the addition of the photomosaics into their existing curriculum, it creates an opportunity for kids to experience science from a new and exciting platform that is also accessible to them. Lisa Cook of the International School of Curacao plans to use the photomosaics with her students year after year. Incorporating the photomosaics as an on-going project will help connect more students and organizations with the Carmabi Foundation as well as have them be a part of local science.

Appendix A

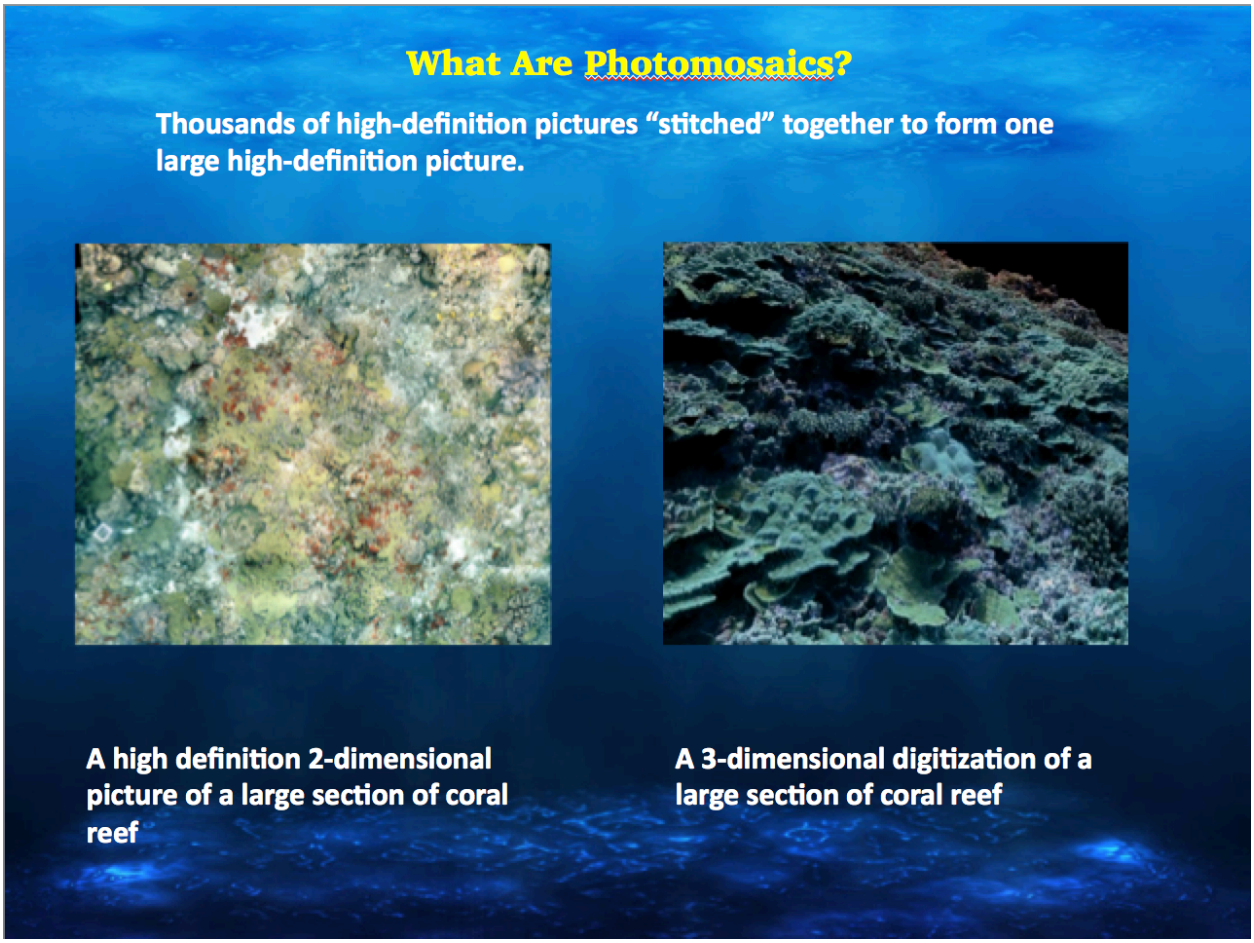

Expanding Ocean Awareness through the use of Large-Scale Photomosaics



Scripps Institution of Oceanography started as the San Diego Marine Biological Station in 1903. It was renamed Scripps Institution of Oceanography (SIO) in 1925 in honor of the support of Ellen Browning Scripps, a well-known philanthropist. In 1960 it became it's own department within the University of California at San Diego. To date, SIO has 103 professors, 82 researchers, and 294 graduate students. Three Nobel Prize winners and 17 National Academy of Science members have come from Scripps Institution of Oceanography. It is one of the world's leading institutions for ocean, earth, and climate science research.

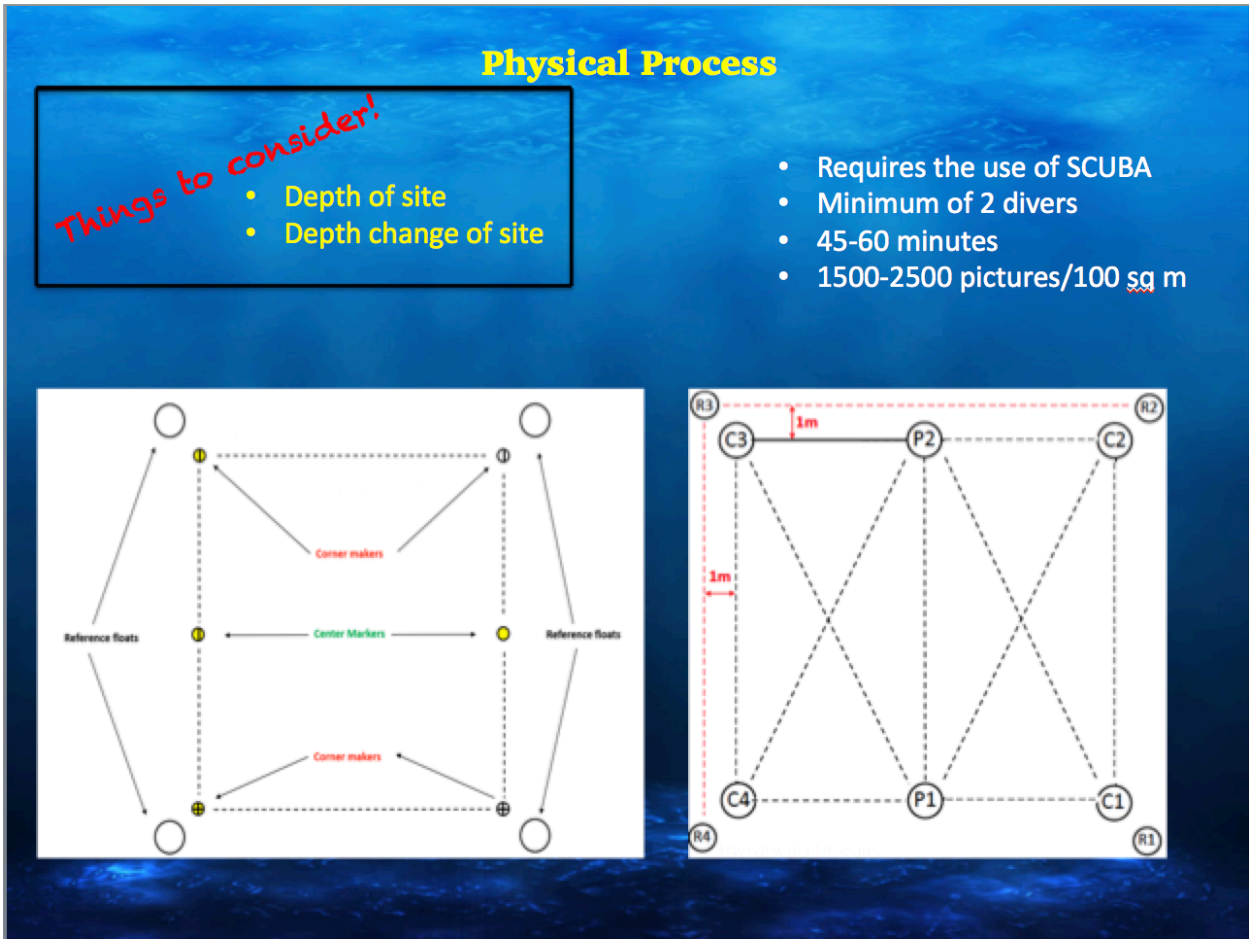


The Sandin Lab at Scripps Institution of Oceanography is conducting studies of the coral reefs around the island of Curacao with state-of-the-art technology. Since 2014, researchers have been collecting images of the coral reefs and turning them into what's called "photomosaics". The reason Curacao is one of their target sites is because it still has some of the healthiest reefs in the Caribbean.

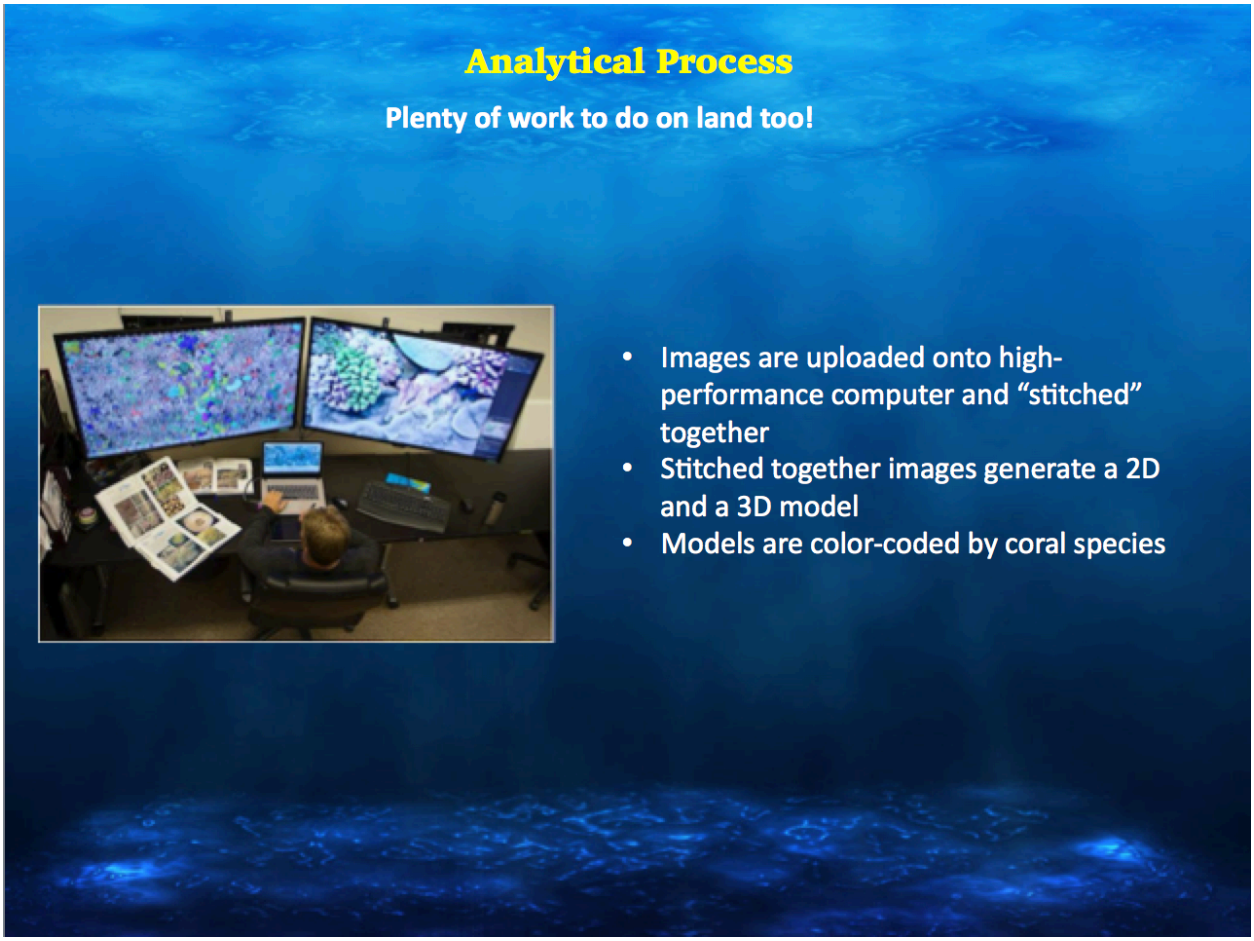


What exactly are photomosaics? In short, they are thousands of high-definition pictures that get stitched together to form on large high-definition image. There are two ways in which a photomosaic can be viewed. One is a two-dimensional picture, which can be viewed like a normal picture. This is called an orthoprojection and looks at the reef from a birds eye point of view. The other is as a 3-dimensional image, which requires special software to be able to view and work with it.

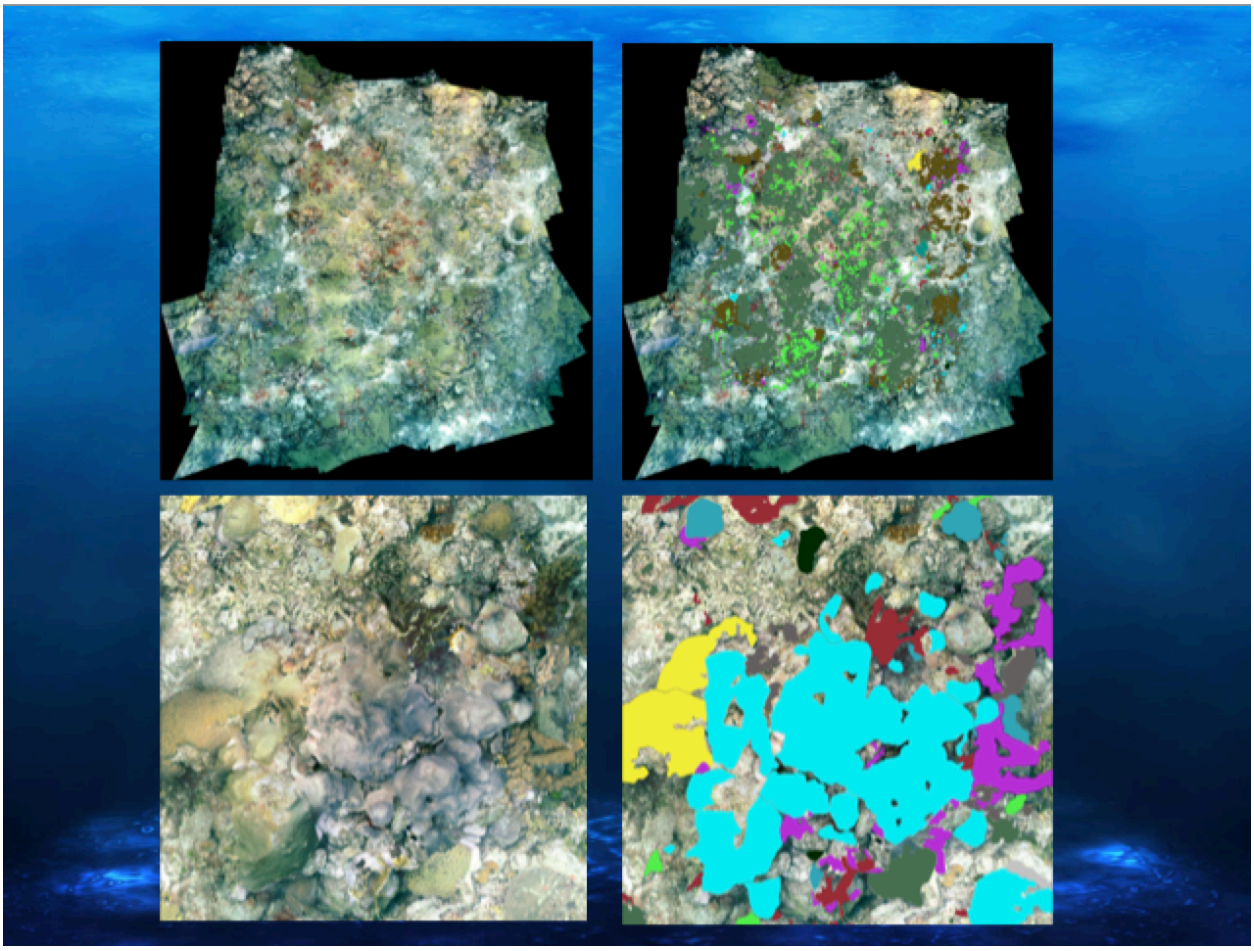
The photomosaics are collected through the use of SCUBA. In addition to the usual SCUBA gear that is needed, there are the appropriate materials to collect the images. The DSLR camera or cameras are used with the underwater housing and uses a wide-angle lens to ensure high overlap among adjacent images. Images are simultaneously captured every second from the DSLR camera, while the GoPro continuously captures HD video. The reference floats and plot markers help the driver of the camera to know where he or she is within the plot. The transect tape is used to measure the size of the plot and between the marker points which helps when calibrating the images later.



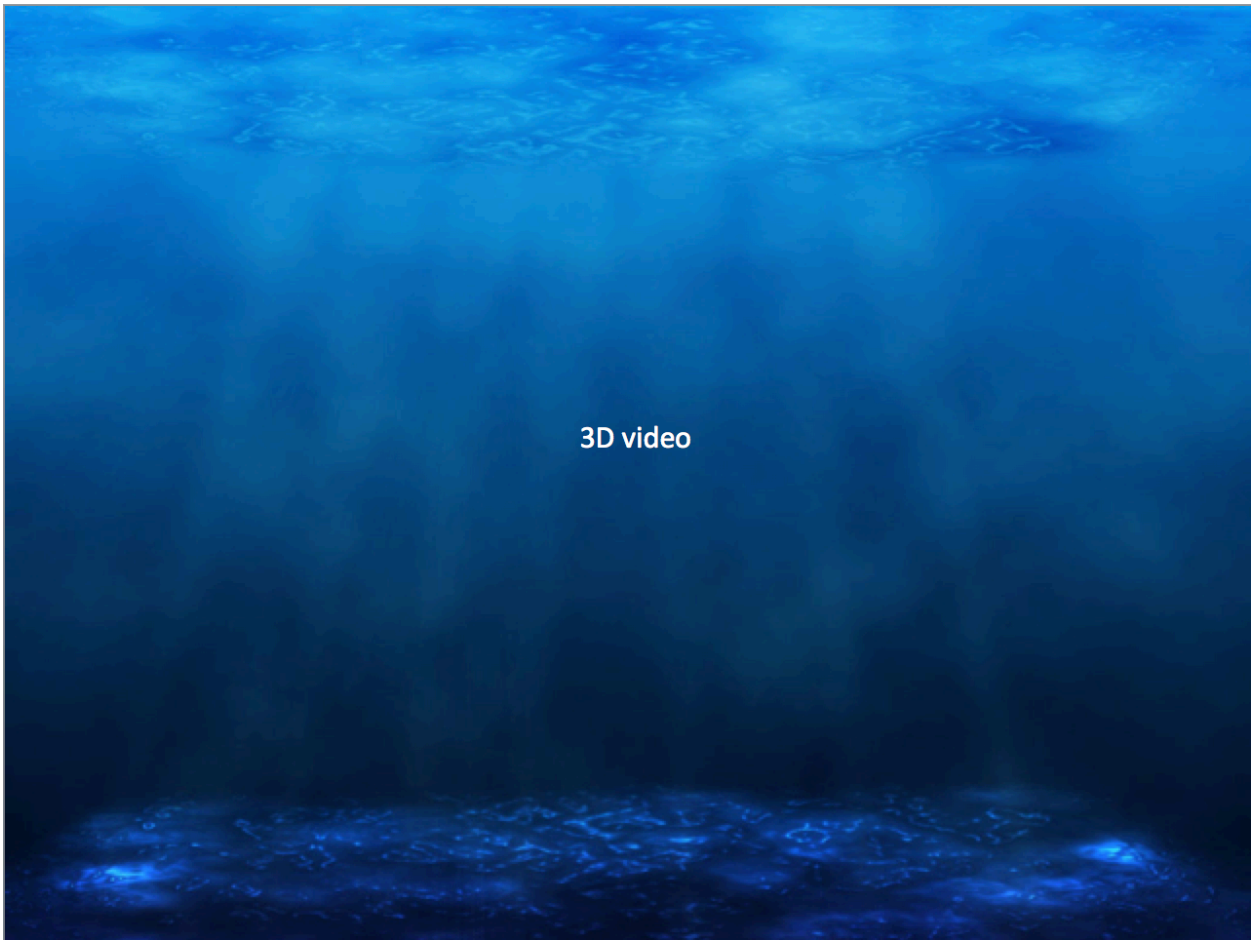
To physically get the photomosaic images, it requires the use of SCUBA. While 2 divers are all that is needed, the process is easier with 3 divers. There are two main things to consider when picking a plot location: depth and depth change. Depending on conditions, a single mosaic will take 45-60 minutes. The deeper a diver is, their air will be used at a faster rate, which will ultimately affect overall dive time. Moreover, it can be physically stressful on the diver to swim up and down a steep plot multiple times while collecting the mosaic images. For these reasons, it is best to pick the location of the plot where there is not a great depth change (i.e. on a steep slope) and in about 10m of water. Once the plot location is determined, the divers will begin the process of setting up the plot and collecting images. The plot will have four floats, one on each corner, to serve as easily visible reference points of the edges of the plot. These will each be 10 meters apart forming a square. Weighted markers will be placed 1 meter inside of the floats, four corner markers and two center markers. These will serve as reference points as well for the diver collecting the mosaic images. The picture on the left shows how the plot should be set up, while the picture on the right shows all the measurements that need to be taken. Measurements are taken between all four corner markers and the cross-sections you see in between them. Each 100 square-metered plot yields 15-2500 pictures.



It's important to note that involvement with these photomosaics requires work both in and out of the water. Once the pictures have been collected in the field, they are brought back to the lab and uploaded onto a high performance computer where lab members work closely with structural engineering and computer software departments to stitch the thousands of images together. This process usually takes 1-2 weeks.



This shows an overview of the reef before and after the coral species are color-coded. Each color represents a different species of coral. One large image like this can have thousands of individual corals to identify and color-code. The images on the bottom show a closer look.

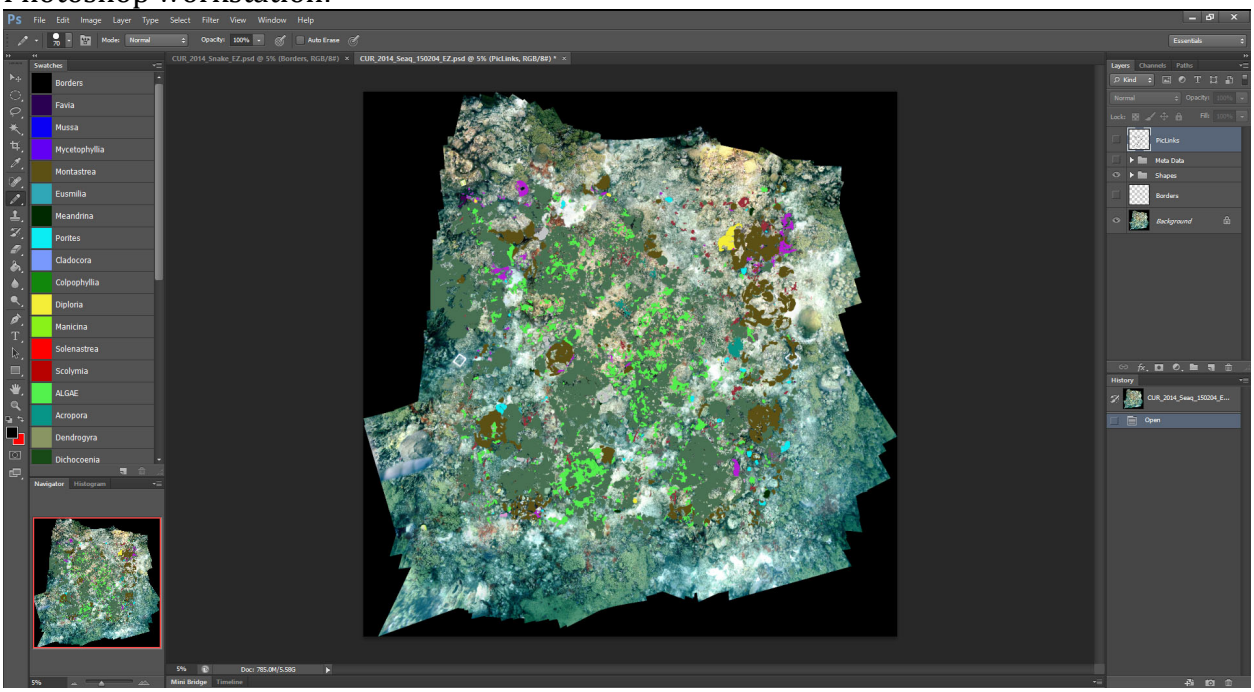


In addition to creating a high-definition 2-dimensional model of the reef, they are able to create these 3-dimensional models as well. This happens to be a video of a 3D model, which is created using software designed by a Scripps colleague. Students in the lab work with the 3D models as well as the 2D ones seen before to identify coral species and color-code them as well. All of this work is put towards understanding how things are changing over time. By coloring in each species of coral, it measures the amount of area they are covering. That information gets put through a mathematical program that measures overall coverage of each species. Year after year this will change and we can see which species are growing or shrinking and better understand their dynamics.

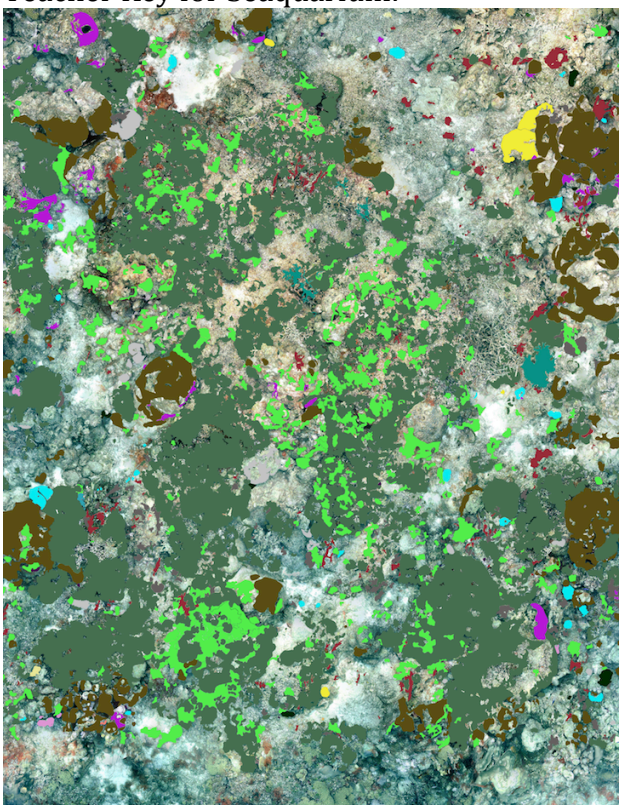
Scripps Institution of Oceanography with the help of Carmabi, is exploring this way to study coral reefs and recognizes the need for this in a scientific application. But it's important to know there are other useful applications for this technology. Marine drug discovery is an important field and a company in San Diego is starting to use these photomosaics for their business. This is an exciting and emerging field that needs the involvement of people like all of you.

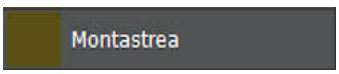
Appendix B

Photoshop workstation:



Teacher Key for Seaquarium:





(More coming soon)

Appendix C

Cheat Sheet

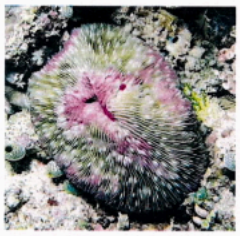
TYPES OF CORAL

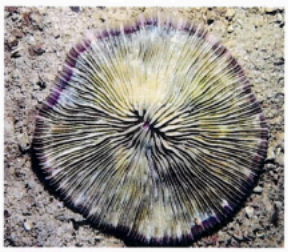
POCILLOPORA

- Little bushels – Not the pink parts!

FUNGIA

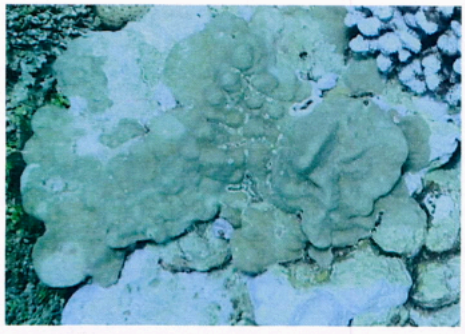
- singular and round – looks like underside of a mushroom

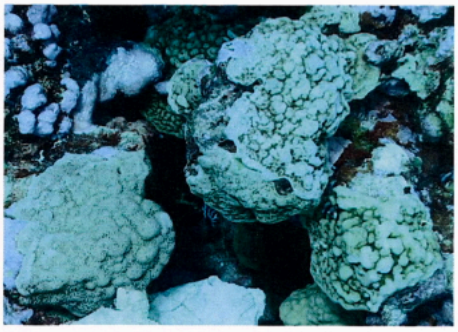




PORITES

- encrusting – plate-like – lighter in color – does NOT have a white edge





Photoshop guide

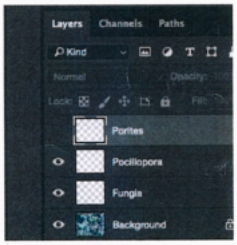
IMPORTANT COMMANDS

TO TRACE THE CORAL:
- Hit the "B" key on the keyboard
- Select **black** as the color at top right of screen
- Make sure to connect the ends!

TO FILL IN THE CORAL:
- Hit "G" on the keyboard
- Select **red** as the color at top right of screen
- Look at the top toolbar, make sure "contiguous" is selected
- Click in the middle of the image you traced

TO FILL IN THE BACKGROUND:
- Hit "G" on the keyboard
- Select **black** as the color
- Look at the top toolbar, make sure "contiguous" is NOT selected
- Click anywhere on the background

TO MOVE FROM ONE SPECIES TO THE NEXT:
- When done with one species, click the "eye" to turn the layer OFF
- Click the NAME of the next species you will work on
- Repeat!



TO ZOOM IN AND OUT:
- Hold the "Z" on the keyboard
- Click on the image and move diagonally from top left to bottom right

TO MOVE THE IMAGE AROUND:
- Hold the space bar
- Click on the image and move it around

TO UNDO A COMMAND:
- Hit "Command-Z" on the keyboard
- If that does not work – ask me!

References

Balm, James. "The Power of Pictures. How We Can Use Images to Promote and Communicate Science - BioMed Central Blog."*BioMed Central Blog*. BioMed Central Open Access Publisher, 11 Aug. 2014. Web. 23 May 2016.

“IUCN, the International Union for Conservation of Nature.” *IUCN.*N.p., 29 Sept. 2015. Web. 2526 May 2016.