

Using underwater video to observe aquaculture gear in Long Island Sound- A Citizen Science Guide

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Introduction

At the NOAA Fisheries NEFSC Milford Laboratory, we are studying interactions between shellfish aquaculture gear and the environment. We are using video from action cameras to document how off-bottom oyster aquaculture cages provide habitat for fish in Long Island Sound. Anecdotal observations from shellfish growers suggest that fish may utilize oyster cages as a food source, for shelter, refuge from current flow or protection from predation. Shellfish farms with many cages add structure to the seafloor and may serve as an artificial reef, attracting greater numbers of fish than found on bare bottom. Our study compares fish interactions with oyster cages to fish activity adjacent to natural structure on a rock reef (see Mercaldo-Allen et al. submitted)

To collect video, we chose action cameras (GoPro Hero 3+ silver) because they are small, inexpensive, easy to use, provide good quality video, and can support high speed and capacity memory media (e.g., SDHC or SDXC cards based on current technology). To observe fish activity, two cameras were mounted to each oyster cage, providing top and side views of the cage structure. To collect video over a full tidal cycle and all daylight hours, we used a timer compatible with the cameras that allowed us to conduct underwater recording at 8-minute intervals every hour for 13 hours. We also developed a “t-platform” stand system for mounting cameras that allowed us to collect video among boulders and at other natural habitats while minimizing addition of new structure to the natural habitat. Our collaborators have also used a more recent camera model (Hero 7) and relied on time lapse photography since a compatible timer is not yet available.

Our study has demonstrated the utility of GoPro® cameras as a tool for observing aquaculture gear in Long Island Sound and other marine environments. This guide, which builds on our experiences, describes how to capture, edit and view underwater video images and is intended for those familiar with digital cameras. This document has been updated to include newer camera models and methods used by our collaborators at Northeastern University and The Nature Conservancy at other locations in the Northeastern United States. A list of supplies and brands we tested are included in this document. NOAA and the NEFSC do not endorse GoPro® or other branded products described here.

Cameras

GoPro Hero 3+ and Hero 4: GoPro Hero 3+ and Hero 4 cameras can be used underwater by adding a waterproof dive case (choose 40 or 60-meter depth). Cameras require a battery, data or SD card and access to the internet for programming. The Hero 3+ and 4 are no longer being produced but refurbished models are available online through third party sellers. GoPro is no longer providing new firmware updates for these models. The final firmware update was released in 2016 and can be accessed through the website.

Photo below shows a Hero 3+ Silver camera in a 40 m dive case



Updating firmware: The process for updating camera firmware is similar for all camera models and is accomplished at the GoPro [Website](#).

The first five steps apply to all camera models:

1. Go to the GoPro [Website](#) and create a free GoPro account
2. From the GoPro home page, click 'Support' on the top navigation bar on the right side. This is depicted as the headset option next to the search icon.
3. Click on 'Update Page', located on the side panel or in the gray box under the search banner.
4. Select the 'Product updates' box
5. Click 'Product updates' on left navigation bar
6. Select 'Hero 3+' or your correct camera

The following instructions are specific to the 'Hero 3+' and steps for other models may be different:

7. Select 'Update manually'
8. Enter GoPro serial number (located in the battery area of the camera), enter email address and click next
9. Select update type and click next step
10. It is best to set up WiFi and Firmware the first time you update cameras. Setting up WiFi information makes it easier to use the GoPro App and tell multiple cameras apart
11. Follow directions for entering a camera name and password for WiFi set up. Select Next Step
12. Follow the prompts to continue
13. Wait for the 'Download' button to become blue and click to download
14. Open your "downloads" folder. Unzip folder by right clicking on the file folder and selecting 'Extract All' and designating where you would like to save it
15. Insert a microSD card from the camera to the computer via a microSD card reader/writer. We used the Vivitar Ultra Slim SDHC Card Reader/Writer.
16. Move the extracted folder to the USB drive and eject drive once transfer is complete
17. Put SD card in camera
18. Turn camera on and the update will automatically begin

19. The camera will flash 'Updating' before it turns off. As long as you do not see a 'Camera Update Failed' message, the update was successful. If you are unsure the version number will show on the camera as you turn it on.

Free software/apps to control cameras and view/manage video files: GoPro offers two desktop computer apps and a tablet app for managing and editing video and programming cameras.

GoPro Quik desktop computer program:

Allows you to take clips and still photos from your video. You can also rotate videos in this app. Rotations applied within the app are saved but this process may alter the sizing. If rotating 90 degrees the field of view is reduced, as seen in the figure below. For this reason, we recommend mounting cameras to capture the desired view instead of altering the video file afterward.

Photo below shows the correct orientation of an oyster cage



Photo below shows the cage has been rotated and much of the view is lost.



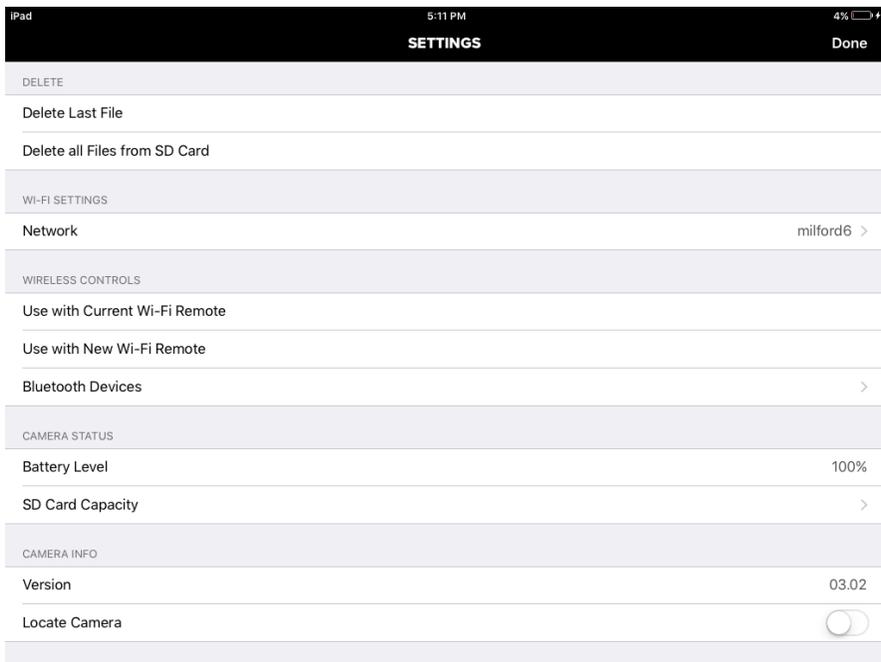
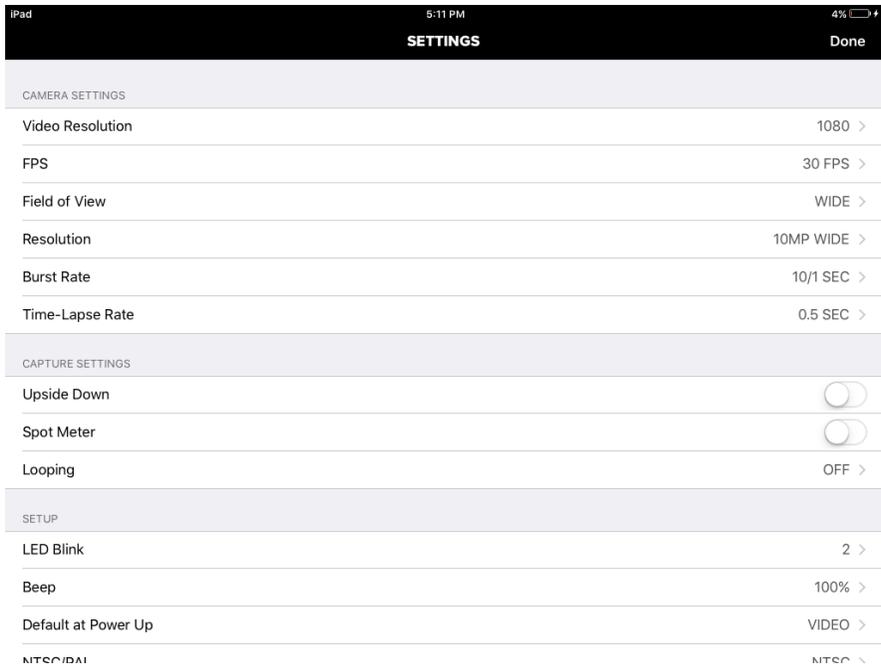
GoPro Fusion Studio desktop computer program: This program provides more advanced video editing than the GoPro Quik program, including clipping and playback speed, as well as alterations to the videos themselves such as color, volume, balance, contrast, and others. Using this app will create multiple copies of your video during the editing process. These copies increase your storage capacity needs. An alternative would be choosing a different image/video software, such as Adobe Photoshop. We have not explored other options, but note that alternative software may require additional cost and/or knowledge. Note: GoPro no longer supports this version of the program and has transitioned to more 360/3D editing software that works well with direct pairing of cameras. The new software GoPro Player (Mac) and GoPro MAX Exporter (Windows) is available on the website.

GoPro Mobile/Tablet app:

This app can be used with a smartphone or tablet. Both Apple and Android versions are available. We found this app useful for checking camera settings, syncing times, ensuring WiFi is on/off, monitoring battery level, and clearing SD cards. Before connecting the camera to this app, update the camera firmware and enable custom WiFi settings, especially if using more than one camera (see step-by-step directions above under “Updating Firmware”). Additionally, you can update your firmware through the mobile app when the camera is connected to the internet. Steps for this are not included in this document. There are also additional video editing features within this app that can be used to create and share video clips. We have not utilized this feature to date. Note: This app has been updated and includes basic editing and can post directly to social media.

To connect camera to the app:

1. Download and open the GoPro App on device
2. Enter your GoPro App username and password. If you have updated the firmware on your camera (see step-by-step directions above under “Updating Firmware”), the login you created is also used in the mobile/tablet app.
3. Click “Connect to Camera”
4. Select “Add New”
5. Select Camera Type and follow prompts
6. Turn on Camera
7. Turn on WiFi, wait to connect. If camera and WiFi doesn’t immediately pair or prompt you for the camera password, then press continue. This will take you to the device WiFi page to connect directly
8. Once connected, return to the GoPro app, this should automatically take you to the camera view. On this page you can take pictures or videos using the app, look at media on the camera or change camera settings.
9. To change settings, click on the wrench icon
10. Use the Time and Date setting if you have multiple cameras to ensure that all cameras are synced to the same time
11. Once you connect cameras to the app on WiFi, you can use the app in the field via WiFi or cellular connection



Our camera settings: Camera settings can be easily changed using the GoPro mobile app for smartphones and tablets.

Resolution refers to the pixel dimensions within the video captured by the camera. Higher resolution yields better video quality, but also creates larger video files. We used 1080, 10MP WIDE for the video resolution in our project.

Field of View refers to the portion of the camera sensor that is used to capture video. The larger the field of view, the more of the scene in front of the camera is captured. We used the Wide setting. Other settings may result in distortion, and it's best to test your camera to optimize this setting prior to deployment.

FPS or Frames per Second refers to the number of frames captured each second by the camera. Higher frame rates produce better quality than slow motion video. We have found that slowing video playback can be useful when identifying fish in suboptimal light conditions however, higher frame rates also increase file sizes. We used 30 FPS in our project.

Additional note: We also turned off the “LED Blink” and “Beep” to eliminate noise and the blinking red light while recording (sound or light could serve to attract or repel fish). In order to do this on the GoPro App click “LED Blink” and select “Off to turn the light off. To turn off noise, select “Beep” and select “Off”

Tips for putting a camera underwater: WiFi will not work once the camera is underwater so all camera setup should be done prior to deployment!

Dive cases: Two case options are currently available for this camera model; both are waterproof to either 40 or 60 meters. When purchasing accessories, it is important to note which case style you purchase to ensure compatibility.



Photo above shows front view of dive cases rated to 40 m (left) and 60 m (right)

Photo below shows the top view of dive cases rated to 40m (left) and 60 m (right)



Lubricant provides additional waterproofing and camera protection:

Use silicone or synthetic lubricant to protect metal parts, seawater is very corrosive. Add a small amount of lubricant to dive case O-rings to ensure a tighter seal and protect cameras from water damage. Add a small amount of lubricant to any metal fittings exposed to seawater (i.e., GoPro thumb screws) to prevent seizing of the metal, and prevent rusting. This simple step will protect your cameras and extend the life of your equipment.

Camera troubleshooting and other helpful tips:

Check to see if a firmware update is available: Check that you are using the most recent camera firmware. Older cameras are less likely to be updated but should be checked periodically. If you are running into issues such as camera turning off, not recording or changing settings then re-download the firmware and update.

Battery troubleshooting: Ensure battery is fully charged and not damaged. Batteries will have reduced recording capacity underwater when water temperatures are low.

SD card: SD cards must be formatted to be compatible with the camera. Newer camera models with higher resolutions may work better with a MicroSDXC instead of a MicroSD card as the memory writing capacities are different. The SD card that comes with the camera will already be formatted. If you are running into recording problems, you may need to reset the SD card. Back up any files from the SD card first. Insert card into the camera. Open the GoPro Mobile app, connect it to WiFi, then select “Delete all SD Files”. The app will ask to “Format SD card” which will correctly set up the card for new GoPro files.

Camera Waterproofing tips:

1. Check that O-ring seals are present and intact as this keeps the case waterproof. Grease O-ring seals with silicone lubricant to aid in secure sealing of the case.
2. Check for cracks in cases. Check that the clip holding the case together is tight fitting and not cracked or otherwise broken.
3. Ensure a tight fit: Camera should not move around in the case. Change the backing if necessary.
4. Water-test a case without a camera in a bucket of water. Although this does not simulate the increased pressure experienced at depth, it is a good place to start.
5. If cameras are deployed in the intertidal zone, the sudden temperature changes that occur when the tide comes in and submerges the case/camera may cause leakage. Proper lubrication of O-rings is especially important in these situations.
6. Silica gel packs placed with cameras during storage can help absorb water and prevent water damage.

Camera Accessories

Magenta Filter: Used to balance the color and reduce green tones or cast in video and/or photos, reducing the need for post-processing. We used the PolarPro GoPro Magenta Filter – Hero4, which is compatible with Hero 3, 3+, and 4 cameras. Separate filters are sold for the 40 vs. 60 m dive case.

Photo below shows 40 m dive case with no filter (left) and with PolarPro magenta filter for GoPro Hero 4



Although effectively correcting for green water coloration, filters considerably reduce the amount of light entering the camera. Therefore, magenta filters are most effective in shallow water depths (<20 feet). Lower light levels at greater depths may require use of post-processing rather than filter correction.

Post-processing refers to manual editing of video using software (see above section on software available from GoPro) and can include balancing video color by adding red back into the video to reduce green coloration. This process requires creation of multiple copies of the same video file, which increases storage requirements. Additionally, converting and editing video files is very time consuming.

Similar filters can be found for newer camera models on third-party sites such as Amazon by searching for magenta filter + your camera model. Options may also include red filters although we exclusively used magenta for our field trials.

Photo below shows image taken without filter (left) and with magenta filter added to camera (right)



Extended backdoor attachment for the GoPro underwater case: BacPac for GoPro is an extension of the GoPro dive case, which allows space for other camera accessories that should be kept waterproof. We used the Vicdozia Waterproof BacPac Back Door Case that is compatible with the GoPro Hero 4/3+ Standard Housing Case. Similar cases can be found for newer camera models through third party sellers.

Photos below shows a top down view of the standard dive case (left) and with addition of the BacPac (right)

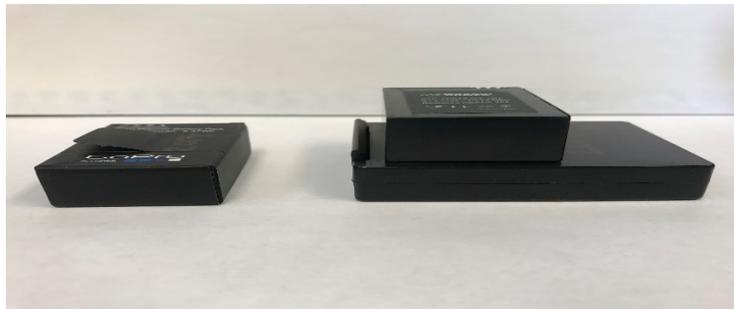


Photo below shows a side view of the standard dive case (left) and with addition of BacPac (right)



Extending battery life through use of a double battery: If length of video recording is limited by battery life and not memory card capacity, the addition of a double battery can increase recording time. Using a double battery underwater requires adding the extended backdoor attachment to the standard dive case (see above). Water temperature greatly affects battery life, lower temperatures shorten battery life and reduce recording time. Important note: when a battery is removed the time and date is reset on the GoPro! Keep in mind if using multiple synced cameras in your project!

Photo below shows a single battery (left) and double battery (right)



Blink Timers: Blink® by CamDo is a programmable timer that can be used with some GoPro camera models to automatically record for set intervals of time after deployment. The Blink attaches directly to the back of the GoPro camera, uses the GoPro battery to operate and is programmed using a cellular- and WiFi-enabled device. Use of a Blink requires the addition of an extended backdoor attachment on the GoPro dive case (see above). Once removed from the camera, the Blink must be reset. Blinks turn the camera on and off at preset times. We have used Blinks for two primary functions in our project: 1) To delay the onset of recording in order to allow fish communities time to recover from the disturbance of camera deployments, typically 18-24 hours; and 2) To extend the battery life by recording short video intervals over a much longer time period than would be possible by continuous video recording. Our project records 8 minute videos over 13 hours, in order to capture video from most daylight hours and over a full tidal cycle.

All setup and troubleshooting documents are available for download on the CamDo [website](#). Step by step instructions are provided on the website, including pictures of the set-up process.

We do recommend updating the software to the latest version upon purchase of the Blink and checking frequently for updates. Because setup of the Blink timers is accomplished through a WiFi connection, programming of the device on a cellular network will allow for easier configuration.

If the Blink software is updated after use, then select “Clear All” the next time you use it. If not, the Blink will not operate properly.

The extended backdoor attachment that we used (BacPac, see above) provides enough space for either a second battery or a Blink, but not both!

Blinks have been updated to the [BlinkX](#) for use with Hero 5 – Hero 8 models but require hardwiring into the camera and may need an external battery source depending on the model. Additional information can be found on the Cam-Do website listed above. Due to these limitations this product cannot be used in conjunction with off the shelf accessories to function underwater. Custom built aluminum housings are currently recommended if time lapse is important to your individual project needs, however, this option can be expensive.

GoPro Smart Remote: The [remote](#) can turn cameras on remotely when connected via WiFi. You can turn on and start recording using multiple cameras simultaneously if previously paired with the remote. This can be useful for remote deployment or syncing the start of video. When pairing the remote, the Wifi may need to be specified between GoPro App and the Remote. If you need to adjust the camera settings but plan to start recording with your remote, then you will need to change the Wifi settings back to remote once settings are complete. Instructions detailing this process are included with the remote

Desiccants: Cameras used in underwater studies, especially the earlier non-waterproof cameras, are continually exposed to moisture. Storing the cameras in a Tupperware that seals along with a desiccant can ensure cameras dry out and prevents damage. If there are large differences in temperature during camera deployment (for example in intertidal systems) GoPro makes [anti-fog inserts](#) that can be used to prevent lens fog. Desiccants are generally reusable and inexpensive and extend the life of your cameras.

Fisheye Lens: We tested the Inon® UFL-G140 SD Underwater Semi-Fisheye Conversion Lens attachment available from Backscatter to increase the field of view captured by the GoPro cameras. Specifically, we used the lens to look down at the top horizontal surface of our oyster cages. The semi-fisheye lens provided a wider field of view than the standard GoPro lens but the curved lens wasn’t compatible with the flat magenta filter we used to remove the green color from video (see above). The lens was also quite heavy, requiring construction of a PVC frame to support its attachment to the buoy lines. The video captured by the lens was also somewhat distorted at the edges. For these reasons, we ultimately did not use this accessory in our project.

Photo below shows Inon® UFL-G140 SD Underwater Semi-Fisheye conversion lens (left) for GoPro hero silver 3+ camera (right)



A PVC bridle with 1-inch mesh was used to mount the GoPro camera with attached semi-fisheye lens situated above the oyster cage with a view looking down.



Photo above shows PVC bridle to support camera with semi-fisheye lens

Camera Field Deployment

Altering video orientation using GoPro software: *Upside down* is a camera setting that allows you to capture video in the opposite orientation of your field of view. This option reduces the need to fix camera positioning through post-processing, which is time consuming and can result in large video files.

Changing height and direction: Pivot arms can change the height and direction of cameras:



Photo above shows pivot arms for mounting GoPro cameras

A variety of mounting pieces are offered by GoPro and other aftermarket producers. Some pieces are available in both aluminum and plastic. Some pieces are curved. Some attach by clips or thumb screws or both. Combining these accessories with the pivot arms allow adjustment of camera angle and direction to obtain the desired view. Most of the mounting parts and pieces are interchangeable among camera models.



Photo above shows mounting accessories for GoPro cameras

Thumb screw tool: The thumb screw tool for tightening screws is a useful accessory for camera deployment. These, in combination with the 1-inch or longer thumb screws, make it easier to attach and secure cameras to a mount that is fixed on an object such as an oyster cage.

Attaching cameras to gear: We used materials that are readily accessible from local hardware stores whenever possible. Some examples include the following:



Photo above shows flexible hose mount for GoPro camera

The above picture shows the mount we used to attach a camera to a corner of the oyster cage. The mount is constructed from $\frac{1}{2}$ inch PVC pipe covered by $\frac{7}{8}$ inch marine reinforced water hose, secured with hose clamps. A GoPro quick release flat surface adapter buckle base is attached to a piece of PVC cut in half at the end to allow for mounting the base. The marine reinforced water hose has some flexibility, allowing the camera to hang down from the top of the cage and provide a view of two sides and also the cage-seafloor interface. This view of the cage-seafloor interface has been effective in capturing fish activity in our videos.

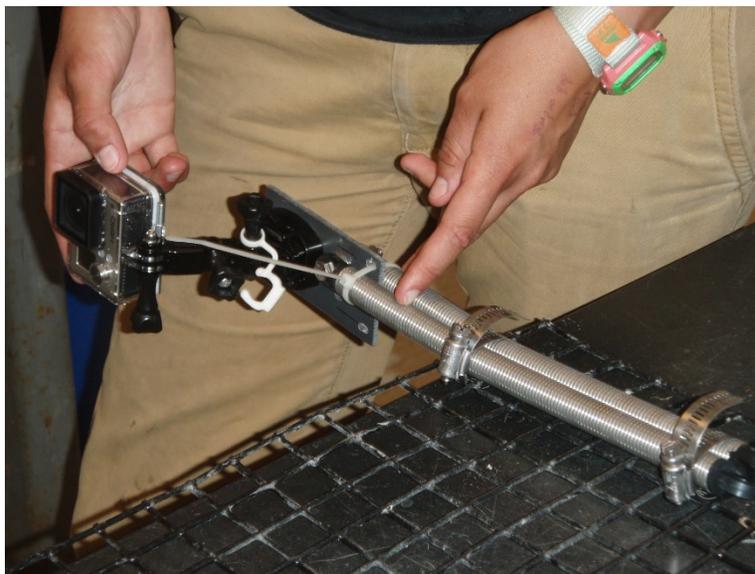


Photo above shows prototype spring mount for GoPro camera

The above picture shows an early prototype mount that we tested but ultimately did not use. This spring attachment placed at a corner of the cage provided more flexibility than the marine reinforced water hose, but unfortunately resulted in too much camera motion during deployments.



Photo above shows the periscope style mount used to view across top of oyster cages

We cut ½ inch PVC pipe to the height of the cage. We used a PVC 90-degree elbow to obtain the proper camera orientation. A GoPro quick release flat surface adapter buckle base was attached to a piece of PVC cut in half at the end to allow for mounting of the base.



Photo above shows T-platform base for mounting cameras adjacent to boulders on the seafloor

In the photo above, the X base was constructed using 1 5/8 inch Aickinstrut fiberglass channel with 90 degree brackets. One-inch vinyl coated mesh was bolted to the top of the strut, and a 5x10 zinc plate was bolted to the top of the mesh to provide ballast. A ½ inch floor flange was attached to the top of the zinc plate. Interchangeable ½ inch threaded black pipe was used to create custom heights based on the dimensions of each replicate boulder. The base was painted black to better blend in with the seafloor.

A few simple tips for optimizing video collection in the field:

Water depth: Areas in shallower water will yield better video due to higher light availability. We found that depths < 20 feet depth (mean high water) produced the best quality video in Long Island Sound.

Tidal cycle: Lower tide will allow for better light penetration. Slack tide may be a time of low current speed and higher quality imaging

Weather: Sunny conditions result in higher light availability. Days immediately following large rain events can have turbid/cloudy water, which reduces video quality.

More Recent Camera Models

GoPro Hero 7 Black: This model, used by our collaborators at [Northeastern University](#) and The Nature Conservancy, is currently available for purchase through GoPro and supported with firmware updates. This camera style is waterproof without an external housing generally to 10m. Other Hero 7 and newer models are similar but the location of the charging ports on the camera vary, which may affect compatibility of products like extended batteries or housings. One important way this newer model differs from the Hero 3+ is that no compatible timer is presently available for recording intermittent video segments, instead time lapse recording can be used to document fish activity at intervals and extend battery life.

Hero 7 Black Setup:

Camera settings: used for these field trials are set to:

- Timelapse video
 - 1 second recorded every 3 seconds
 - The frequency of time capture can be changed to record one second every 0.5-10 seconds. Here it is up to the user to determine the best settings for your individual project needs. The more frequent the recording time the more battery life consumed.
- 2.7k resolution
- **Wide** Field of View

Settings used here were applied at field sites in Cape Cod, Massachusetts both in intertidal and subtidal environments. Similar optimization was taken into consideration when selecting frequency of data collection, battery life, lack of delayed recording time and water clarity.

Hero 7 Accessories:

- [Power bank](#) is used to extend the battery life during recording.
- [Dive case](#) can be used in conjunction with the power bank above.

To increase waterproofing, the power bank can be wrapped in plastic and O-rings treated with silicone to increase seal strength underwater.

Photo below shows power bank wrapped in a plastic bag and taped to increase waterproofing.



Mounting system:

A tripod mount was used to connect a GoPro through ½ inch PVC with ¼ inch nuts and 2-inch screw (below)



Photos above show tripod mounting system

To view oyster bottom cages, ½ inch PVC was used to construct the stands. The height of the upright PVC piece was 30 inches. A 5-way PVC cross base was used to connect the upright and legs for the stand. Each leg was made from 1-foot sections of PVC and rebar. The rebar provided weight and stability and caps placed on the ends of the legs kept the rebar in place.



Photo above shows PVC mounting stands for cameras placed adjacent to oyster trays.

In the picture below is a mount created using the same materials as above but in a different configuration for floating cages. The arm with the GoPro extends 2 feet, with a 1-foot anchor points and a 0.5-foot leg down to the middle of the cage.



Photo above shows camera mount for floating cage

Data Management

Increase speed of file transfer: When transferring files, it is more efficient to use the same SD card reader used to transfer files on to a computer instead of using the USB cord provided with the camera.

Create a logical folder system to organize and store videos on your computer: Create a system for storing videos so you know when and where they were recorded. This will make it easier to find specific videos later. Start this process early before you have large numbers of videos or it may become confusing. **DO NOT RELY** on the “date modified” associated with a file to record when video was taken, because depending on the way a computer folder is set up, clicking on a file could change the date modified.

Video files are large – be prepared! How much storage you need depends on how much video and at what quality you record. As you increase video quality, the files produced will be larger. Video quality is controlled by the camera settings (see camera section of this document). Increasing frames per second and resolution will result in larger file sizes. The camera settings we describe in this document produce a 900 mb (0.9 gigabyte) file for each 8-minute interval of video that we record. Newer camera models and higher resolution defaults will require additional memory storage. However, the prices of large storage systems are decreasing.

Continuous video recording: If you record a continuous video file, the GoPro camera separates those videos into multiple video files for management. This helps for downloading and playback of videos.

If possible, it is a good idea to store your video in two places in the event of a technology mishap: External hard drives can be used to back up video separately from your primary computer. Cloud services like GoPro Plus offer an option for storing raw video files either in complement or as a primary backup option.

Video Analysis

What to do with video you create? Video clips can be great outreach tools, can be used for development or just enjoy the views! **Basic analysis** Using common computer applications such as Excel you can keep track of the fish observed in the video.

Free software exists to help you track and record what you observe in your videos: Behavioral Observation Research Interactive Software ([BORIS](#)) is a free downloadable behavior analysis software that allows you to set up your own analysis framework specific to your study. There is an [instruction and user guide](#) available online. You can use it to keep records of fish abundance of multiple individual species that you observe in your videos. You can also create variables for each of these individual species, so you can record activities such as feeding, moving in and out of the cage, etc. This software will require a time investment to set up a project and learn the program.

Useful links

[Capturing Life on Shellfish Farms:](#) Two NOAA-funded projects are documenting how shellfish farms interact with the environment

[Milford Lab's GoPro Aquaculture Project Page:](#) Using GoPro Cameras to Understand Interactions Between Shellfish Aquaculture Gear and the Environment.

Northeastern-Nature Conservancy [Partnership:](#) collaborating with oyster farmers to study how growing oysters can benefit people and nature

Rutgers [project](#) investigating fish and invertebrate interactions with oyster aquaculture gear and natural habitats using GoPro cameras in New Jersey.

Suggested Reading

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