INFORMATION

REPORTS

NUMBER 2018-06

FISH DIVISION

Oregon Department of Fish and Wildlife

A stereo video system for monitoring Oregon's Marine Reserves: Construction, testing, and pilot study of a convertible stereo system for lander and SCUBA surveys

Oregon Department of Fish and Wildlife prohibits discrimination in all of its programs and services on the basis of race, color, national origin, age, sex or disability. If you believe that you have been discriminated against as described above in any program, activity, or facility, or if you desire further information, please contact ADA Coordinator, Oregon Department of Fish and Wildlife, 4034 Fairview Industrial Drive SE, Salem, OR 97302
503-947-6000.

This material will be furnished in alternate format for people with disabilities if needed.
Please call 541-757-4263 to request

A stereo video system for monitoring Oregon's Marine Reserves: Construction, testing, and pilot study of a convertible stereo system for lander and SCUBA surveys

Ashley Knight, Oregon State University, ODFW Marine Reserves Fellow
Jessica Watson, ODFW Marine Reserves Program
Jaqueline Dixon, Oregon State University
Lindsay Aylesworth, ODFW Marine Reserves Program
Cristen Don, ODFW Marine Reserves Program
David Fox, ODFW Marine Resources Program

CONTENTS

I. Introduction

Accurate fish size measurements are important for understanding fishery management topics such as population size structure, growth rates, and biomass estimates. These topics are also important metrics for evaluating marine protected area (MPA) performance. Studies using stereo video fish length measurement techniques have been used to address some of these topics, such as tracking growth of juvenile Atlantic Cod (Elliot et al. 2016, 2017) and obtaining biomass estimates of Hake and Walleye Pollock (Boldt et al. 2018). However, MPA managers are only just beginning to use stereo video fish-sizing platforms (e.g. Walsh et al. 2017) to track long-term ecological changes in areas where fishing is restricted.

The use of stereo video to measure fishes remotely has been increasing over the past two decades and has advantages over traditional extractive measurement approaches (e.g. hook and line sampling). Stereo video allows researchers to measure fish without handling or bringing them to the surface, potentially decreasing mortality. Additionally, the video samples fish of all visible sizes in a system, avoiding "hook selectivity" (Alós et al. 2008). Improvements in technology have increased the range of camera options (Boutros et al. 2015, Letessier et al. 2015) as well as lowered the overall cost of systems. Similarly, improvements in the user interface of measurement software have allowed users to process stereo data more efficiently.

Stereo technology has been employed on a variety of video platforms, each with important features depending on the environment of the study area. Diver operated video (DOV) systems are one of the most common platforms, occasionally replacing divers who collect fish size data along transect surveys. The quality of DOV data in comparison to diver-estimated fish sizes have been shown to be highly dependent on divers' ability to estimate fish sizes by eye and as a reflection of their diver experience (Harvey et al. 2001a, 2004). There has been considerable research regarding the accuracy of fish sizes estimates made by stereo systems in comparison to those made by divers *in situ* (e.g. Harvey et al. 2001b, 2002), but many of these comparisons have been done in tropical waters where visibility is sufficient (e.g. >3 m). Lander platforms (often also referred to as remote underwater video, or RUV) are also common and can be deployed baited ("BRUV") or unbaited. Landers and BRUVs have merit in waters less appropriate for divers such as deep areas, rough seas, or when studying animals such as sharks (Watson et al. 2005, Langlois et al. 2010, Harasti et al. 2016, Watson & Huntington 2016).

Ocean conditions play a large role in the ability to use video imagery that can result in stereo measurements. Specifically, the visibility of the water effects both the video quality needed to make an accurate stereo measurement, as well as the ability for a diver to see a fish *in situ* and make an estimate of size. Some research has been able to link water conditions and stereo measurements (Hannah & Blume 2016). However, in an area such as Oregon, with perpetually capricious ocean conditions, the benefits and challenges of application of video techniques for long term data collection must be weighed carefully.

The following pilot study was conceived as project funded in part by a State Wildlife Grant (#F15AF00352) awarded to the Oregon Department of Fish And Wildlife's Marine Reserves Program. The objectives of this grant were to a) build and calibrate a DOV and lander system, b) test the system for accuracy, c) train volunteer divers to operate the system during existing MPA dive surveys, and d) determine recommendations for application of the stereo video system(s) for long-term MPA monitoring. This report aims to document our process in building, calibrating, and testing a stereo video system. It also outlines some conclusions and recommendations for ecological monitoring in Oregon's Marine Reserves.

II. Methods

1. Construction

1.1 Assembly of stereo systems

Two near-identical stereo systems were built. They were based on successful GoPro HERO® systems previously built by ODFW researchers (M. Blume and R. Hannah, pers. comm.) as well as by commercially available systems (e.g. SeaGIS Pty Ltd, Victoria, Australia). GoPro HERO® cameras were selected because of their small size, low cost, and increasing evidence of stereo video applicability (Letessier et al. 2015). While both systems described here contain the same basic components and structure, they differ in minute arrangements in camera position and alignment that are critical to stereo accuracy, but their performance should be nearly identical. To differentiate in the field and for processing, they are referred to as BLUE and ORNG (and labeled with blue and orange colored tape as such), but in most cases when "stereo system" is referred to hereon, either system is relevant.

Each system (Figure 1.1) is arranged on an aluminum beam 8 cm wide by 60 cm long by 1 cm thick. Four brackets are bolted to the beam using two bolt:washer:locking-nut combinations (8 total). Each bracket is 5 cm wide by 21 cm long by 0.6 cm thick. The brackets are bent at a 90-degree angle and bolted to the two Sexton acrylic GoDeep housings using three hex-bolts per side (12 total). These housings are spray-painted black to reduce internal glare and each contain one GoPro HERO® 4 Black Edition cameras with BacPac® external batteries. The two GoPro HERO4 cameras used for each system (BLUE and ORNG) are labeled BLUE-RIGHT & BLUE-LEFT, ORNG-RIGHT & ORNG-LEFT to prevent deploying the systems with the cameras in the incorrect housings.

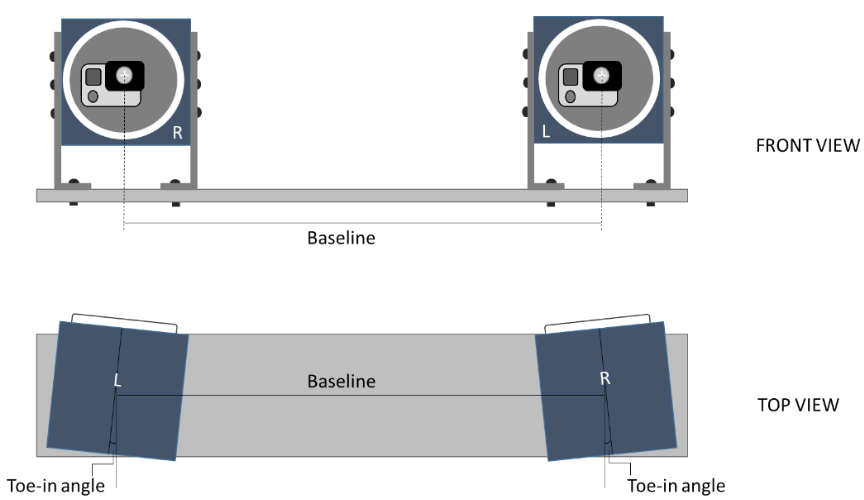


Figure 1.1: Illustration of a stereo camera system. Each GoPro HERO® 4 Black camera is housed in a Sexton™ GoDeep housing and bolted to an aluminum beam. Baseline is ~40cm for each system and toe-in of the cameras is 7°.

The baseline (separation of the cameras measured between the centerline of each camera lens) of each system is approximately 40cm. Each GoPro HERO camera sits with its lens centered in the housing port. The cameras are aimed slightly inward at a toe-in angle of approximately 7°. The baseline and toe-in angle distance varies minutely between the two camera systems and can be calculated to the nearest mm and degree, respectively, in the calibration process.

Initially, the housings used dome-ports to maximize the field of view. However, it was determined the curvature of the lens decreased image quality as well as increased measurement error (J. Seager, pers. comm.). All ports were replaced with flat-surface ports and the scuba data described in this report are from the flat port configuration. Lander pilot evaluation data, however, were collected prior to changing from dome to flat ports. These data are not used in the assessment of accuracy of the cameras.

Each system can be used independently as a diver-operated video (DOV) system (Figure 1.2a) or both can simultaneously be bolted into an aluminum stereo lander frame facing opposite directions (Figure 1.2b). Having both systems onboard a boat for scuba surveys (with one as backup) has proved useful for efficiency in the field. Having both systems bolted into the lander frame allows for two opportunities to collect useable video data per deployment.

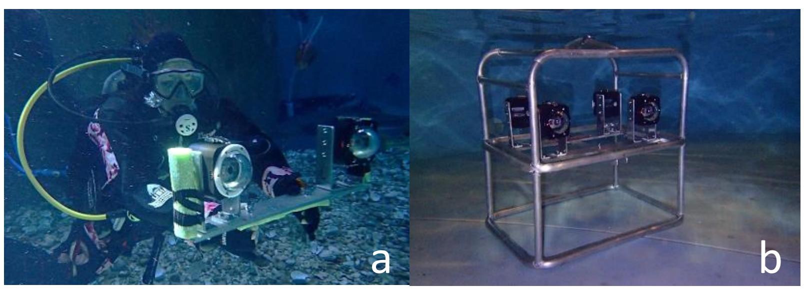


Figure 1.2 Each stereo camera system can be (a) used independently as a stereo DOV or (b) both systems can be bolted into a lander frame.

1.2 SCUBA diver operated video (DOV) platform

To use a stereo system as a DOV (figure 1.3), the system described above was held by divers and swum along a transect line laid out on the seafloor as video data were recorded. These pilot study data focus on fishes, but habitat and invertebrate data can also be collected in this way. Three additions to the system described above included a) attaching lightweight floats to achieve neutral buoyancy at depth, b) handlebars attached to the system (in the form of two 6-inch stainless bolts attached to the aluminum beam with wing-nuts), and c) attachment of lights on movable arms to the housing brackets (see more below on the lighting configurations).

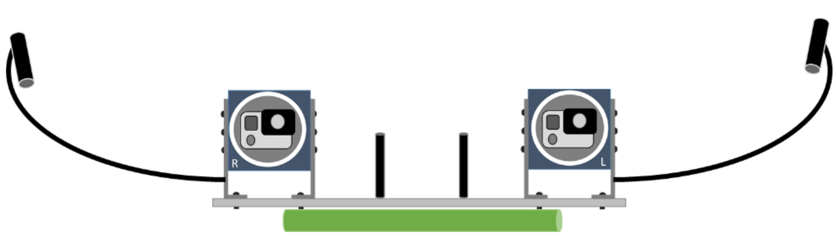


Figure 1.3 DOV design with lights and handlebars. The green tube underneath represents flotation material.

1.3 Double Stereo Lander (SteLa) platform

The Stereo Lander (SteLa) was designed to be deployed and recovered over the low gunwale of ODFW's 25' vessel, *R/V Shearwater.* Both stereo systems can be bolted in a custom welded aluminum lander frame for deployment remotely (Figure 1.4). The total height of the lander system was kept to a minimum in order to increase the ease of bringing it onboard with the vessel's davit and pot-hauler. It can be maneuvered on and off the deck by one person (ideally, two). The two camera systems face in opposite directions and provide two opportunities for obtaining usable video data.

SteLa measures 66 cm in height, 72 cm in length across the cameras, and 55 cm depth. The stereo system cameras are at a height of 42 cm from the bottom to maintain consistency with previous ODFW lander configurations. It is made of custom welded aluminum. The design of the frame is intended to both protect the cameras and minimize hang-ups on the seafloor. To ensure that the lander "drops" through the water column quickly, upright, and on-target, holes were drilled throughout the aluminum tubing and four 1.5 kg weights were attached at bottom of each vertical support. A shackle attaches the lander to floating polypropylene line with a surface buoy.

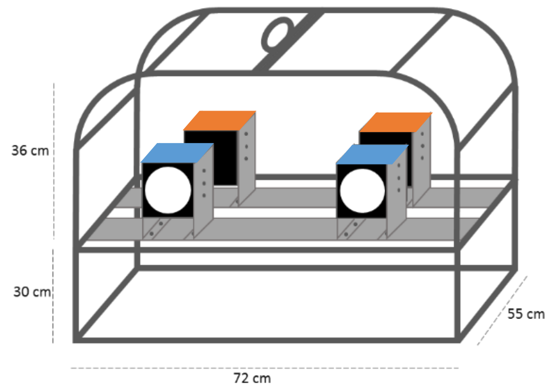


Figure 1.4 SteLa configuration and measurements (lights not pictured)

The lander was designed such that if the horizontal bars forming the base needed to be permanently removed, they could be cut off and the lander would instead land on the four vertical "feet" remaining. Prior to testing, there was concern that the horizontal bars would contribute to tipping when the lander landed on uneven surfaces on the seafloor. In pilot testing the lander was able to land upright often, but in future use these horizontal bars could be removed if deemed beneficial.

1.4 Lighting for the DOV and SteLa

Adequate illumination is needed to obtain clear imagery from which to conduct stereo measurements. Each stereo system for both the DOV and SteLa are equipped with two BigBlue™ 1800 lumen LED lights. On the DOV, each light is attached to an adjustable 50 cm arm, which is bolted to the outer edge of the housing mounting bracket (Figure 1.3). For SteLa, the lights are attached via hose-clamp to the frame, one above each camera. Ideally, the lights for SteLa would be extended on arms, away from the cameras as with the DOV, but the risk of damaging the arms in the deployment and recovery processes outweighed the benefit of having them extended.

The light intensity (lumens) is adjustable on BigBlue lights and testing was conducted to determine which setting was best. It was determined that no single setting was best and that it depended greatly on the condition of the visibility of the water column. For example, when there were many suspended flocculent particles, a lower setting (1000-1400 lumens) was best to reduce backscatter. When the water clarity was good (no suspended material), the 1800 setting provided the most light to sufficiently illuminate targets in the distance. For DOV use, the lumen-level can be adjusted *in situ* by the DOV operator. For SteLa use, it is recommended that the footage be previewed topside after the first drop of the day or area and lumen-levels be adjusted accordingly.

2. Digital settings and software

2.1 GoPro settings and related equipment

It is critical to stereo measurements that each camera is always used in the exact same housing (see below for more details on calibration) with the same settings from a calibration onward. All cameras in this study were set with the settings found in Appendix A. The camera settings are based on system specs and user preference (e.g. camera orientation, LED flashes, and beeps). The video settings were obtained by consulting other users of GoPro cameras, stereo GoPro systems, and those who collect video data in similar conditions. They are set for obtaining a high-quality image (e.g. 1080p resolution) and allowing the camera to digitally optimize the image (e.g. ProTune 'off' and spot meter 'on'). Some settings are set to avoid impairment of stereo accuracy (e.g. auto-low light 'on' will affect the frame rate and FOV 'medium' minimizes image distortion). The frame rate (30 fps) was selected based on a rapid enough rate to allow for stereo synchronization and slow enough to minimize file size (J. Seager, pers. comm.).

The Wi-Fi function on the GoPro cameras is used for controlling them via the GoPro Smart Remote. There are two remotes, each one exclusively assigned to each camera pair (ORNG or BLUE) and is programmed to control only the associated system. These are used to turn the cameras on and off simultaneously, once they are already in the housings. See Appendix A for protocols on using the remotes. Leaving Wi-Fi on can affect the battery life, but since the GoDeep housings are difficult to open, it is suggested to leave the Wi-Fi on during use and minimize opening the housings. With BacPacs on each GoPro camera and Wi-Fi continuously enabled, our experience demonstrates that the cameras can remain on and recording for about 2 hours.

2.2 Measurement and calibration software

When this pilot project was conceived and funded, it was the intention to use a MatLab Python script "Calib" toolbox (Boguet 2015) for calibration calculations and *SEBASTES*, a python-script based GUI for measuring objects in stereo imagery (as in Williams et al. 2010). Despite the low cost of these two scripts (not considering the cost of a MatLab license), they proved to be extremely inefficient and time consuming for the purposes of this study. This is mainly attributable to the step requiring the conversion of movie files (e.g. MPEG) to still images files (e.g. JPEG) for use in *SEBASTES*.

In April 2017, a number of ODFW Marine Resource Program groups all using stereo technologies pooled together to purchase a shared license of SeaGIS (SeaGIS Pty Ltd, Victoria, Australia) calibration hardware and measurement software. SeaGIS's *CAL* calibration and *EventMeasure* measurement software are more efficient, easy-to-use, are accompanied by personnel support, and are being used in research operations world-wide. Since some of the scuba pilot data and all of the SteLa pilot data were collected using the old approach, this is referred to as the "Python" approach where needed, versus the "SeaGIS" approach used otherwise.

2.3 Calibration

Calibration of stereo video is required to "train" the software as to how the two cameras in a stereo pair are positioned relative to each other. The measurements gained in the calibration step are stored in a "calibration file". This file is then used by the measurement software, to calculate measurement values from the stereo imagery. The build of the stereo system (camera spacing, angles, etc) as well as the particulars of each camera used are all incorporated into building the calibration data file. If a system is disassembled or any part of the system is replaced (e.g., a camera or a housing port), a new calibration must be conducted. Frequent checking of the system is recommended to check that the calibration remains accurate. Over time, a system may "drift" out of calibration and require that a new set of calibration files be created.

Originally, the stereo systems were calibrated using a 42 by 42 cm checkerboard and the "Calib" toolkit in Matlab (Figure 2.1a). Later, the stereo systems were calibrated using CAL software and "the cube" (SeaGIS, Figure 2.1b). The cube consists of a black aluminum cube 1 by 1 by 0.5 m with reflective dots placed on two surfaces. A "cube file" (.PtsCAL format) accompanies each unique cube produced by SeaGIS and contains the precise measurements between each dot on the cube. See Appendix B for detailed calibration protocols.

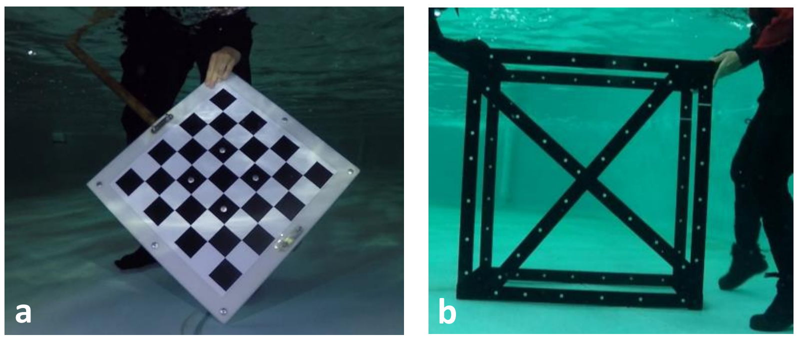


Figure 2.1 Stereo systems were calibrated first using a) the checkerboard, and later b) the cube

Before any footage is obtained for calibration or measurements, a synchronized event must occur between the right and left cameras. This allows for the imagery from both cameras to be synchronized later in the software. For the studies described here, either a movie "clapper board" (Figure 2.2a) and/or a flashlight aimed at both cameras simultaneously by a diver who will turn it on and then off (Figure 2.2b) were used. The cameras must remain on after this event is performed. (Using the sync event to synchronize the cameras in the software is discussed later.)

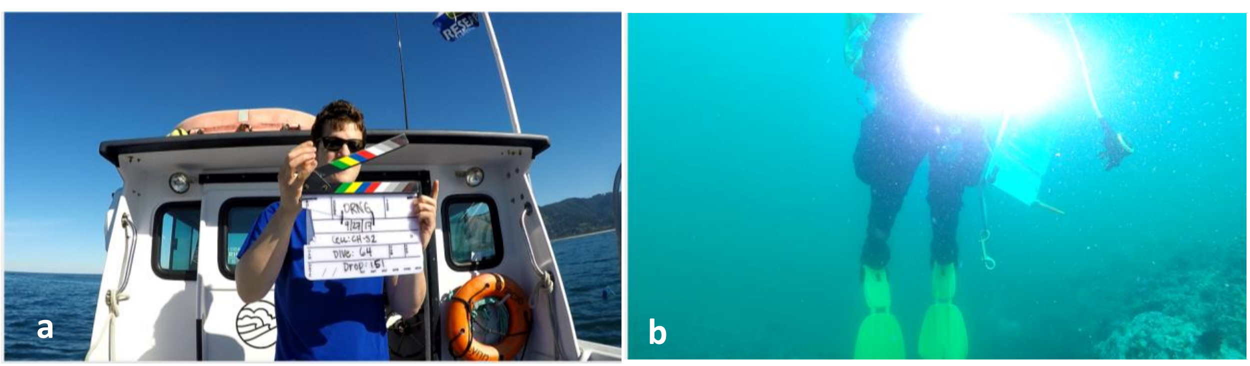


Figure 2.2 All stereo footage was synchronized with at least one action before collecting data. Common methods are a) "clapper board" above the surface and b) flashlight flash below the surface.

2.3.1 Collecting calibration imagery

In a shallow pool or tank, the cube is filmed with the stereo system in at least 20 configurations (see SeaGIS CAL user manual or Appendix B for each). The stereo system must remain still and stable as the cube is moved around. Alternatively, the cube can be held steady and the stereo system rotated in 20 configurations. This can be helpful if the pool is too shallow or if one wishes to examine whether the cameras are stable in their housings (J. Seager, pers. comm.). The calibration is conducted in water and is valid for measuring objects in water.

2.3.2 Maintaining and testing the integrity of the calibration

The integrity of the calibration may diminish over time. If the cameras are not extremely immobile within the housing and/or if the housings are bumped out of alignment, the calibration file created previously will need to be re-created. With the SeaGIS *EventMeasure* software, assessing the integrity of the calibration over time can be evaluated using a scale bar, filmed underwater (Figure 2.3). The precise distance of lines $\overline{AB}$, $\overline{AC}$, $\overline{BC}$ on the scale bar are known. By measuring each distance as the bar is moved around the field of view of the system, measurements not within acceptable accuracy of the known point distances will result in the need for a new calibration. Acceptable accuracy is dependent on the study parameters. For the purposes of this pilot study, we considered acceptable accuracy to be <1.5 cm error for a good-quality image of the scale bar.

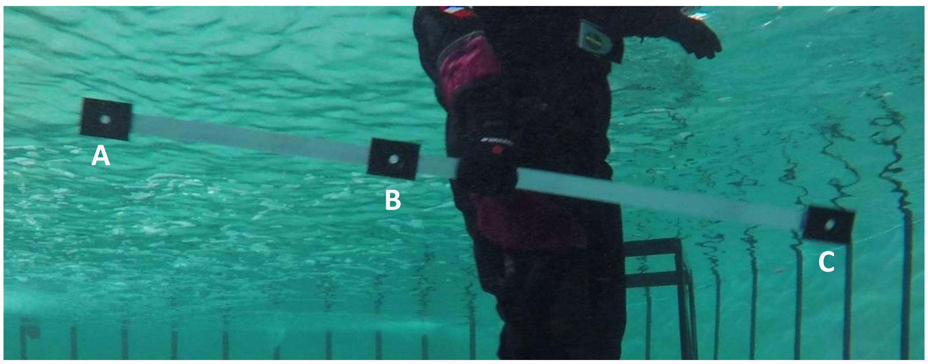


Figure 2.3 SeaGIS scale bar tool. The distance between each point (A, B, C) is known and can be used to test the integrity of the camera calibration.

3. Calculating field of view (FOV)

Field of view (FOV) often refers to the area in the view of a given camera. However, in the case of stereo cameras, FOV may refer to the area where both camera's FOV's overlap. This is the area in which stereo measurements can be made. Determining the area (in square meters) of the seafloor visible in the overlapping field of view is necessary for computing fish density measurements (e.g. number of fish in a given area).

FOV was determined with SeaGIS *Event Measure* software using the method outlined in figure 3.1. FOV is dependent on the horizontal visibility of the water on any given day (e.g. underwater visibility due to water clarity).

The value for the "visibility" (v) in figure 3.1 can be obtained by measuring the distance to a stationary object (e.g. a sea anemone, rock, or kelp holdfast) located in the overlapping FOV at the edge of the visible distance in an image (maximum distance of v). In the *EventMeasure* software, this is a simple operation that involves marking the exact point in both the right and left image, where the "range" value (synonymous to v) is provided. The overlapping FOV of any given video frame along a transect can be calculated, and for lander drops this value can be used for the entire drop, assuming the camera does not move. The 40° angle value was calculated for the ORNG and BLUE systems by making a number of measurements of footage taken in the water with transect tapes laid out in the overlapping-FOV.

This method is useful for *estimating* the area of the overlapping FOV, but comes with many caveats, including the angle at which the lander lands on the seafloor and does not take into account any obstructions (e.g. large rocks) within the overlapping FOV.

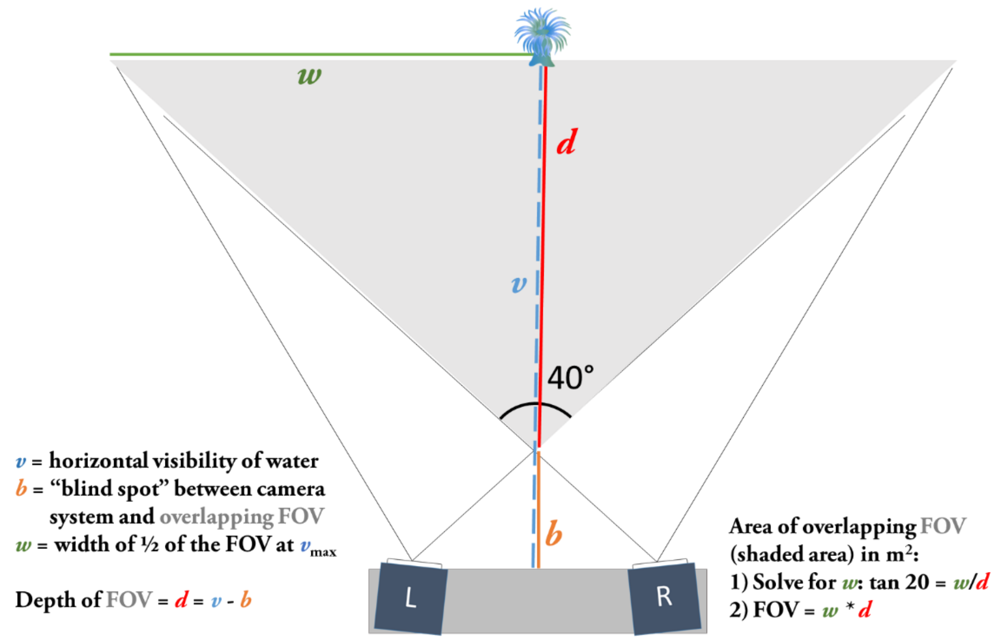


Figure 3.1: Schematic of components needed to calculate the area of overlapping FOV (shaded grey area).

4. Field and post processing protocols

4.1 Stereo DOV Field Protocols

Stereo DOV surveys were conducted in combination with existing PISCO-based SCUBA fish surveys (see ODFW 2015), where divers record all fish observations on a slate with an underwater datasheet. When adding the stereo system to the survey, one diver manages the stereo system while the other collects data on the datasheet.

Once the dive site is decided and a down-line dropped, the stereo diver receives the camera from the deck crew before entering the water. Deck crew will have turned on and started recording with the GoPro Smart Remote. The deck crew will have also completed the first "sync event" before passing the system to the stereo diver. The buddy diver is prepared to collect fish data as per regular fish survey protocols. During the dive, a transect tape is attached to the down line and constantly connects the divers with their starting point (which they will also return to and use for ascent).

Once on the seafloor, the horizontal visibility is measured with the transect tape and recorded, as per the survey protocols. Then, at the beginning of the first (and each sequential) transect, the buddy diver performs a sync event using a flashlight. Multiple syncs are critical in the event of any camera drift or malfunction. The stereo diver indicates the beginning of the transect by holding up 1, 2, or 3 fingers (based on which transect is about to start) in front of both the R and L cameras. The stereo diver begins swimming in a random direction, following all of the habitat selection protocols of a typical fish survey (e.g. hard substrate, <5 m relief change, see ODFW 2015 for a complete description). The diver must aim the stereo system such that the cameras face forward (with a very slight down angle) and the system is maintained about 0.5-1.0 m above the seafloor. The diver may tip the camera system facing down as they travel over large crevices so that the lights can illuminate any fish. The camera system may also be tipped down as the diver swims over a fish.

Meanwhile, the buddy diver hovers above the stereo diver's right or left shoulder and collects fish data as per normal protocols. The buddy diver's 2 by 2 m theoretical data collection zone is centered on the same FOV of the stereo cameras. If the stereo buddy is moving too quickly for the buddy diver to gather and transcribe data, a signal is given.

At the end of the transect tape (30 m), the stereo diver waves a hand in front of each camera to signal the end of data collection. The buddy diver also ends data collection. The tape is reeled up back to the down line and another transect is conducted. On occasion, one more transect can be done by connecting another transect tape to the original tape and continuing in the same direction for an additional 30 m transect.

4.2 Training and evaluating volunteer divers to operate the stereo DOV

Volunteer scientific scuba divers of the Marine Reserves program were trained to conduct stereo camera transects. This stereo training was above and beyond the training given to all survey volunteers for identifying fishes and invertebrates. Stereo diver training entailed:

- a verbal briefing on the protocol
- an in-water training, including completing a short dive in an exhibit (large aquarium tank) at the Oregon Coast Aquarium
- review of in-water training videos to discuss techniques and modifications.

During the in-water training, the protocol was demonstrated once and then each diver was given the camera to run a "transect". Upon surfacing, any modifications to improve technique were discussed. The resulting in-water training video collected by each diver was shared with the group and discussed so that all divers could identify acceptable techniques that resulted in usable video for data purposes. It is recommend that divers be re-trained every year to re-familiarize with the technique and familiarize themselves with any changes or modifications to the protocol.

4.3 Stereo Lander (SteLa) field protocols

The SteLa is deployed off the *R/V Shearwater* at pre-determined locations. Once the vessel is on-site, both stereo systems are activated and recording using the GoPro Smart Remote. Next, the sync event occurs (clapper board) and the system is lowered over starboard gunwale into the water on pre-determined lengths of polypropylene line. The lander is allowed to freefall until slack in the line indicates it is on the seafloor. A marker buoy is attached to the lander line for relocation and ease of recovery.

The lander is allowed to "soak" for 8 minutes whereupon it is hauled back onboard using a davit and pot hauler (as per Watson & Huntington 2016). Once back on board, the cameras are turned off with the remote and the vessel travels to the next site.

4.4 Video processing protocols

For both DOV transects and SteLa drops, video from the GoPro cameras are downloaded onto a hard drive, and data files re-named to reflect the corresponding stereo system (ORNG and BLUE) and camera position (right/left). Videos are uploaded to the stereo measurement software for quantification and measurement of fishes. (For detailed protocols on uploading imagery to *EventMeasure (EM)*, see the *EM User Manual*.)

4.4.1 Identification and measurement

Transects and drops are viewed in *EM.* Each fish observed is identified to species (or genus where needed) and measured in the best positioning possible. For the purpose of evaluating the ability of these systems to obtain usable footage in Oregon's environment, a "sizability" score was also given (see below for details). All data are recorded in *EM* as text files and later concatenated and uploaded to an Excel or Access database.

4.4.2 Sizability

One of the objectives of this study was to determine the proportion of fish that could be identified and measured from the imagery. A fish was given an "image quality" rating (1-4) as an observer attempted to size the fish in the software program. Fish were considered "sizable" if they were rated as 3-4 and "unsizable" if they were rated from 1-2:

Rating 4: Perfect image, fish is very clear, easily sizable
Rating 3: Good image, unobscured fish, clear enough discern tail and snout points
Rating 2: Less than good image, fish is either at a difficult angle for measurement, is positioned curved/curled, or image is not clear enough to obtain a confident line between snout and tail points
Rating 1: Bad image. Tail and/or snout are unclear or obscured in one or both cameras

III. Results and Discussion

5. Pilot study results

Both platforms (DOV and SteLa) were tested at a variety of locations off the Oregon Coast from Port Orford to Cape Falcon. Pilot data were collected for the DOV in fall 2016 as well as spring and fall of 2017. Pilot data for SteLa were collected only in fall of 2016.

SteLa was deployed ("dropped'') off the *R/V Shearwater* 52 times between 14 September 2016 and 11 October 2016 (Table 5.1). Overall, the system performed as expected. After the drops on 14 Sept 2016, additional holes were drilled and additional weights were added to the lander frame, to make the lander sink faster. This improved accuracy of the system to land on the targeted location on the seafloor. On subsequent deployments, the method of deploying the frame over the gunwale quickly (and thus on-target) was improved. During test deployments, water surface conditions were good (e.g. wind <15 kts, swell <2 m). The ability to deploy the system in rougher, more questionable conditions is not covered here.

Since each drop has the potential of collecting data from either of the two stereo camera systems, a drop was considered "usable" if footage from one of the systems met the standards of the existing Marine Reserves video lander protocol (ODFW 2015). The proportion of usable drops on the last two days of deployment were low due to an error in camera setup and very poor underwater visibility at deep depths.

Table 5.1 Summary of stereo lander drop data to determine feasibility of use on the Oregon coast from ODFW vessel R/V Shearwater

		Drops	
Date	Site	Total (useable)	Depth ranges (m)
09/14/2016	Cavalier Reef	7 (0)	17-24
09/15/2016	Cape Foulweather	12 (7)	14-20
10/03/2016	Seal Rock	14 (11)	10-21
10/11/2016	Seal Rock	19 (6)	14-27

The stereo DOV system was deployed off the *R/V Shearwater, R/V Gracie Lynn,* and *M/V Two-thirds*. All three vessels are very similar platforms for dive operations and are considered interchangeable for the purposes of the DOV pilot study. In total 71 pilot transects were conducted (Table 5.2), 54 of which were deemed usable. "Useable" required that the protocol was followed, both cameras were fully functional, and/or the underwater visibility conditions were appropriate.

Fish sizes were not used in analyses for transects conducted prior to switching to the SeaGIS *EventMeasure* software (n=17, April 2017), due to the changes in analysis software, calibration method, and the replacement of the camera lens ports. Data from these early transects are not used in the assessments and figures below, but are included in the summary in Table 5.2.

Table 5.2: Summary of transect data from initial testing of the stereo DOV at monitoring sites along the coast.

		Transects	
Date	Site	Total (useable)	Depth ranges (m)
08/25/2016	Cape Foulweather	8(6)	10-19
10/07/2016	Nellies/Tichnor Cove	6(6)	9-15
10/12/2016	Otter Rock	2(2)	10-12
03/20/2017	Otter Rock	6(5)	10-20
05/31/2017	Cape Falcon	3(3)	13
06/14/2017	Otter Rock	6(6)	8-11
08/31/2017	Cascade Head	9(9)	10-20
09/04/2017	Cascade Head	9(9)	15-20
09/05/2017	Cascade Head	4(3)	15-20
09/27/2017	Cascade Head	18(17)	10-20

5.1 Assessment of "sizability"

For the SteLa imagery, about half of all fish seen on lander drops were sizable (Figure 5.1). Some improvements made to the stereo system in general, over the course of the pilot study, have greatly improved the ability to size more fishes. Most critically, the dome ports on the camera housings were replaced with flat ports, resulting in a clearer image. In terms of species richness observed with SteLa imagery, four fish species and one fish species complex (Blue/Deacon Rockfish) were observed.

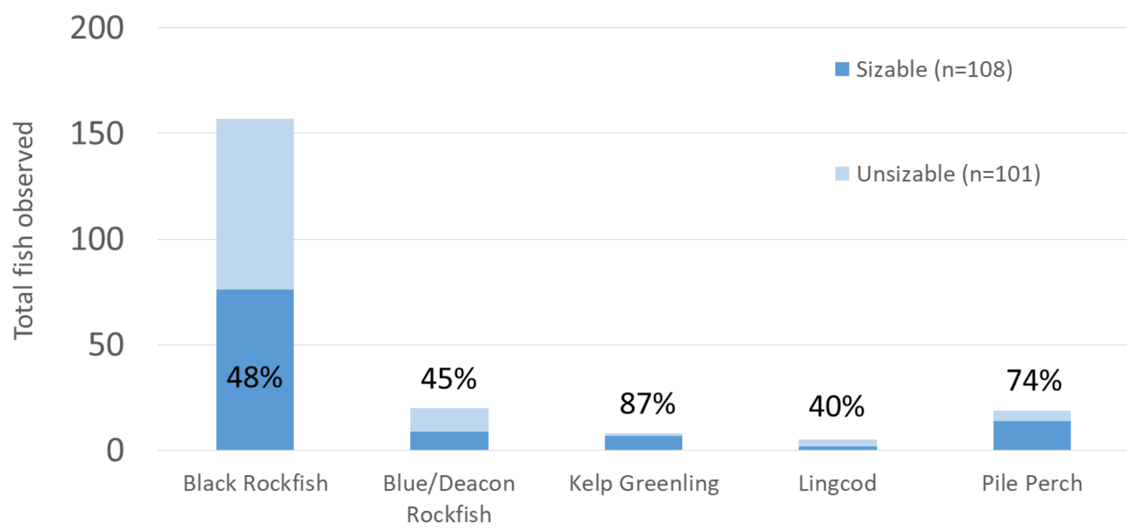


Figure 5.1: Counts for species and species complexes seen in SteLa imagery, where total counts of each species/complex observed are shown. Percentage values indicate the percentage of observed fishes that were "sizable".

For the stereo DOV imagery, less than half of the fishes observed were sizable (n=67). A summary of "sizability" of fish observed on all useable transects (n=54) conducted from 20 Mar through 27 September, 2017 (Figure 5.2). All transects were conducted in water visibility ranging from 1.7-5.2 m. For a majority of the dives the visibility was >3 m, which is the recommended visibility condition in order to have high-quality imagery. These conditions are also consistent with the current ODFW Marine Reserve scuba fish survey data collection protocol (ODFW 2015).

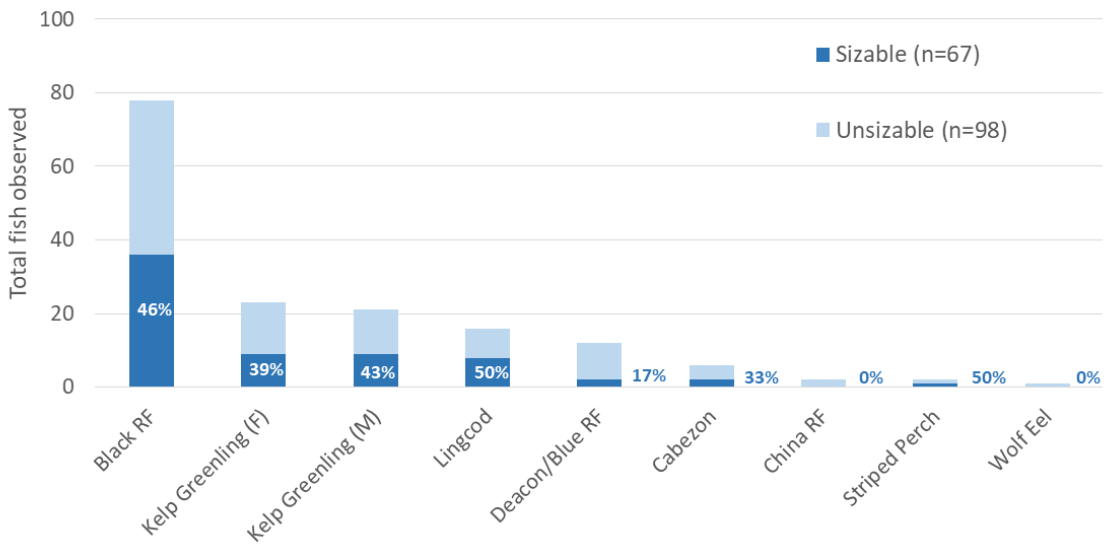


Figure 5.2 Counts for species seen in stereo DOV imagery. Percentage values indicate the percentage of observed fishes per species that were "sizable".

5.2 Assessment of diver accuracy

To gain an understanding of the diver's accuracy in sizing fishes by eye, eight divers were tested using fake (plastic) fishes of known sizes (ranging from 5 cm to 91 cm). Each diver was shown a series of 57 fishes underwater at approximately 3 m distance. Divers recorded their size estimate to the nearest cm and these estimates were compared to known lengths of fake fishes.

The diver accuracy assessment was conducted in a pool and are reported for four divers (Figure 5.3). Overall, these data show that divers are fairly accurate but there are inconsistencies across divers and size intervals of fishes. Divers were able to size most fish within 5 cm, although they notably tended to oversize large (>50 cm) fish. While it was valuable to see how divers performed at estimating measurements in a controlled situation, it was also deemed important to understand how they performed *in situ* with live fishes with the task loading of an actual survey. The next section compares these *in situ* data.

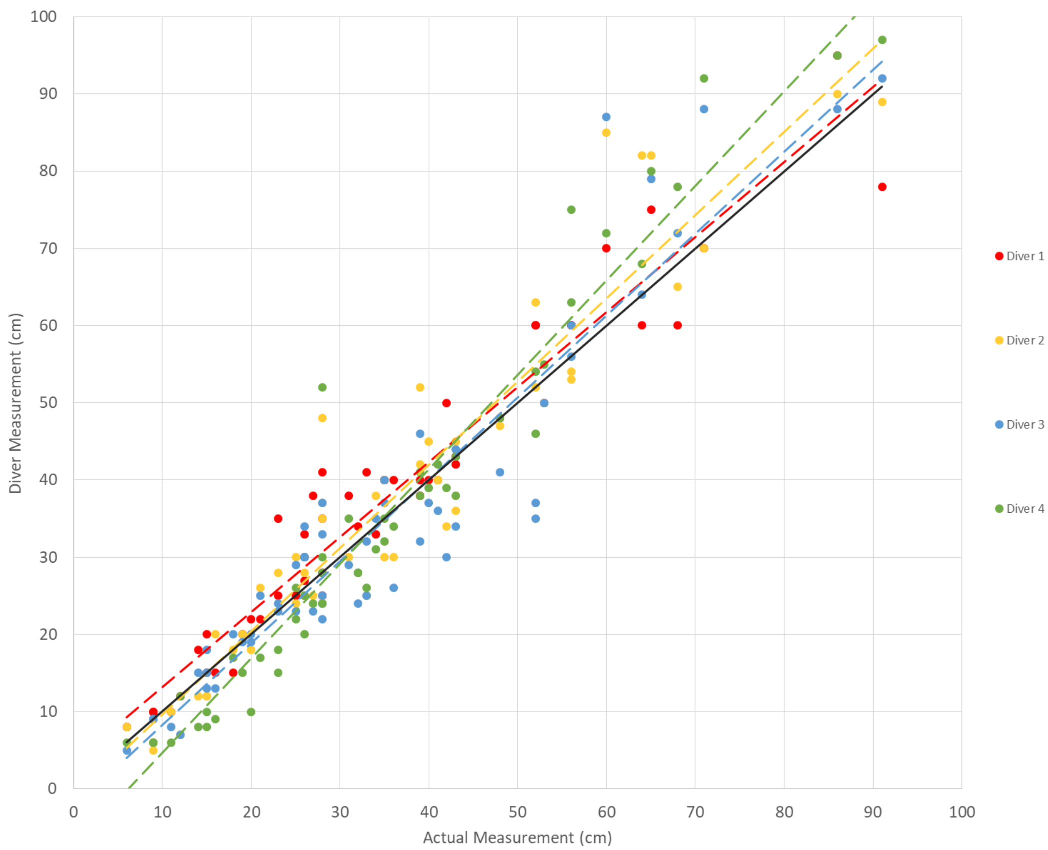


Figure 5.2: Estimates of plastic fish size (cm) as compared with actual sizes for four volunteer divers. Dotted lines correspond to a linear fit for each diver's data. The black line represents a "perfect" diver measurement where all measurement estimates are accurate to the centimeter.

5.3 Diver vs stereo DOV in situ: *Abundance and size comparisons*

Data collected from DOV were compared to diver's estimates *in situ* using three different metrics: fish observed, fish missed, and fish size comparison.

Comparison of DOV and diver data are summarized by:

1) Comparison of total count of fish observed by each method.
2) Comparison of total count of fish 'missed' per species.
3) Comparison of direct measurements of each individual fish

5.3.1 Total fish observed per method

To compare total fish observed by each method, the number of fish seen by each method (diver and stereo DOV) were summed over all transects (Figure 5.4). For nearly all species, the DOV saw more fish than the divers. This could be due to the advantage in the DOV with ability to review video repeatedly and see fish that were not seen initially. Black Rockfish are not shown in Figure 5.4 due to the high variability in counts, by both divers and DOV, due to schools.

It is important to consider that, as a diver looks down to write on the datasheet, s/he may miss a fish while the video will record all fishes in the FOV regardless. However, this higher count by DOV may also be due to double-counting: a situation where the fish exits the FOV and then re-enters later. The DOV has a higher propensity to double-count, whereas divers are trained to avoid double-counting by noting peripherally when fish enter, exit, and re-enter the sampling window. The video reviewer in post-processing is unable to account for this.

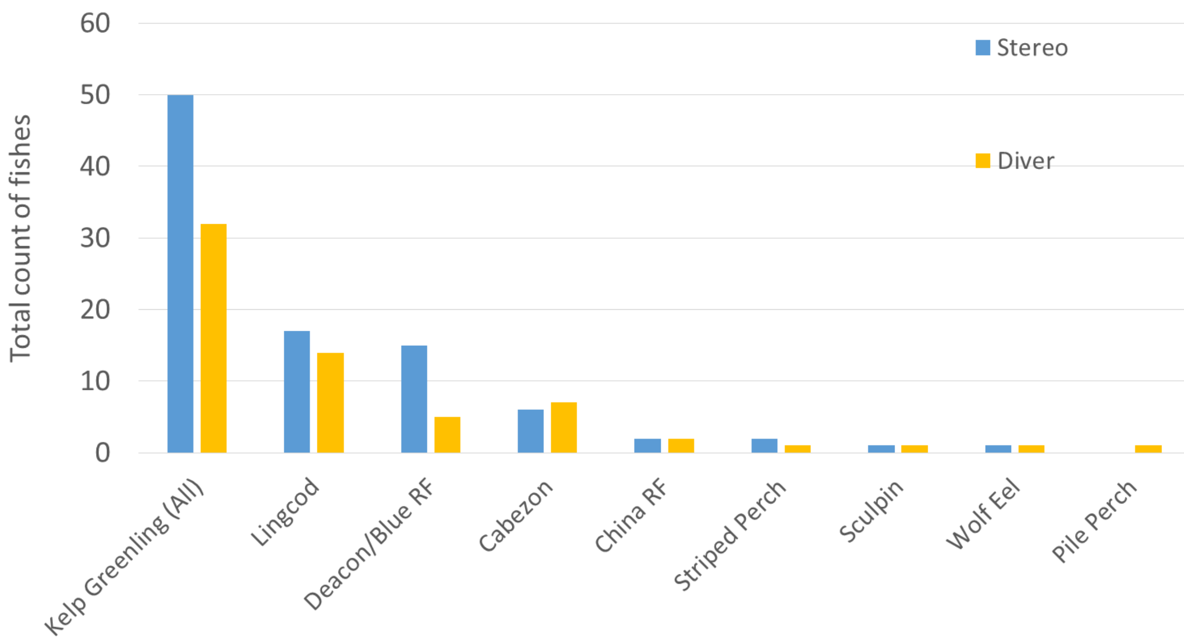


Figure 5.4: Count of fish seen by each method

5.3.2 Total fish missed per method

To investigate if one method was more likely to underestimate fish counts ("missing" fish) than the other, the number of observed fishes by each method were plotted (figure 5.5). Fish were either: a) observed by both the DOV and the diver, b) observed by the stereo DOV only ("missed" by the diver), or c) observed by the diver only ("missed" by the DOV).

For Kelp Greenlings (male and female) as well as Blue/Deacon Rockfishes, the DOV detected nearly 50% more fishes than the diver. While these fish are quick-moving and susceptible to double-counting, it is unlikely that all diver-missed fish can be attributed to double-counting. In fact their darting behavior may actually make them more easily missed by a diver, and more easily seen in video. It is worth noting that both methods are equally acceptable, but the likelihood of double counting (as described above) cannot be resolved.

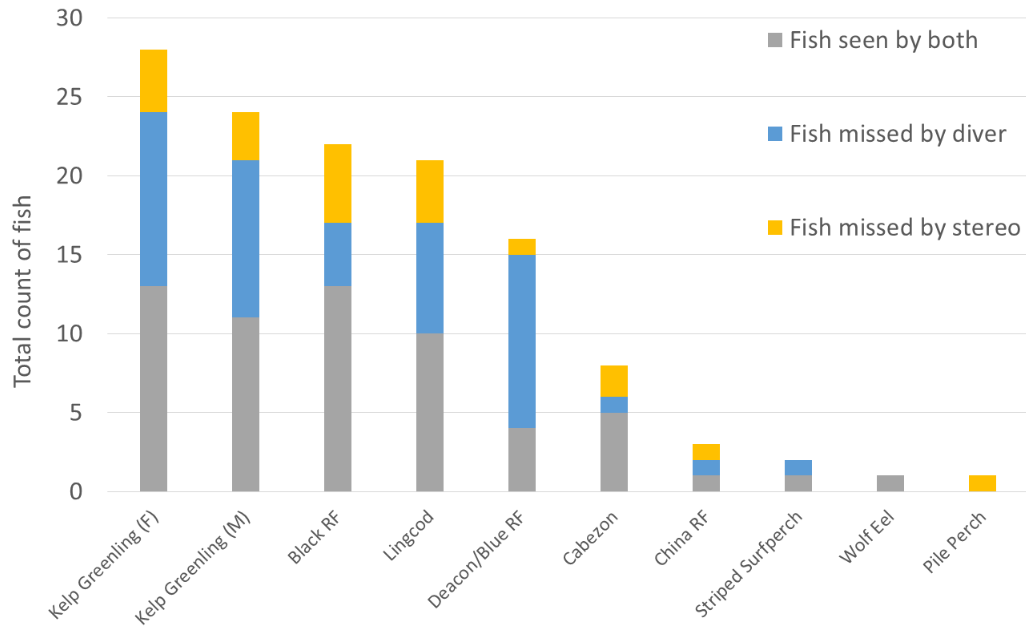


Figure 5.5 Number of fish seen by both tools (DOV and diver), missed by the divers, and missed by the stereo DOV.

It is important to note that not all Black Rockfishes observed in the video are represented here. Only Black Rockfishes that were seen individually or behaving as solitary demersal individuals are reported (Figure 5.2). In many instances, the video data recorded large schools (30-60+ individuals) of Black Rockfish that surrounded the divers. These schools are incredibly difficult to enumerate must be processed using a different protocol not addressed here.

5.3.3 Direct measurement comparisons

Direct size measurements of individual fishes seen by both the diver and DOV *in situ* were compared. The comparison was contingent on the assumption that some fish observed by the diver on a given transect could be matched with those in the video. These comparisons were not frequently possible with high certainty, resulting in a low sample size. For *in situ* data, making a direct comparison of an individual fish measurement in post-processing was difficult because it was often impossible to align diver and DOV observations *post hoc*. For example, if three Lingcod were observed by the diver, s/he would write down three size estimates. It was unknown in post-processing which of those three sizes corresponded with the three (or sometimes fewer or more) Lingcod observed in the DOV footage. Therefore, when only one individual of a species was seen on a transect by both methods, it was assumed to be the same individual.

The number of fish from which direct comparisons could be made is limited (n=26, figure 5.6). These individuals represent six species: Lingcod, Black Rockfish, Blue/Deacon Rockfish, Cabezon, Striped Surfperch, and Kelp Greenling. Assuming that the stereo camera measurement was most accurate (based on calibration and measurements of the scale bar), the data show that, overall, divers tend to overestimate size for larger fish (>50 cm) and either accurately size or underestimate the size of smaller fishes (<50 cm). Since all of the larger fish in this subset are Lingcod and Cabezon, it was not determined if these species - which are elongate and/or oddly-shaped, bottom-dwelling, and cryptic in nature – are difficult to size or if divers simply perform more poorly at larger size intervals. Additional comparison data should be collected in future studies to clarify these reasons.

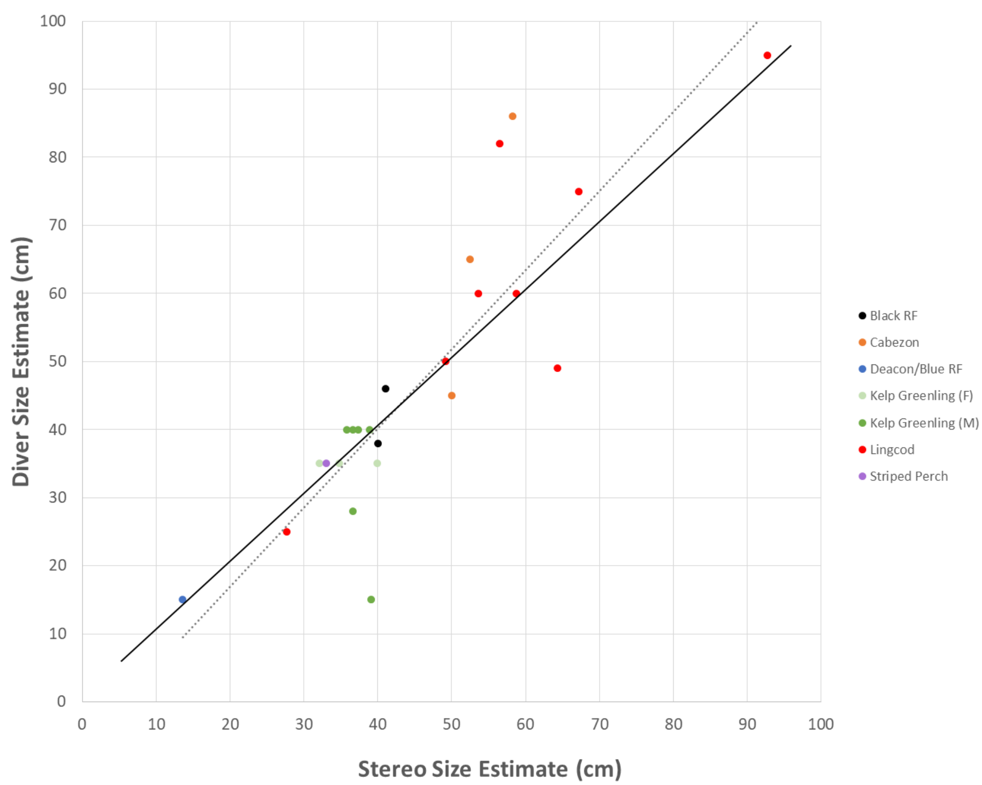


Figure 5.6 In situ comparison of diver size estimates and stereo DOV measurements for 26 individuals from 6 species. The solid black line represents a hypothetical perfect correlation between diver and DOV measurements. The dashed line represents the actual linear best-fit line demonstrating the divers' propensity to oversize larger fish and undersize smaller fish.

5.4 Tradeoffs in time for video preparation and data processing

For the most efficient evaluation of long-term monitoring data collection, it is useful to consider the trade-offs in data preparation and processing. To evaluate tradeoffs methods the time it took to prepare, collect, and then process video from one sampling unit from each SCUBA-based system (a transect from diver or DOV) and from each lander-based system (a drop from the existing lander and SteLa) were compared (Table 5.3). Preparation time includes camera system assembly in the field and stereo calibrations (where applicable). Processing time includes downloading, viewing, making measurements in the SeaGIS software (where applicable), and QAQC of video data.

The effort in time for preparing the videos for processing using the SeaGIS approach varied depending on the method (Figure 5.3). It is important to note that video processing time decreased considerably over the course of this pilot project as a) the SeaGIS software replaced the time-intensive, cumbersome MatLab/Python-based approach and b) video review staff became more familiar with the stereo techniques.

Training times are not included in these estimates. Training for divers involves fish identification and size estimation (conducted over a 3-day course and independent learning) and software training for staff to perform video processing includes practice and familiarization with the software. It is worth noting that in a situation using only DOV, all divers do not need to be trained to identify fishes *in situ*. Only one or two video reviewers are needed to identify and measure all fish in the video. Therefore, migrating to a video-based fish survey could save a significant amount time training volunteer divers to identify fish *in situ*.

Table 5.3 Estimates of time effort per method per one sample unit. "Preparation" time includes camera assembly and stereo calibrations (where applicable). "Processing" includes downloading, viewing, measurements (where applicable), and QAQC of video data.

Method/Tool	*Sample unit*	*Method preparation time*	*Data post-processing time*
SCUBA fish survey	*transect*	*None*	*10 min*
Stereo-DOV survey	*transect*	*15 min*	*23 min*
Lander survey	*drop*	*10 min*	*23 min*
SteLa survey	*drop*	*15 min*	*20 min*

For stereo DOV surveys, when compared to diver surveys, video data post-processing time greatly increased the overall data entry time. For diver surveys (non-DOV), diver-recorded data from datasheets are simply entered in an Excel spreadsheet and checked for errors. For stereo DOV video footage, total time was nearly 30 minutes. It should be noted that this time is an average and ranges considerably depending on the number of fish observed on a transect.

For SteLa video processing, when compared to the existing lander method, minimal additional time was needed to perform the additional methods for stereo-video. In fact, using the SeaGIS *EventMeasure* software to view non-stereo data could substantially improve the speed of existing video lander protocols, which are currently processed in Adobe Premiere.

IV. Conclusions and Recommendations

6. Conclusions and program recommendations

6.1 Stereo technology

The stereo systems developed for this project have been successful in accuracy and implementation. Additionally, they were developed at a reasonably lower cost (approximately US$2000 per system, including cameras) compared to commercially available systems (approximately US$5000 per system, not including cameras).

Stereo technology requires additional staff time in the form of training and post-processing effort. In the case of stereo DOV, this is substantial given that in the non-video method requires very little post-processing: only data sheets need to be entered after the surveys are completed. It takes considerably more time and effort to prepare for and process imagery data for diving operations. However, if scuba fish surveys switched to a wholly video-based approach, much time could be saved in diver fish-identification training and testing as well as sizing training and testing.

In the case of the SteLa system, the new stereo-protocol adds only a small additional amount of effort for training and processing over the existing video processing protocols. Additionally, the new video review software used for measuring fishes in stereo video can also be used to annotate and QAQC existing lander video footage far more efficiently.

6.2 Stereo-DOV

Some generalizations can be made about the benefits and challenges of using a stereo DOV to enumerate and measure fish compared to diver-estimates. The DOV has the advantage of video playback of a transect where the footage may be reviewed repeatedly, whereas a diver quite often has only a moment to identify and estimate the size of a fish. However, the diver has the advantage of noting and dismissing the instance where a fish remains on the periphery of the transect boundary and periodically re-enters the transect boundary (double-counting). These fish are possibly double-counted by the DOV. Further, the DOV is more consistent at accurately measuring fishes. Divers vary in their ability to measure fishes based on a variety of reasons, ranging from personal ability to task-loading to ocean conditions. Although a notable amount of fish from DOV footage are non-sizable due to image quality, a diver following protocol will provide a fish size for each observed individual. However, the accuracy of these diver fish estimates *in-situ* is difficult to confirm.

6.3 Stereo-Lander (SteLa)

Over the course of the stereo-lander pilot study, the design and deployment protocol of SteLa was improved. The lander frame fits the needs of deployment off the *R/V Shearwater* and the system can land and collect video footage in the same seafloor and sea-state conditions as the previously used lander configurations. Similar to the existing (three-camera) lander, SteLa has the advantage of multiple camera systems, increasing the chances that usable video footage is collected on each drop.

6.4 Recommendations

Weighing these benefits and challenges, the following recommendations are given and rely on the priorities of the ODFW Marine Reserves Ecological Monitoring Program in the upcoming data collection years.

1. Continue collecting DOV footage on all SCUBA fish surveys. While one diver collects abundance and size data on a datasheet, the second (buddy) diver will follow alongside and collect stereo DOV of as many fish as possible in the same general area. The data resulting from the datasheet diver will likely be a better estimate of abundance (most attributable to the event of double counting), where the size data collected from the stereo DOV will contribute to more accurate size frequency estimates of a reserve or other given area.

2. Implement SteLa alongside or in lieu of existing mini-landers. Prior to the SteLa, two “mini”-landers were operated in 8-minute intervals off the *R/V Shearwater*. SteLa can easily be added into the rotation and the benefit of adding fish sizes to the current metrics (e.g. MaxN) would provide easily obtainable and valuable data.

3. Continue exploring stereo data capabilities. Additional capabilities worth exploring are whether stereo video can easily and accurately obtain other reserve-relevant metrics such as density, biomass, and size-structure estimates.

References

Alós, J, Palmer M, Grau AM, Deudero S. 2008. Effects of hook size and barbless hooks on hooking injury, catch per unit effort, and fish size in a mixed-species recreational fishery in the western Mediterranean Sea. *ICES Journal of Marine Science: Journal du Conseil* 65(6):899-905.

Boguet, J. 2015. *Camera Calibration Toolbox for Matlab* http://www.vision.caltech.edu/bouguetj/calib_doc/

Boldt, J, K Williams, C Rooper, R Towler, A Gaurthier. 2018. Development of stereo camera methodologies to improve pelagic fish biomass estimates and inform ecosystem management in marine waters. *Fisheries research* 198: 66-77.

Boutros, N, M Shortis, E Harvey. 2015. A comparison of calibration methods and system configurations of underwater stereo-video systems for applications in marine ecology. *Limnology and Oceanography Methods* 13: 224-236.

Elliott, S, P Ahti, M Heath, W Turrell, D Bailey. 2016. An Assessment of Juvenile Atlantic Cod *Gadus Morhua* Distribution and Growth Using Diver Operated Stereo-Video Surveys. *Journal of Fish Biology* 89(2): 1190–1207.

Elliott, S, W Turrell, M Heath, D Bailey. 2017. Juvenile Gadoid Habitat and Ontogenetic Shift Observations Using Stereo-Video Baited Cameras. *Marine Ecology Progress Series* 568: 123–35.

Hannah, R, M Blume. 2016. Variation in the Effective Range of a Stereo-Video Lander in Relation to Near-Seafloor Water Clarity, Ambient Light and Fish Length. *Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science* 8:62–69.

Harasti, D, K Lee, R Laird, R Bradford, B Bruce. 2016. Use of baited stereo remote underwater video system to estimate the presence and size of white sharks (*Carcharodon carcharias*). *Marine and Freshwater Research* 68: 1391-1396.

Harvey, E, D Fletcher, M Shortis. 2001a. A Comparison of the Precision and Accuracy of Estimates of Reef-Fish Lengths Determined Visually by Divers with Estimates Produced by a Stereo-Video System. *Fishery Bulletin* 99(1): 63–71.

Harvey, E, D Fletcher, M Shortis. 2001b. Improving the statistical power of length estimates of reef fish: a comparison of estimates determined visually by divers with estimates produced by a stereo-video system. *Fisheries Bulletin* 99: 72-80.

Harvey, E, D Fletcher, M Shortis. 2002. Estimation of Reef Fish Length by Divers and by Stereo-Video - A First Comparison of the Accuracy and Precision in the Field on Living Fish under Operational Conditions. *Fisheries Research* 57(3): 255–65.

Harvey, E, D Fletcher, M Shortis, G Kendrick. 2004. A Comparison of Underwater Visual Distance Estimates Made by Scuba Divers and a Stereo-Video System: Implications for Underwater Visual Census of Reef Fish Abundance. *Marine and Freshwater Research* 55(6): 573–80.

Langlois, T, E Harvey, B Fitzpatrick, J Meeuwig, G Shedrawi, D Watson. 2010. Cost-Efficient Sampling of Fish Assemblages: Comparison of Baited Video Stations and Diver Video Transects. *Aquatic Biology* 9(2): 155–68.

Letessier, T, JB Juhel, L Vigliola, J Meeuwig. 2015. Low-Cost Small Action Cameras in Stereo Generates Accurate Underwater Measurements of Fish. *Journal of Experimental Marine Biology and Ecology* 466: 120–26.

Oregon Department of Fish and Wildlife [ODFW]. 2015. Oregon Marine Reserves Ecological Monitoring Report 2012-2013: 1-113 http://oregonmarinereserves.com/content/uploads/2016/02/EcologicalMonitoring_Report_ODFW_2015.pdf

Walsh, A, N Barrett, N Hill. 2017. Efficacy of baited remote underwater video systems and bait type in the cool-temperature zone for monitoring 'no-take' marine reserves. *Marine and Freshwater Research* 68: 568-580.

Watson, D, E Harvey, M Anderson, G Kendrick. 2005. A comparison of temperate reef fish assemblages recorded by three underwater stereo-video techniques. *Marine Biology* 148: 415-425.

Watson, J, B Huntington. 2016. Assessing the performance of a cost effective video lander for estimating relative abundance and diversity of nearshore fish assemblages. *Journal of Experimental Marine Biology and Ecology* 483: 104-111.

Williams, K, C Rooper, R Towler. 2010. Use of stereo camera systems for assessment of rockfish abundance in untrawlable areas and for recording pollock behavior during midwater trawls. *Fisheries Bulletin* 108:352-362.

Acknowledgements

We wish to thank a number of individuals for their contributions to this pilot study. Field support and diving assistance from Jenna Walker, Doug Batson, and Jim Burke of the Oregon Coast Aquarium. Field support, project conception, and data processing from Brittany Huntington, Kelly Lawrence, and David Wagman of ODFW. Access to Port Orford sites from Greg Ryder on the M/V Two-Thirds. Review of this document from Stephanie Fields, Matt Blume, and Scott Marion of ODFW and James Lindholm of California State University Monterey Bay.

Appendix A: GoPro settings and remote

I. Settings used for the GoPro Hero 4 cameras used throughout the pilot project

CAMERA SETTINGS:	VIDEO SETTINGS:
WiFi = **RC and APP**	Video Resolution = **1080**
Orientation = **UP**	FPS = **30**
Default Mode = **VIDEO**	FOV = **MEDIUM**
QuikCapture = **OFF [N/A]**	Auto Low Light = **OFF**
LEDs = **2**	Spot Meter = **ON**
Beeps = **OFF**	ProTune = **OFF**
Video Format = **NTSC**	White Balance = **NA**
On-Screen Display = **ON**	Color = **NA**
Auto Off = **NEVER**	Shutter Speed**: NA**
Date/Time = **[SET]**	ISO limit = **NA**
Delete = [Previous files are always deleted and	Sharpness = **NA**
the camera cards re-formatted before each use.]	Exposure Value Compensation = **NA**

II. Using the Smart Remote with GoPro HERO 4

A. To turn on Wi-Fi, press and hold the button on the side of the camera (with the wrench on in) until the blue light blinks. Ensure that the Wi-Fi settings are as below before placing the camera in the housing.

B. To use the remote:

1. Turn on the power (button with a line through a circle) – just push the button once.
2. To make the sync the desired cameras to the remote (only need to do this once), simultaneously press the record (red circle) and the power button. (Make sure all cameras you want to connect have Wi-Fi activated.)
3. Remote will display the number of cameras that it "found" (i.e. is in control of).
4. To begin/end recording, press record once.
5. To turn on/off cameras press and hold the power button.

C. To use the GoPro App on iPhone:

1. Download the "GoPro Capture" app from iTunes and open it.
2. When first connecting, go to "add new" and follow instructions (see below for passwords).
3. If reconnecting, go to iPhone settings and choose the WiFi network for the camera to which you are connecting.
4. Go back to the GoPro app.
5. To control the CAMERA, select control. You can access all the settings here.
6. To view footage on the memory card, select MEDIA and play any clip you'd like.

Appendix B: Calibration Protocols

Note: These are greatly simplified protocols used during this pilot study. For more details, refer to the SeaGIS *CAL* User Manual.

I. Collecting cube footage in a pool

Materials needed: Stereo systems with prepared GoPros in housings, calibration cube, scale/measurement bar, crate with soft weights, transect tape, stereo tool kit (tools, desiccant, zip ties, spares), GoPro remotes, clapper board, underwater flashlight.

1. Turn on cameras, begin recording, and sync the system with the clapper board.
2. Set the stereo system on the upside-down crate with a weight to hold it steady.
3. Sync with the flashlight.
4. Place the cube ~3-4 meters away from the stereo system in the middle of the two cameras.
5. Give the ok sign to the cameras, and begin:
    a. cube head-on
    b. tilt top of cube towards stereo
    c. tilt top of cube away from stereo
    d. tilt right side of cube towards the stereo
    e. tilt left side of the cube towards the stereo
    f. rotate cube clockwise once and repeat steps 5 a-e
    g. repeat step 5f until all sides of the cube have faced down
6. Sync the cameras again with the flashlight (for good measure).
7. Film the scale bar around the entire FOV of the camera (near, far, right, left, at different angles relative to the cameras).
8. Remove from the water, stop recording, shut down.

II. Using CAL Software

A. Folder structure

1. Make a folder with:
    a. Right and left calibration video files (named such)
    b. COPY of the cube file (.PtsCAL)
    c. Right and left .CamCAL files (Ideally, the ones from the previous calibration should be used. If they are not available, choose the appropriate file for the type of camera and housing used.)
2. Open CAL (must have USB license key plugged in)
3. Create new project:
    Project > New Project [file name structure: YYYYMMDD*_SYST, e.g. 20170419_BLUE]
    *Use the date that the calibration footage was taken
4. Load CamCAL files:
    Camera > Right/Left > Read…
5. Load cube file:
    Object Points > Read…
6. Set picture directory:
    Picture > Set picture directory > [browse to folder that contains videos]
7. Create measurement file:

Measurement > Write… [file name structure: YYYYMMDD_SYST, e.g. 20170419_BLUE]

8. Check that all files are loaded:

    Project > Display…

    [There should be 6 rows, each with a similar name and path name]

9. Load videos:

    Picture > Left > Open… [Select first video in sequence]

    - when prompted to "define sequence", you can "add file" to add other videos that should be "attached" to this one, and adjust the order as needed.

B. Calibration

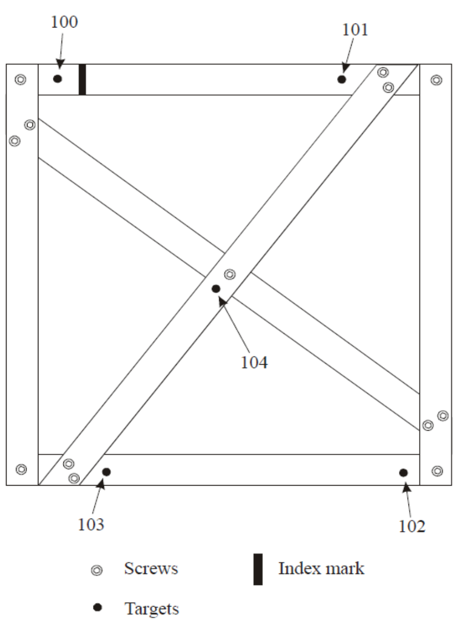
1. Sync the cameras and check the "lock" box.

2. Begin clicking on the resection (target) points. Go clockwise from 100-103. (104 is usually not needed.)

    TIP: Use SHIFT+Click to get the centroid box

*DON'T worry about zooming in and clicking right on the dot. As long as the dot is within the centroid box, it will center it for you!

Figure A1: Cal points clicked on by the user (source: SeaGIS CAL user guide)



3. Repeat for all **<u>20</u>** orientations of the cube. Choose frames where the most number of dots on the cube are visible.

* If your "No. Points" in lower left table is <70 now, it (hopefully) will improve at a later step.

*After the first image set (right and left), you only need to click the points on the LEFT image. The RIGHT image points should pop up automatically after you've done the LEFT.

*You may enjoy some shortcuts at this point:

    Homescreen: [spacebar] opens the LEFT video viewer

    Video viewer: [spacebar] starts/stops the video

        [enter] closes player and jumps to that frame for both RIGHT and LEFT images

Either screen: -> jump forward 1* frame
<- jump back 1* frame
*When your increment is set to 1. Change the number of frames in the box in upper left of either screen. **Remember that you did this though!**

4. Compute bundle adjustment (Adjustment > Compute bundle adjustment)
    - If it FAILS, consult the manual
    - If it succeeds, check the following…
    a. [Upper box], note the following
        i. *Average image residual*
        ii. *Eligible image measurements*
        iii. *Redundancies*
    b. Details (Lower box):
        i. *Camera parameters > focal length*
        ii. *Object point summary:*
            No. points not estimated
            Relative precision
        iii. *All image measurements*
5. Measurement > Delete rejected
6. Measurement > Find targets in all images
7. Adjust > Compute bundle adjustment
8. Measurement > Delete rejected
9. Adjust > Compute bundle adjustment

*Review the 4a and b sections above – things should be improved

10. Measurement > Stereo constraints > Configure

*Clicking *automatic* should place everything in the right columns. Check to see that things look correct.

11. Measurement > Stereo constraints > Estimate…

*Check base separation. This is your distance between your cameras, it should roughly match what you know this to be.

12. Measurement > Stereo constraints > View…

* *Number of exclusions* should be **<4**

13. Measurement > Stereo constraints > Export
    YYYYMMDD_[system]_[camera].cam (e.g. 20170616_BLUE_L.cam)
14. Save everything else as follows:
    a. Close CAL [X], you will be prompted to save things with pop-up windows
    b. Object point data: DO NOT SAVE
    c. Measurements: SAVE (overwrite)
    d. Camera data: SAVE AS [system]CamCAL_[camera] (e.g. BLUECamCAL_L)

FOR USING EVENTMEASURE, USE THE CAM FILES GENERATED IN STEP 13. E.g., = 20170616_BLUE_L.cam

III. Checking the calibration with scale bar footage

A. Load the project in EM
    1. Create new measurement file
    2. Set picture directory, load L & R videos
    3. Load L & R camera (calibration) files

4. Information fields: Edit field values (just put “test” for both – this isn’t real survey data)

B. Begin measurement

1. Sync cameras, check lock box
2. Measure long, medium, and short distances on bar at various places in the FOV.

**Use the centroiding square where possible

3. Values should be within your desired range, based on your unique scale bar values.

OREGON
Fish & Wildlife

3406 Cherry Ave. NE

Salem, Oregon 97303