

How to build a low-cost underwater camera housing for aquatic research

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Abstract

Remote cameras are an increasingly important tool in field-based biological research. Terrestrial researchers can purchase inexpensive off-the-shelf cameras, but aquatic researchers face challenges in adopting similar systems for underwater science. Although technology allows researchers to deploy cameras in any aquatic environment, high procurement costs are often a barrier, particularly for studies that require the collection of lengthy videos. In this note, we provide a detailed guide explaining how to assemble an underwater camera system for less than \$425 USD. We focus especially on the construction of the underwater housing, which is typically the most expensive component of an underwater camera system. As described, this system can record 13 h full high-definition videos in depths up to 100 m. It can be constructed and assembled with limited technical background using tools available in most workshops. The guide includes a general overview of the system, a full list of components, detailed instructions on constructing the camera housing, and suggestions on how to mount and use the camera in fieldwork. Our goal for this note is to promote the wider use of remote underwater cameras in aquatic research by making them accessible to those with limited financial means.

Key words: action camera, remote camera, digital video, behaviour, benthic ecology, science communication

Introduction

Aquatic science relies on technologies that provide information about the underwater environment. Underwater cameras are a widely used tool to perform direct observations on the behaviour of organisms in their native habitat and can greatly supplement the data derived from other means. As an example, cameras can be used to study the behaviours of organisms that interact with static (e.g., [Renchen et al. 2012](#); [Bacheler et al. 2013](#); [Favaro et al. 2014](#)) and mobile fishing gear (e.g., [Nguyen et al. 2014](#); [Underwood et al. 2015](#)) in situ.

The merits of applying camera systems in biological studies have been amply demonstrated in the terrestrial realm, where a mature body of evidence has described their application to studying ecosystems ([O'Connell et al. 2011](#)). Many of these systems are inexpensive and readily available as off-the-shelf products, which has assisted in the proliferation of this study technique. In contrast, underwater camera systems can be substantially more expensive, due primarily to the challenges associated with operation in an aquatic environment.

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The utility of underwater cameras for aquatic science depends in part on the specifications and capabilities of the camera gear (Favaro et al. 2012; Underwood et al. 2012; Struthers et al. 2015). For cameras that are self-contained (i.e., do not need to be connected to a boat or other fixed power source at the surface), there are essentially two categories: expensive systems that are highly capable; and inexpensive systems that are limited in battery life, safe operating depth, storage capacity, and low-light sensitivity (e.g., Struthers et al. 2015). For researchers that need to record video for longer periods of time (e.g., studying deployed fishing gear), systems specific to the project often have to be designed and built (e.g., Jury et al. 2001; Bacheler et al. 2013). Trial-and-error associated with the design and construction process can add to the cost of underwater projects and prevent them from being completed in a timely manner. This can result in researchers avoiding the use of underwater cameras, or selecting off-the-shelf cameras that can only record for short durations due to limitations in battery life.

In this note, we describe a camera system that we constructed from components available at general hardware and consumer electronics stores. There are four components to this system: the camera itself, the external battery pack, the housing, and the mounting frame connected to the fishing gear (or other structure) under examination. We devote most of this note to describing the construction of the underwater camera housing, which is often the most expensive component to procure when assembling a camera system for aquatic research. The underwater housing described in this note was adapted from a design shared on a hobby website (Anonymous 2006). The total cost of components for one housing was \$145 USD (Supplementary Material 1).

With proper care taken in construction, the housing is capable of being safely used at depths up to 100 m. It is large enough to contain a small camera such as a Sony Action Cam with an additional battery pack, and the configuration we describe in this note is capable of recording full high-definition videos at 1080p resolution for 13 h (Sony Corporation 2014). This note provides sufficient detail for someone with limited technical experience to procure the materials and construct the underwater camera housing. Our hope is that this note empowers researchers to construct inexpensive housings that facilitate the collection of long-duration video recordings in aquatic environments.

Materials and methods

Camera components and necessary tools

We selected a Sony HDR-AS20 Action Cam and attached an Anker Astro E4 13 000 mAh battery pack (any battery pack with at least a 10 000 mAh capacity and a USB connection should suffice) to increase battery life and recording duration. Using a 128 GB Micro SDXC memory card, we were able to record continuously for 13 h at 1080p resolution.

The tools required for this project comprise: pencil, marker, tape measure, ruler, calipers, miter saw equipped with a plastic-cutting blade, band saw, lathe, scissors, fine sandpaper, masking tape, four 2 mm shims (we suggest using coins), string, steel punch, drill press, 1.95 mm (5/64") drill bit, and a No. 1 green Robertson screwdriver. Figure 1 shows a completed housing, and Fig. 2 shows the raw materials and hardware needed for its construction. Finally, Supplementary Material 2 demonstrates how to execute each step of the construction process.

Construction of the underwater housing

To construct the underwater housing, detailed instructions are provided in Supplementary Material 3 with accompanying photos and text describing how to complete each step. We recommend using these instructions while reviewing the accompanying video (Supplementary Material 2) to aid in the construction process. These instructions guide the researcher through preparation of all the

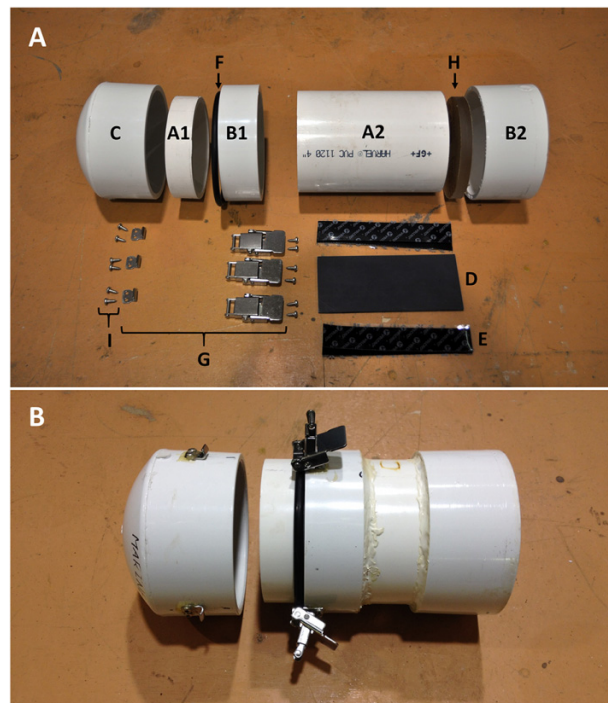


Fig. 1. Disassembled camera housing, showing (A) all components prepared for assembly, with part labels corresponding with those in Fig. 2, and (B) completed housing.

necessary components and assembly of the completed housing (Fig. 1). We also include a description of each component and its price at the time of writing (Supplementary Material 1).

The housing itself consists of two main parts: the body of the housing and the end cap that latches firmly onto the body to form a watertight seal. The body contains the camera and external battery, and features a clear, acrylic viewport on the front end. The housing is constructed using 10.16 cm diameter (4") schedule 40 (0.6 cm wall thickness) PVC piping components. We used schedule 40 PVC components as they are inexpensive, widely available, and durable. The components required to construct the housing are widely available at most hardware stores, and the housing can be constructed and assembled with limited technical background using tools available in most workshops.

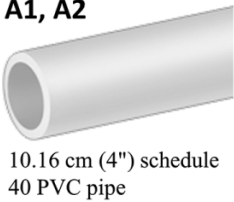
Construction of the housing does not take a large amount of time and is mostly limited by the time required for the epoxies and adhesives to fully cure. For example, the final step in construction of the housing requires the use of 3M™ 5200 marine adhesive sealant, which specifies a cure time of 5–7 d. We estimate that preparation of the component pieces and actual assembly time should take approximately 4–5 h.

Use in the field, care, and maintenance

The underwater housing can be affixed to fishing gear or other structures. For our research project, we built wooden frames to mount the camera systems to crab pots, similar to the designs of Jury et al. (2001) and Favaro et al. (2012) (Fig. 3). We held the underwater housing firmly in place using a large 114–165 mm diameter gear clamp that allowed for easy mounting and removal of the camera housing. Depending on the application, researchers must consider whether to add external lighting. If external lighting is used, we recommend using lights capable of consistent illumination for the duration of video recording (to avoid illumination problems such as those experienced by Favaro et al. 2012). We also recommend red lights, as they are less visible to many marine organisms than

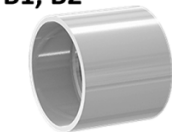
i: PVC

A1, A2



10.16 cm (4") schedule 40 PVC pipe

B1, B2

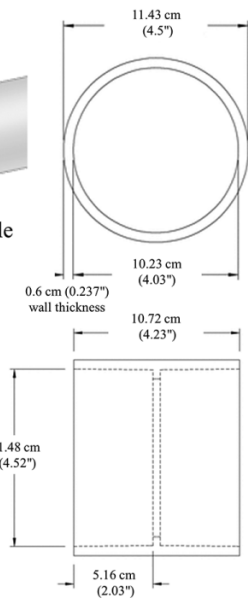


10.16 cm (4") schedule 40 PVC coupling

C



10.16 cm (4") schedule 40 PVC unthreaded cap



ii: Camera Mount

D



0.32 cm (1/8") PVC sheet

E



3.54 cm (1") Industrial-strength hook & loop

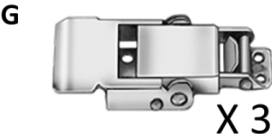
iii: Hardware

F



O-Ring, 0.635 cm width, 11.43 cm internal diameter, 12.70 cm outside diameter (1/4" width, 4 1/2" ID, 5" OD)

G



Internal compression spring-draw latch

H



Optically clear acrylic circle, 1.27 cm (1/2") thickness, 12.7 cm (5") diameter

I



Stainless steel screw, No. 6, 0.95 cm (3/8")

iv: Adhesives

J

Clear PVC cement

K

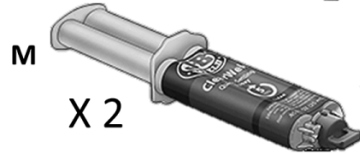
Clear PVC primer

L



3M™ 5200 marine sealant

M



Adhesive epoxy*

*Self-mixing epoxy is preferable (e.g. Permatex™ self-mixing 5 minute epoxy)

Fig. 2. Components needed to construct the camera housing. Product renderings provided by McMaster-Carr (Cleveland, Ohio, USA).

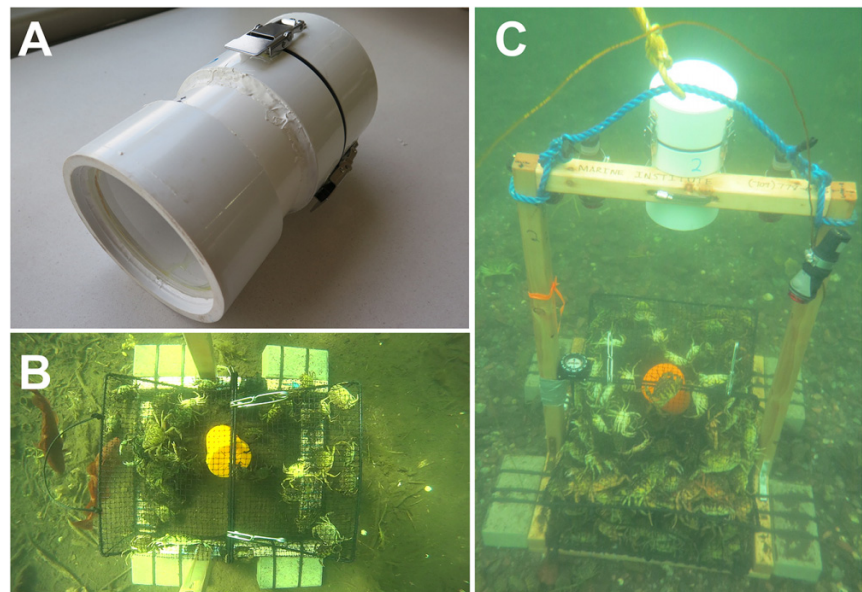


Fig. 3. Photographs depicting (A) a completed camera housing, (B) an example screen grab from a camera system deployment, and (C) the fully assembled camera system, deployed at sea.

full-spectrum lights (Goldsmith and Fernandez 1968; Widder et al. 2005; Weiss et al. 2006). In our specific application, we used Light and Motion (Marina, California, USA) Gobe Plus flashlights equipped with red light attachments (the Gobe Focus Head). We found it preferable to use lights with red LEDs, as opposed to white LEDs covered by a red filter, because the red LED uses less energy to produce the same intensity of light.

The underwater housing requires little maintenance. Although many housings require the use of O-ring grease to facilitate the seal, we do not recommend doing so with our system because we found that it can increase the chance of a leak. If the O-ring is kept clean and free from debris, compressional force alone is enough to maintain a water-tight seal. Be sure to inspect the O-ring regularly for signs of wear and damage. Additionally, if the housing is being used in a salt water environment, it is important to rinse it thoroughly in fresh water after each use.

Hydrostatic pressure testing

The maximum safe operating depth for these housings depends on the care taken during the construction process. Therefore, we recommend that all housings be tested for leaks either in a hydrostatic chamber if available or in the field at-depth before installing a camera inside. We recommend testing empty camera housings at depths exceeding those intended for use in the study.

To measure the maximum safe operating depth of this housing design, we used a hydrostatic testing chamber. We tested two housings: one that was built to the exact specifications outlined in this note (housing A); and another that was built the same way, but with less sealant around the inside and outside of the viewport (housing B). We tested each housing separately in the hydrostatic chamber by steadily increasing the hydrostatic pressure to the point of failure (i.e., leakage or implosion). We applied water-finding paste around the viewport and O-ring seal on the inside of each camera housing to determine the entry point of leaks. Any contact with water would change the colour of the paste from grey to purple and would indicate the location of a leak. Slow leaks inside the chamber

were indicated by a gradual drop in pressure inside the chamber, whereas a catastrophic leak (e.g., implosion) would be indicated by an instantaneous drop in pressure.

Results

We have used these underwater housings to conduct field-based research in coastal waters of Newfoundland, Canada during the summer months of 2015 and 2016 to assess the efficiency of two types of fishing gear designed to catch European green crab (*Carcinus maenas*) and American lobster (*Homarus americanus*), respectively. Field research was conducted under Experimental Licenses NL-3133-15 and NL-3271-16 issued by Fisheries and Oceans Canada. The field research only involved invertebrates; therefore, it was classified as a Category A study and was registered with Memorial University's Animal Care Committee. We built a total of seven camera systems that were deployed a total of 160 times, for a combined total of 2794 h underwater. Cameras were deployed in depths ranging from 2 to 16 m, anywhere from 6 to 26 h duration. Across the entire study, we experienced an incident where three camera housings experienced minor leaks on the same day in 2015. We identified that the leakage was caused by the use of O-ring grease. Compression forced the greased O-ring out of place, which compromised the seal and caused the leak. As a result, we did not use O-ring grease during any other deployments and experienced no further issues.

Hydrostatic pressure testing results

Housing A experienced a slow leak at 4760 kPa (equivalent to a depth of ~470 m), and housing B experienced a slow leak at 2000 kPa (equivalent to a depth of ~200 m). The water-finding paste indicated that in both camera housings the leaks occurred around the viewport. This large difference demonstrated the importance of taking great care to seal the lens thoroughly. This also suggested that increasing the thickness of the camera housing (e.g., by using schedule 80 PVC) would not necessarily increase the depths at which this design could operate.

Discussion

Electronics change quickly, but the need to keep them dry does not. It is always necessary to procure an underwater housing to record in situ video, and these housings are often among the most expensive parts of a camera system. It is our observation that although the video quality of off-the-shelf cameras has improved, and cameras have shrunk, they have not improved in their ability to record long-duration videos as battery life and storage capacity are still limiting factors. It is notable that newer action cameras are capable of recording in 4K resolution, but these videos are more memory intensive than standard high definition. In addition, aquatic researchers are more limited than their terrestrial counterparts in their ability to rely on motion sensors because of the frequent movement of currents, vegetation, and particulate matter which contribute to false-positive activations of the camera.

For our system, the total component costs at the time of writing were \$145 USD for each housing, \$320 USD for the camera, memory card, and battery, and \$40 USD for materials for the wooden frame used to mount the cameras to our particular traps. The lighting solution that we used cost \$650 USD. The most cost-effective way to produce this housing is to build more than one at a time because many materials (e.g., PVC pipe, O-rings) are sold in pre-set quantities or lengths, so this note will leave the researcher with an excess of materials.

If researchers simply need to record short shallow water videos in well-lit environments, then an action camera with an off-the-shelf housing is sufficient (see [Struthers et al. 2015](#) for review). Time-lapse cameras are cheap and widely available, but they do not allow the user to record long,

continuous videos, which is a necessity for certain applications. In addition, most industrial fishing occurs in water too deep for most consumer camera systems (Morato et al. 2006), so accessing these depths for the length of time needed for fisheries research is more challenging. We see this housing as filling an important niche: an extremely low-cost solution for researchers that need to record long videos at shallow to moderate depths and that do not have access to the necessary funds to purchase specialty equipment. In addition, although construction experience is helpful (especially in the use of a lathe), we believe that a relatively low level of pre-existing technical skill is needed to follow these instructions in comparison with other do-it-yourself camera options currently available (e.g., Cazenave et al. 2014).

There are many uses for camera systems in underwater environments and their flexibility is only limited by the creativity of the researcher. To list a few applications, underwater cameras can be used to study fish behaviour (Hammar et al. 2013; Binder et al. 2014; Domenici et al. 2014), monitor interactions with fishing gear (Jury et al. 2001; Bacheler et al. 2013; Robbins et al. 2013), evaluate bycatch reduction devices (Favaro et al. 2013; Cairns et al. 2014; Lomeli and Wakefield, 2014), assess abundance and community structure (Clarke et al. 2012; Harasti et al. 2014), or map habitat and bathymetry (Schmidt and Rzhanozov 2012). However, many studies involving action cameras are still limited by the duration and quality of video they are able to record. We are hopeful that this detailed note will make it easier for researchers to procure and use underwater cameras in their own research to facilitate long-duration video recordings in the underwater environment.

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Author contributions

Conceived and designed the study: JAB, NZ, GL, BF. Performed the experiments/collected the data: JAB, NZ, GL, BF. Analyzed and interpreted the data: JAB, NZ, GL, BF. Contributed resources: GL, BF. Drafted or revised the manuscript: JAB, NZ, GL, BF.

Competing interests

BF is currently serving as a Subject Editor for FACETS, but was not involved in review or editorial decisions regarding this manuscript.

Data accessibility statement

All relevant data are within the paper, the Supplementary Material, and on Figshare (see [Supplementary Material 2](#)).

Supplementary material

The following Supplementary Material is available with the article through the journal website at doi:[10.1139/facets-2016-0048](https://doi.org/10.1139/facets-2016-0048).

Supplementary Material 1: Detailed list of hardware for housing, product numbers for an online hardware retailer, and price at time of writing.

Supplementary Material 2: <https://dx.doi.org/10.6084/m9.figshare.4042932>—In this video we demonstrate all steps necessary to construct the underwater camera housing described in the note. Step numbers in the video correspond to each step in the supplementary material. Component labels correspond with labeling in [Fig. 2](#).

Supplementary Material 3: Fully annotated construction guide, including photos demonstrating each step.

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