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Diver deployed autonomous time-lapse camera systems for ecological studies

Piotr Balazy [a], Piotr Kuklinski[a,b] and Jørgen Berge[c,d]

[a]Marine Ecology Department, Institute of Oceanology, Polish Academy of Sciences, Sopot, Poland; [b]Department of Life Sciences, Natural History Museum, London, UK; [c]Faculty of Biosciences, Fisheries and Economics, UiT The Arctic University of Norway, Tromsø, Norway; [d]Arctic Biology, University Centre in Svalbard, Longyearbyen, Norway

ABSTRACT

Photographic time-lapse techniques are especially useful in the marine realm for visualising long-term processes and remote monitoring of sites/objects/organisms where the presence of researchers might cause some study bias, or access is limited or impossible. With rapid advances in technology development there is easy access to new tools for time-lapse photography and setting up systems is relatively inexpensive. The essential requirements for low-cost autonomous time-lapse camera systems to be self-sufficient and reliable enough to withstand the extended periods of deployment (up to one year) on the sea floor at up to 50 m depth are presented. In this example a custom-made system developed originally for monitoring the activity of filter/suspension feeders and scavenging fauna in the polar conditions is described. The major issues encountered during the preparation and deployment which should be of benefit to users involved in underwater time-lapse photography are considered.

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Introduction

Time-lapse photography involves capturing repetitive frames at a fixed time intervals in order to visualise processes that may otherwise be imperceptible to the human eye when viewed in real time (i.e. hours to even years). When played back at a higher speed these long-term processes can be viewed in just few seconds or minutes. Using this technique, in addition to observing processes that are otherwise too slow for human perception, it is also possible to preview or monitor sites/objects/organisms remotely for extended periods of time. This is especially valuable in the marine environment where direct observations cannot easily be made. Many observation sites are logistically challenging because of high travel costs and/or harsh weather conditions (e.g. low temperatures, ice cover and total darkness during the polar night), and in places where human presence should be reduced to a minimum. In strictly protected areas, or where there may be negative effects from human intervention or diver driven bias, it is sometimes the only method suitable.

In the literature there are many examples of where underwater time-lapse photography has been successfully used for these purposes, in a wide range of conditions from shallows to deep sea, and from tropical to polar regions. It has been exploited to reveal aspects of behaviour and ecology of a number of benthic taxa such as cnidarians (Bongaerts et al. 2012), annelids (Tunnicliffe et al. 1990), echinoderms (Meyer et al. 1984), mollusks (Lord 2011), arthropods (Hargrave 1985) and fish (Armstrong et al. 1992). This has encompassed investigations of relationships between different species (Riedel et al. 2008), their movements (Kaufmann & Smith 1997), growth patterns (Barnes & Crossland 1980) and their influence on the environment (Rowe et al. 1974). Physical (http://www.bbc.co.uk/nature/16250444) and anthropogenic (Davis et al. 2012; Godø et al. 2014) processes that may affect biological life have also been visualised with unattended time-lapse camera systems deployed by divers. A recent, and impressive application of this method took place in Antarctica (http://www.bbc.co.uk/nature/16250444) at Little Razorback Island where a BBC crew filmed for the first time the formation of a brinicle – a fragile tube of ice that forms around the sinking plume of cold, dense water extruded from the sea ice (Cartwright et al. 2013). The whole phenomenon took approximately a week (the filmed event lasted for 5–6 hours). The resulting short film revealed how benthic life can be threatened by the ice action with slow moving animals (e.g. sea stars, sea urchins) becoming trapped during formation of the ice brinicle. The utility of time-lapse filming has thus

CONTACT Piotr Balazy balazy@iopan.pl Marine Ecology Department, Institute of Oceanology, Polish Academy of Sciences, Powstancow Warszawy 55, Sopot 81-712, Poland

added significantly to previously very limited knowledge of the time scale involved in the formation of these ice structures.

Over the past few years several underwater time-lapse camera systems have been proposed (e.g. Allen et al. 1978; Fedra & Machan 1979; Lampitt & Burnham 1983; Smith et al. 1993). However, in order to build up a custom made, low-cost system that will be self-sufficient, reliable enough to withstand the extended periods of time (up to one year) of deployment on the sea floor (at up to 50 m depth) there are a number of issues that need to be addressed. The key points are considered in this article and potential solutions available on the market are reviewed. In some cases this involves modification of standard low-cost products, such as GoPro, Canon or Nikon compact and digital single-lens reflex (SLR) cameras in order to construct research installations suitable for challenging on-site deployment.

Challenges and solutions

The first and most important challenge is the choice of a suitable camera; this is key to obtaining good results in terms of image quality. There is a very wide range of options available on the market, but where the budget is limited and the aim is to keep the system as inexpensive as possible, a few key criteria need to be considered. As well as the number of effective pixels (the minimum recommended is 8 mln), the size of the sensor and the tonal range, the main feature for consideration is the capability of the built-in time-lapse controller. The majority of simple cameras offer only a few interval settings. For example, the GoPro camera HERO5 Black offers only a maximum of 60 second intervals, which can be extended up to 60 minutes only when used in the 'Night Lapse Photo' mode. More advanced compact cameras, such as the Nikon P340 or P7800, can take pictures only up to 10 minutes apart. Even where some of the popular simple cameras such as the Panasonic Lumix DMC-FT5 provide other opportunities (30 minute intervals) they might support only a certain number of shots (in this case 1000 pictures). Digital SLR Cameras aimed at semi-professionals (e.g. Nikon D300), do not have such limitations but can be costly. A potential alternative for consideration is to utilise one of several external time-lapse controllers that are available on the market, combined with a cheaper camera. For example the DigiSnap 2700 by Harbotronics (https://www.harbortronics.com/Products/Digisnap2700/), is designed especially for long-term time-lapse project and includes various connections for controlling power to the camera, lighting or a strobe. A real-time clock can be configured to take a specified number of pictures (in a sequence from 1 to 65,535, or infinite) at any interval desired from 0 seconds to 255 hours, 59 minutes and 59 seconds (which is over 10 days) and is able to cooperate with many modern digital camera models. The newest version DigiSnap Pro is even more versatile (https://cyclapse.com/products/digisnap-pro/).

Similar products are also available off-the-shelf for use with GoPro cameras. For example, the Time Lapse Intervalometer by Cam-Do (http://cam-do.com/GoProTimeController.html) allows the user to programme shots at time intervals from 5 seconds to infinity, with a delayed start and repeated cycle (from 15 seconds to one week or more). When fitted with the light trigger option the camera can be started when a light shines on the controller. This also has the advantage of extending the battery life by turning off the camera between the shots. With the Programmable Scheduler the photographer can programme time-lapse sequences to be shot during certain hours of the day, every day or every business day. A disadvantage of this controller is its relatively large size and this ultimately compromised the key advantage of GoPro camera – its small size. This product has now been superseded by Blink, which in addition to being smaller than the Intervalometer, also has additional programming features. Another potential solution for controlling time intervals is contained inside the software of Canon compact cameras. A tool called the Canon Hacker's Development Kit (CHDK, http://chdk.wikia.com/wiki/CHDK) equips a simple point-and-shoot PowerShot series with the capabilities offered by the SLRs (e.g. time lapse). CHDK is free to use and modify with firmware released under the GNU General Public License. This means that by implementing pre-existing, or custom code, an amateur programmer (within some hardware limitations) can control the camera. Importantly this causes no permanent changes to be made to the camera thus avoiding warranty issues. Although there is an extensive list of cameras that can potentially be controlled in this way, some newer models have encrypted firmware which prevents such modifications being made.

Although in principle it is possible to connect underwater time-lapse systems directly to the surface to provide a live view, because of the complexity, higher costs and risk of damage to the whole setup by wave, current, and in some places, ice action, possible set ups for this are not considered here. The deployed system must therefore have a self-contained memory card for storage of the photographic data. There are numerous formats for memory cards and compatibility with the camera must be considered. In the case of long-term projects choice of memory card format is generally a compromise between high resolution, (and thus the quality of the photographs) and the amount of available data storage space on the card. Usually a camera that can accept up to 128 GB cards will be suitable for year-round projects (when taking pictures every 30 minutes). It will be large enough to hold about 17,520 lowest compression/highest resolution JPEG images (approximately 6 MB per image).

Where the time-lapse system is planned to be deployed for a long period an alternative camera power source is usually required as the standard batteries may lose charge before the end of the observation period. Depending on the shooting schedule and camera model this duration will vary; under normal conditions a standard GoPro battery will last for ∼2 hours or 110–140 shots, while a basic digital SLR camera will take 700–900 pictures. Supplying additional energy may require custom-made modifications; however, there are some ready-made products available for certain cameras (e.g. GoPro Battery Eliminator by Cam-Do). External energy supply on the cable from the shore would be the best choice, but in contrast to large research stations which may have the necessary facilities, in remote locations high capacity rechargeable battery packs are typically required. From the large number of available cell types (LiPo, NiMH, Li-ion) lithium-ion batteries are recommended due to their reliability, low self-discharge rate (1–1.5% per month) and better resistance to low temperatures. Nickel metal hydride cells are unsuitable for long-term investigations as even unused they lose their capacity quickly (1–1.5% per day) and are also much heavier. It is important to check the on-line power consumption models for different cameras prior to deployment (e.g. https://cam-do.com/pages/photography-time-lapse-calculator). If possible a precautionary option is to add additional power capacity (e.g. 50%) as a backup for unexpected conditions, for instance the reduction in capacity caused by a cold water environment. A system that is designed to monitor over a one year period and where pictures are taken every 15–30 minutes. should have batteries of at least 40 Ah capacity.

Depending on the scientific purpose (e.g. shooting pictures in the complete darkness of the polar night) and expectations regarding the outcomes (colour rendition) a complete system may require a light source. The lamp should have wide field of view (100°) and be strong enough (guide number 24) to light up the object of interest. Compact lighting set ups are ideal (see e.g. tiny and low-cost Nano by Fantasea) as they are less affected by drag when currents occur. Typically, lights are mounted using standard photo/video arms with tightly screwed ball-head clamps. Stroboscopic lights need a large amount of power for charging; an alternative is to utilise video LED lights synchronised to light up momentarily with the shutter. It is prudent to divide the power for the lights and camera into two separate dedicated batteries.

Housings to protect the camera and sensitive electronics from the marine environment are an essential part of the underwater time-lapse setup. As standard commercial underwater housings are generally not applicable to custom time-lapse installations, they need to be designed specifically. On a basic level these can easily be manufactured by sealing a tube that is large enough to fit all the parts inside, except for the movable light. Inside this housing there should be a stable frame for mounting the camera. Custom-made cylindrical housings can be made of acryl, delrin (polyoxymethylene) or any other material that is stiff, resistant to crushing (as some force is typically required to mount the housing on a tripod or frame, the housing should not deform as it may cause leaking) and can operate in temperatures from −2 to +30°C. Acryl is more fragile and prone to scratches, but has the advantage of being transparent, so that there is no need to design a viewfinder for the camera lens. It also means that the system can be viewed without opening the housing. However, it should be noted that the time-lapse images can only be inspected after recovering the device to the surface as this type of design does not allow for any modification of camera settings underwater. Proper water resistance can be obtained by placing two o-ring seals in a row and tightening these with metal latches. Systems based on such closures can be deployed to several tens of metres in fresh or salt water (see e.g. divers primary torches, UW scooters). To remove the internal moisture and avoid any fog on the glass viewfinder bags of silica gel should be placed inside the housing. A system with these elements is commercially available, called Hydrolapse (https://www.harbortronics.com/Products/Hydrolapse/). It appears to be the only product for this purpose that is available to purchase at present and is based on a simple digital SLR camera – the Canon Rebel T3 (1100D). This camera setup has been used in a number of studies (e.g. mountains, glaciers of Antarctica) and in the shallow underwater environments (up to 30 m, e.g. in the Gulf of Mexico) where it enabled unattended time-lapse imaging of marine processes that lasted up to 6 months, taking about 12 pictures per day. Guided by the design and application of this system a similar time-lapse setup was constructed (with some modifications necessitated by the need to simplify the design for affordability). This setup was designed for one year of deployment at maximum working depth of 50 m in the Arctic conditions and was carried out by GRALmarine (Figure 1, http://www.gralmarine.com). Example images from the system are provided in Figure 2. The practical application of the device can be found at Berge et al. (2015) and http://www.polartimelapse.net/.

Figure 1. Custom made time-lapse camera system made by GRALmarine.

A special frame is required in order to mount this imaging system on the bottom surface at a site. The relatively compact size of the system (30 cm long and a diameter of 20 cm) and the lightweight (< 15 kg) construction makes it easy to mount and deploy even from a small rubber boat. The construction can be a folding tripod with bottom-looking camera (monitoring the activity of benthic fauna over a specific area), or a straight-looking setup (observing a certain part of the sea floor) fixed to a flat metal frame (Figure 3). Here an insight in the latter one is provided, where the cylindrical housing is attached to a steel plate and completely enclosed in two profiled plastic brackets. The u-shaped brackets can be then attached to the metal frame by butterfly nuts utilising 8 mm bolts welded into the frame (use of fixed bolts has the advantage of preventing unwanted rotation while mounting the brackets during diver deployment, making the process quicker and easier). Distancing pieces can be used to alter the optical axis of the camera both horizontally and vertically, even underwater by divers wearing thick dry gloves. Ease of on-site adjustment is of prime importance underwater, being especially useful when the object to be photographed is located at some point above the sea floor. An additional advantage is that this type of design allows recovery of just the housing, leaving the heavy frame on the sea-bottom, for example, for changing just the camera settings or downloading the data. Some housings can exhibit a positive buoyancy and thus on the top of the bracket there are loops for clipping some weights to make it more neutrally buoyant in seawater. The metal frame also serves as a stabilisation platform for the whole construction. After placing the setup on the sea floor, rocks present in the vicinity can be placed on its sides in order to stabilise the platform (Figure 3(b)). The setup should be heavy as it has to be stable for extended periods of time. The frame consists of three pieces, which can be bolted together both ways: in a line – to make them larger and more stable, or one above the other when there is no enough space, for example, between boulders or rocky shelves.

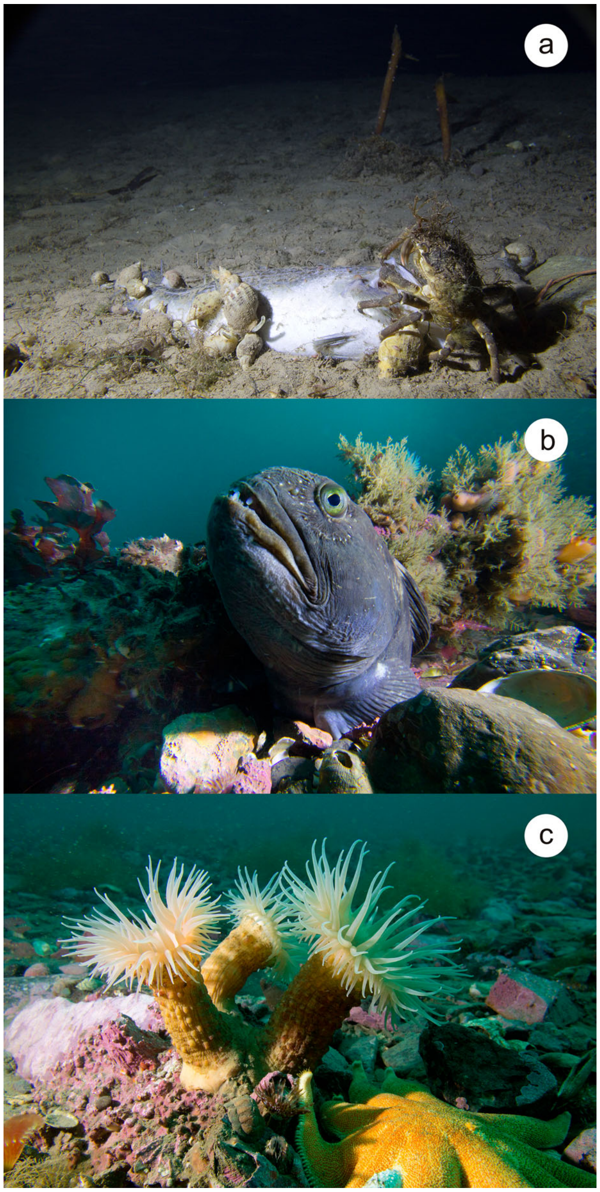

Figure 2. Example images from the system: animals at bait (polar night, Spitsbergen, 12 m depth; 20 mm, F11, ISO 100, −1.33 EV, 1/6 sec) (a), Atlantic wolffish *Anarhichas lupus* in his hide (polar day, Spitsbergen, 20 m depth; 10 mm, F16, ISO 400, −1.33 EV, 1/10 sec) (b), rocky bottom epifauna (polar day, Spitsbergen, 17 m depth; 21 mm, F14, ISO 400, −1.33 EV, 1/20 sec). Full time-lapse movies accessible at www.PolarTimeLapse.net.

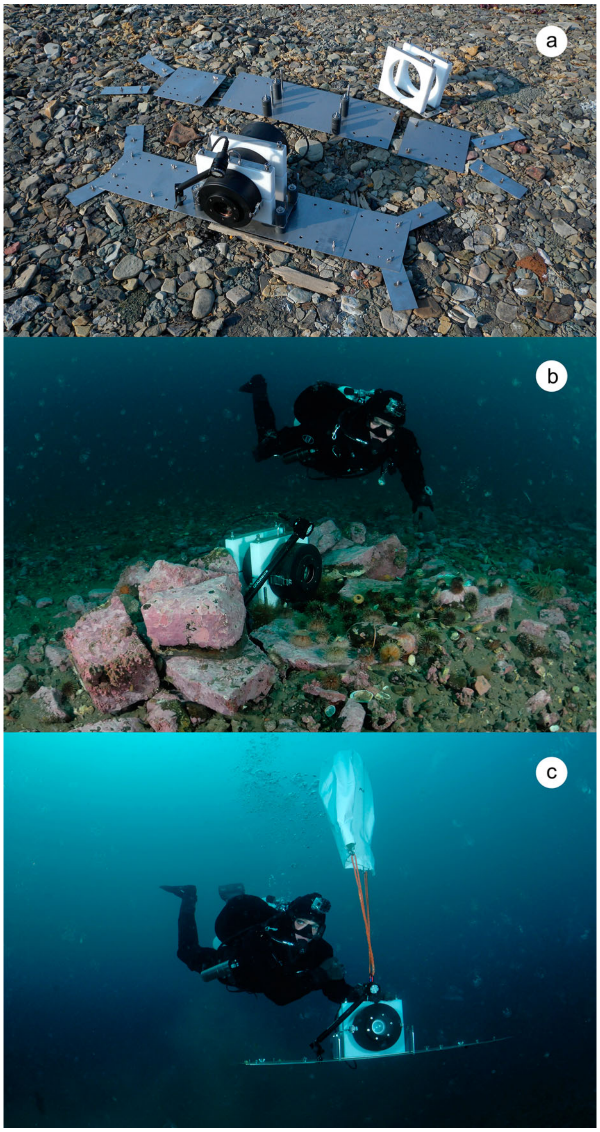

Figure 3. Straight-looking setup mounted on a frame: on the surface (a), underwater (b) and during recovery (c).

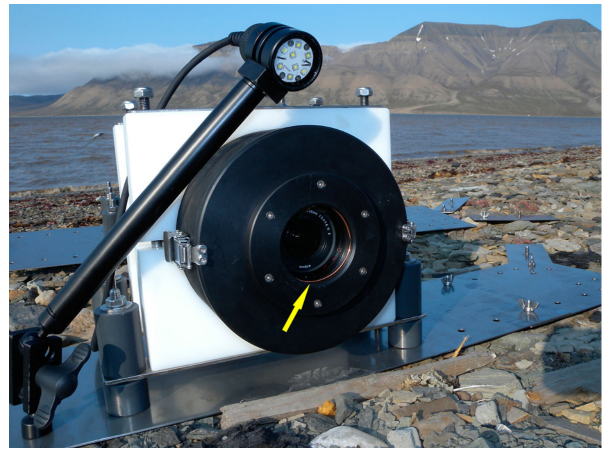

Figure 4. Example of mounting a copper wire around the glass camera port.

Additionally, at the corners of the metal frames there are moveable flats that further increase the surface or help to anchor the whole construction. All parts used are stainless steel (Figure 3).

Biofouling caused by marine growth is a particular issue in time-lapse photography devices deployed in underwater environments for any extended duration. Although settling of algae or encrusting organisms on much of the housing or frame can be discounted, the surfaces most at risk are those in front of the camera lens and the lamp, so keeping these clear is crucial for the success of the project. According to our knowledge to date there is no transparent anti-fouling paint and therefore the only available coating option is to cover the parts surrounding the camera lens with several layers of products that are manufactured for protecting ship hulls. There are many of these on the market, with each one designed for a slightly different surface type and specific marine environment. Paints containing toxic copper, organotin compounds or other biocides can impede growth and development of algae and sedentary invertebrates but their use is often prohibited, depending on location, so contacting the local authorities is advisable. As an alternative, a mechanical anti-fouling tool can be utilised such as the Hydro-Wiper by ZEBRA-TECH LTD (http://www.zebra-tech.co.nz/hydro-wiper/#1448316839227-423bbbd8-d908), which is synchronised with the shutter. When fitted with a brush and run every 30 minutes this prevents biofouling of the surface. These devices have proved to be highly efficient in cleaning numerous marine instruments; however, the purchase cost may be equivalent to that of the entire home-made imaging system. Thus, in order to improve the action of anti-fouling paints a bare copper plate (or thick copper wire) might be added around the glass camera port, as well as around the lamp (Figure 4).

The development of electronic equipment proceeds very fast, and the number of camera models and devices mentioned here may be improved or superseded in a few years. However, the general principles described in this paper relating to the construction and deployment of underwater time-lapse photographic devices are expected to have universal application for conducting successful underwater investigations in the future.

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ORCID

Piotr Balazy http://orcid.org/0000-0002-1126-3151

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