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research tools in marine science

A new compact rotating video system for rapid survey of reef fish populations

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ABSTRACT.—A new, compact, inexpensive, remote submersible rotating video system (SRV) is described in detail for use in fish and habitat surveys. The SRV was designed to remotely simulate the widely used Bohnsack-Bannerot fish-survey method. The positive attributes of SRV include: (1) elimination of potential diver effects on fish behavior; (2) efficiency (multiple simultaneous deployments); (3) less ship time; (4) cost effectiveness; (5) depth limits far exceed scuba; (6) non-destructive to habitat; (7) non-extractive; (8) useful in situations dangerous for divers; (9) provides a permanent high-resolution record of the survey and habitat condition; and (10) fish behaviors unlikely to be observed by divers may be recorded with SRV. However, the SRV may underrepresent small cryptic species and laboratory time would be necessary to evaluate the videos.

Research on marine fishes increasingly employs a variety of fishery-independent methods to monitor spatial and temporal patterns in populations. Fishery-independent methods include: underwater visual census (UVC), underwater video, aerial and satellite images, acoustics, and experimental fishing with hook and line, nets, or traps. The types of data obtained from the various types of surveys are: species identity; abundance or density; sizes; and habitat quantification.

Ecologists and fishery scientists are expanding their use of UVCs as a way to non-destructively quantify fish abundance and community structure in a diverse set of marine habitats. UVCs can be conducted by scuba divers, manned submersibles, remotely operated vehicles (ROVs), or drop cameras. The various techniques, each with its own biases, include belt and line transects, rapid visual technique (RVT = roving diver), and point counts. Video-based techniques are now proving particularly useful because they are relatively cost effective and non-extractive, can exceed diver capabilities in terms of depth limitations and hazardous conditions, can reduce the impact of divers on fish behavior when deployed remotely, and provide a permanent record of the survey and habitat condition (see Murphy and Jenkins 2010 for review). Recent developments in video technology have reduced the cost, increased the resolution, and decreased the size of video recorders. These improvements have allowed the development of compact complimentary systems that provide even greater cost effectiveness and the ability to survey fish populations over a greater range of conditions.

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The objective of the present paper is to describe in detail a new, inexpensive remote device designed to support a compact video camera and simulate standard UVC point counts such as those of Bohnsack and Bannerot (1986). This submersible rotating video system (SRV) continuously surveys 360° around the point of anchorage on the bottom. Although many underwater camera systems have been described, and are being used (see Mallet and Pelletier 2014 for review), only one other rotating video system has been described (Pelletier et al. 2012)—we compare SRV with the Pelletier et al. system below.

Here we also describe highlights of ongoing research using paired comparisons of SRVs with Bohnsack-Bannerot point counts to illustrate biases in both methods, but the complete set of results of this comparison will be reported elsewhere.

Description of Research Tool

SRV was designed and constructed to simulate stationary visual point counts of reef fishes, such as the method of Bohnsack and Bannerot (1986). This research tool consists of a waterproof housing containing a sealed lead-acid rechargeable battery that powers a 2-rpm (revolutions per minute) gear motor (Fig. 1). The gear motor can be turned on and off by a magnetic switch controlled by a magnet secured by Velcro to the outside of the housing. The switch is normally closed, so the motor is turned off when the magnet is attached to the housing just opposite the switch inside. The stainless steel shaft of the gear motor penetrates the center of the top plate and is sealed by two O-rings set into seats inside the hole accommodating the motor shaft. The housing is constructed of 6-in (15.24 cm) diameter schedule-80 PVC pipe. The top and bottom plates of the housing are made of 1-in (2.54 cm) thick PVC plate. The plate is turned down on a lathe so that the top and bottom plates fit snugly into the pipe for part of their thickness and the remaining part matches the outside diameter of the pipe. The bottom plate is glued into place by schedule-80 PVC glue to make a water-tight seal, and the top plate is removable to provide access to the inside of the housing. When the top is closed, it is sealed by an O-ring about the diameter of the inside of the pipe. The top is secured by four stainless steel compression spring latches. A single GoPro HD camera is mounted on a platform clamped to the top of the shaft of the gear motor. When the unit is turned on, the camera continuously rotates 360° at 2 rpm. A stainless steel frame, designed to protect the camera during deployment, is composed of two arching rods attached to the top plate of the housing. A simple gimbal is attached to the bottom of the housing so that the camera remains upright during deployment regardless of the off-horizontal angle of the bottom.

During deployment, the SRV is held upright (Fig. 2) by a hard plastic float [7.1 lbs (3.2 kg) of lift] attached to the top of the frame and a weight attached to the bottom of the gimbal via two longline clips and break-away links (small plastic cable ties). For the weight, we use 12 lbs (5.5 kg) of limestone rocks in a small burlap bag [10 in (25.4 cm) × 14 in (35.6 cm)]. The surface line is attached directly to the weight via a weak link, but then a connecting line is attached securely to the SRV so that any tension on the float (e.g., wave action) pulls on the weight, and does not deflect the SRV. Thus, the video camera remains stable while rotating. The purpose of using a bag of rocks for weight is in case it becomes snagged on bottom structure the rock bag disconnects via weak links from the SRV and the haul line. The only material left on the bottom is a biodegradable bag and rocks—the SRV floats to the surface.

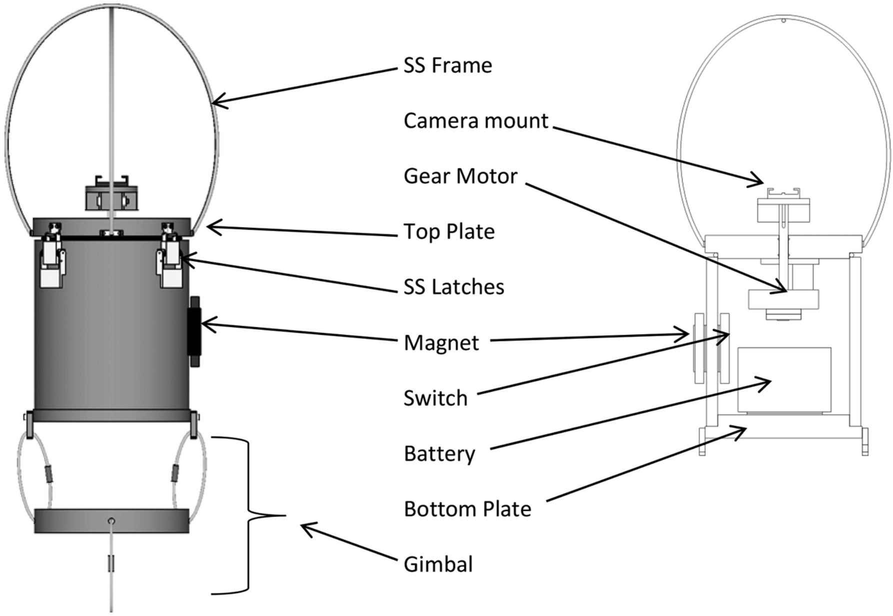

Figure 1. External and cut-away views of the submersible rotating video system showing the various components.

One other rotating underwater video system has been described (Pelletier et al. 2012), but the system differs significantly in both construction and function. Pelletier et al.'s system does not use a compact HD camera, but instead a larger HD camera with a 30 GB hard drive. Their system is not gimbaled, so that if it falls on uneven bottom, the camera may not be level. They support their system with monofilament lines attached to a float above the camera—bottom currents may cause the lines to become entangled in the unprotected rotating camera. Also, they use an "electric engine" to rotate their camera in a step-wise manner—each step is about a 60° turn for about 30 s, so that it takes about 3 min to make a complete revolution. By contrast, our camera is gimbaled so that the camera is always level, even on uneven bottom and in moderate currents (up to 0.5 kn). Our camera is protected by a steel frame so that debris on the bottom, such as lost monofilament line, will not entangle it. SRV rotates continuously at 2 rpm, a rate of rotation slow enough to allow identification and enumeration of fish in range of the camera, and fast enough to avoid ambiguity as to whether or not individual fish are counted multiple times. Our system is also very compact and sturdy so that many SRVs may be taken on a vessel and deployed concurrently. Both systems use a motor to rotate the camera, but it is unknown whether or not the sound of the motor affects fish behavior. With a SRV, there are no overt signs of altered fish behavior so it is doubtful that fishes are either attracted or repelled by the faint sounds of the motor. Pelletier et al. (2012) do not indicate depth limitations of their system, but they used it only in shallow depths (<20 m). We have used our system in shelf depths from shallow reefs to mesophotic reefs 100 m deep. Both systems are capable of recording fish within at least a 5-m radius. Although fish can be seen at distances >5 m, species identification becomes uncertain at greater distances.

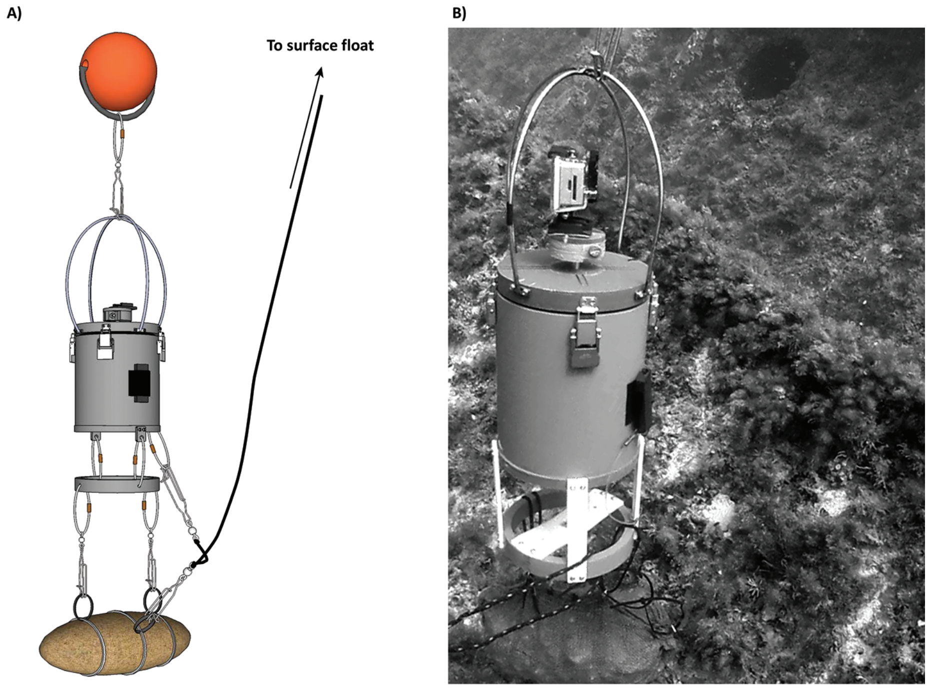

Figure 2. (A) View of the submersible rotating video system (SRV) ready to deploy with float, anchor, and rigging. (B) Photo of SRV deployed in the field. Stainless steel long-line clips are used to connect the components. The hard plastic float retains buoyancy with depth; the anchor consists of rocks and biodegradable materials, burlap and cotton-cord bands. If the anchor becomes entangled on the bottom, strong tension on the haul line causes SRV to break cable ties and leave the anchor on the bottom. Photo courtesy of K Wall.

Data Collection and Analyses

The SRV was designed to simplify and expedite reef fish surveys and to eliminate possible diver effects on fish behaviors. In our experimental surveys, we predetermined drop coordinates, and then deployed SRVs on those coordinates from our research vessel. One of the bars of the protective frame of the SRV was marked with a piece of black electrical tape. The tape provided a reference for each revolution and was the starting and ending point for fish counts. We leave the SRV on the bottom for a minimum of 20 min (40 revolutions of the GoPro HD camera), then retrieve the system.

Video data are stored on 16 or 32 GB-Secure Digital (SD) cards, then transferred to external hard drives in the laboratory. Fish counts are made during the first 20 revolutions, similar to the 10-min survey time of the Bohnsack-Bannerot method. Videos can be analyzed on any media player, but very good video imagery can be obtained using the open source, cross-platform VLC multimedia player (http://www.videolan.org/vlc/index.html) with adjustments to optimize video clarity.

While analyzing the videos, the main objective is to estimate the total number individuals of each species within the observation quadrat and to record habitat type and condition. Each revolution provides a new subsample of species and abundance. Thus, there are twenty 360° subsamples in each SRV deployment plus an additional

20 revolutions. After analysis of the first 20 revolutions, the additional 20 are viewed rapidly (3× speed) to determine if additional species enter the quadrat, and if they do, they are added to the species richness list. A "minimum" count for sedentary species [e.g., black sea bass, *Centropristis striata* (Linnaeus, 1758)], is the greatest number seen during each revolution. For schooling species actively moving past the SRV, the "minimum" count is the greatest number seen in one continuous view (i.e., the reviewer is certain that individuals are only counted once). The "maximum" count for actively schooling species is the total number that pass the field of view (i.e., reviewer is uncertain as to whether individuals are counted more than once); "maximum" and "minimum" counts are equivalent for sedentary species. The revolution with the greatest "minimum" count for a species is the best estimate of the total number of individuals within the observational quadrat.

To standardize the radius of the quadrat, we attach a 3-m long 0.5 inch (1.3 cm) PVC pipe (foldable in 1-m sections) to the SRV weight. The distal end of the pipe is marked to give a reference of 3-m distance. In waters with greater clarity, the pipe, and therefore the radius of the quadrat, could be extended to 5 m. We use 3 m as the minimum visibility for our surveys in the northeastern Gulf of Mexico because visibility can be highly variable depending on weather conditions.

Current and Future Application(s)

The SRV is a simple and inexpensive research tool for the remote survey of demersal fish population densities. We have used them over 2 yrs, mostly on shallow reefs (<15 m deep) in the eastern Gulf of Mexico, but we have also used them in water depths of 60 m in Pulley Ridge off southwest Florida and 100 m in the Alabama Alps off Alabama in the northeastern Gulf of Mexico. Thus, the SRV can be used with the standard GoPro housing in water depths up to 100 m, but this depth range does not limit the SRV itself, only the GoPro standard housing. With strengthening of the GoPro housing, the system could be used in greater depths. However, light limitations at greater water depths would require that lights be installed on the housing. The SRV is limited to about 6 d of continuous rotation because of the power limitation of the 12-V DC rechargeable battery. Nevertheless, the system without modification could effectively monitor fish populations at all shelf depths where visibility is acceptable and light is not limiting.

The SRV is presently being compared with the Bohnsack-Bannerot survey method using a paired field experiment. SRVs were randomly deployed on reefs in the eastern Gulf of Mexico, allowed to record for 20 min, and immediately followed by the Bohnsack-Bannerot method at the exact location. Given the paired design of our study, we were able to directly estimate the difference in counts between the diver-based method and those conducted with the first 10 min recorded by the SRV. All data were first summarized as the minimum number of individuals observed during any single point during the surveys (e.g., during one observation by the diver or one rotation with the SRV). For each taxon, we then calculated the difference in number of individuals observed during each paired survey. Mean (2 SE, 95% confidence intervals) values were then calculated for each taxon and those that did not cross the reference line at zero had significantly higher counts, on average, by one of the methods (positive values for higher counts by diver methods, negative values for higher counts by the SRV). Results from seasonal surveys for over 2 yrs indicate that the

SRV observed 115 taxa (7 unique) and the Bohnsack-Bannerot method observed 129 taxa (21 unique). All taxa that were unique to one of the two methods were observed in only 1–4 of the 48 surveys by each method. Indeed, 3 of 7 taxa unique to the SRV and 16 of 21 unique to the diver method were observed only once. Of the 108 fish taxa observed by both methods, the abundances of 97 (90%) were not significantly different between the diver and the SRV. Among the other 11 taxa, three were found at significantly higher abundances (i.e., 95% confidence interval not crossing the zero line) by the rotating camera [gray snapper, *Lutjanus griseus* (Linnaeus, 1758); porgies (Sparidae); and sheepshead, *Archosargus probatocephalus* (Walbaum, 1792)]. All three of these taxa are commonly fished in the area, including by spearfishers, suggesting diver-avoidance behaviors. The other eight taxa were found at higher abundances by the diver surveys. Four of these taxa seem to be attracted to scuba divers [greater amberjack, *Seriola dumerili* (Risso, 1810); sharksucker, *Echeneis naucrates* (Linnaeus, 1758); slippery dick, *Halichoeres bivittatus* (Bloch, 1791); and bandtail puffer, *Sphoeroides spengleri* (Bloch, 1785)], suggesting inflated abundances when divers are present. The other four taxa found at higher abundances by the diver surveys (seaweed blenny, *Parablennius marmoreus* (Poey, 1876); cubbyu, *Pareques umbrosus* (Jordan and Eigenmann, 1889); belted sandfish, *Serranus subligarius* (Cope, 1870); lizardfish, *Synodus* spp.) are small and/or typically cryptic animals (Fig. 3). These preliminary data indicate that the SRV provides a method that eliminates diver effects that are often unknown and rarely tested, thus may be highly suitable for fished species and others that tend to demonstrate strong aversion to the presence of human observers on open-circuit scuba. However, diver-based surveys may be more suitable for studies that focus on smaller and/or cryptic species. Holistic studies may benefit from using both methods.

The positive attributes of the SRV include: (1) elimination of potential diver effects on fish behavior; (2) efficiency (multiple simultaneous deployments); (3) less ship time; (4) cost effective; (5) depth limits far exceed scuba; (6) non-destructive to habitat; (7) non-extractive; (8) useful in situations dangerous for divers; (9) provides a permanent high-resolution record of the survey and habitat condition; and (10) fish behaviors unlikely to be observed by divers may be recorded with the SRV. However, the SRV may underrepresent small cryptic species, a problem also encountered in diver surveys (Smith-Vaniz et al. 2006), and laboratory time would be necessary to evaluate the videos.

Non-rotating drop cameras have been used by the US National Marine Fisheries Service (NMFS) Southeast Regional Center to survey reef fish populations in the Gulf of Mexico since the 1990s. A short history of that effort can be found online: http://www.sefsc.noaa.gov/labs/mississippi/surveys/reeffish.htm. Presently NMFS uses a four-camera array, each camera covering one-quarter of the 360° field of view. One of those cameras is chosen randomly for analysis as long as the field of view is not obscured. Their system is large, heavy, and expensive, whereas the SRV is small, light, and inexpensive. Also, multiple SRVs may be deployed simultaneously to increase the area of coverage in the same amount of time that a single large system can be deployed. Both systems may be deployed with or without bait, but problems often arise from baiting—discussed below (Harvey et al. 2007, Wraith et al. 2013). Multiple SRVs can be deployed from small boats, but large four-camera systems require large vessels and heavy equipment to deploy and retrieve the camera system.

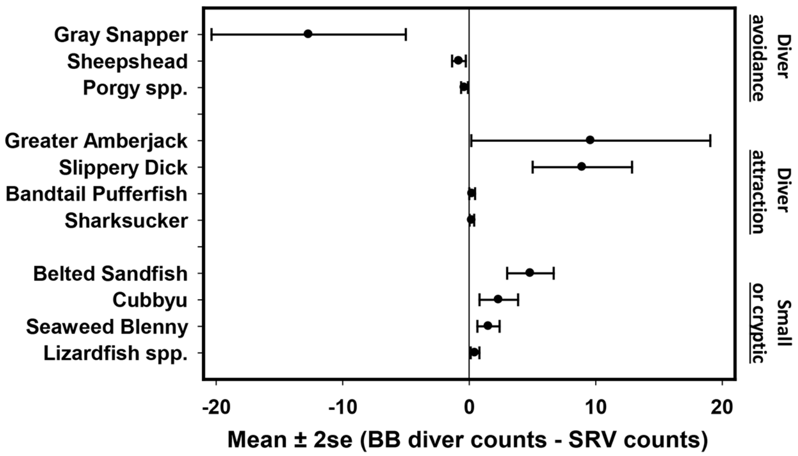

Figure 3. Mean (± 2 SE, 95% CI) difference in observed minimum counts for the 11 taxa that differed between Bohnsack-Bannerot and marine rotating video system methods. Significant differences may have been due to diver avoidance and attraction behaviors as well as crypsis. See text for species names and authorities.

SRV is presented here as a device to survey primarily a cylindrical quadrat as a point count to determine the composition and abundance (or density) of fish within that quadrat—that is, no bait is used. Baited systems attract fish from distant areas, inflating abundance or density in the viewing area, so bait is inappropriate for our objectives. A commonly used baited video system is the baited remote underwater video (BRUV, description and use given by Harvey and Shortis 1996 and Harvey et al. 2002). However, many problems and uncertainties are encountered when using baited video systems (Harvey et al. 2007) including: (1) different baits attract different species (demonstrated experimentally by Wraith et al. 2013); (2) even if the same type of bait is used repeatedly, other problems may exist such as species selectivity and/or time to respond to the bait; (3) the satiation factor must also be considered—many species of fish feed at specific times of day (many top predators are crepuscular feeders) so the timing of deployment of baited systems may affect the composition and abundance of attracted fishes; and (4) the distance and direction of the bait odor plume varies depending on the current velocity and direction. Therefore, we do not bait the SRV, but use a different strategy—we canvas a reef type or seascape feature with multiple randomly placed SRVs. This approach allows us to use statistical models such as proposed by Royle and Nichols (2003) and Royle (2004) for population estimates based on point counts or presence-absence data.

Some modifications could be made to SRVs to increase versatility, including: (1) stronger video camera housings for deeper deployments; (2) an intervalometer on the compact video system allowing video sampling at predetermined intervals over long-term deployments; (3) lights allowing deep (>100 m) and/or night-time deployments (the most effective lights would be in the visible red range of the spectrum (600–700 nm) because most marine fishes cannot detect these wavelengths (Marshall et al. 2003); (4) stereo cameras for the measurement of fishes; and (5) multiple lasers could be developed for the estimation of quadrat radius.

Modifications increase versatility, but they also increase cost. The cost for materials to construct a SRV as depicted in Figure 1 is approximately $100, not including the cost of lathe work and assembly. The compact video camera is several hundred dollars. The SRV, as described in this paper, is attractive in large part because of its low cost. For example, a SRV would be useful for fisheries monitoring in regions with limited monetary resources such as some areas of the Caribbean Sea, for graduate student research projects, or for monitoring fish assemblages on newly deployed artificial reefs. A SRV would also be useful to test or calibrate other visual or video survey methods. Low cost allows researchers to deploy multiple units on a seascape feature to estimate habitat variability and the distribution and abundance of the reef community relative to habitat features—this cannot be accomplished with large and/or expensive units.

Disclosure Statements

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