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Column

Understanding and Quantifying Bias in Visual Fisheries Surveys Using Advanced Technology

Fisheries Technology Series

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Considering the myriad of ways in which advanced technology is being used in fisheries research, keeping atop of the newest developments is a challenge. The transfer of such specialized knowledge, even within the fisheries community, can be difficult, thereby hindering more widespread use of advanced technology in fisheries research. This predicament can be further compounded when information exchanges between the freshwater and marine fisheries communities are limited. In a constantly shifting technological landscape, affecting stronger information transfer about technology within the fisheries community will lead to greater innovation, broader application, and more efficient and accurate science. This is the goal of the AFS Fisheries Information and Technology Section (FITS).

Over the next year, FITS will be coordinating regular columns in *Fisheries* to highlight some of the ways in which the latest advanced technologies are being used in marine and freshwater fisheries research. To learn more, visit: https://units.fisheries.org/fits/, find us on Facebook (@AFSFITS), and attend the Section's symposium at the 2019 Annual Meeting in Reno, Nevada.

In the past several years, it has become common for stock assessments and fisheries research projects to incorporate data from visual surveys. These surveys are not new in their own right, as researchers have been deploying cameras underwater for decades to observe various fish communities and habitats. However, the growing accessibility of relatively cheap, small form, high-definition action cameras (e.g., GoPros) has facilitated the rapid development of highly advanced underwater camera systems. Researchers have accordingly begun to rely less on traditional means of collecting fisheries data, namely extractive gears that often destroy benthic habitats. This has resulted in the research and development of numerous manned submersibles, remotely operated vehicles, autonomous underwater vehicles, stationary camera arrays, and towed camera platforms. As with any type of sampling approach, visual fisheries surveys are not exempt from experiencing some level of bias. However, by using different types of advanced technology, researchers are beginning to address this issue by attempting to quantify the bias in visual surveys and thereby improve data quality.

One of the most common methods of deploying optic and acoustic sensors (e.g. an HD camera or an imaging sonar, respectively) is aboard stationary landers; these systems are used around the world and vary in their respective designs and capabilities, but all typically have small deployment footprints resulting in sparse areal coverage over the sampling domain. The positive trade-off is that they can generate data over long time periods within the sampled volume (application dependent). One of the most notable sources of bias associated with these ground-tending systems (Textbox 1) is that they are often baited. This makes estimating densities difficult due to unknown attraction distances (i.e. functional sampling areas are larger than calculated sampling areas). Additionally, cameras tend to have restricted fields-of-view (~70˚) necessitating specialized count methods such as MaxN (Textbox 1; Campbell et al. 2018; Ellis and Demartini 1995) to avoid double-counting individuals.

Recently, the convergence of high-speed computing and advanced digital optics has resulted in the creation of full-spherical cameras. This has offered the unprecedented opportunity to view the world with "eyes in the back of your head," and it has also presented a unique, in-situ approach for investigating the aforementioned biases associated with stationary landers. Through a National Marine Fisheries Service Office of Science and Technology grant, the National Oceanic and Atmospheric Administration's Mississippi Laboratories received funding to evaluate existing full-spherical camera technology, then design and fabricate their own system. The result is known as the SphereCam system (Figure 1), which produces full-spherical stereo imagery and is capable of sampling marine photic and mesophotic reefs down to 300 m depths using ambient light. The SphereCam allows for precise evaluation and measurement of the habitat surrounding the point sample, as well as precise tracking and measurement of fish throughout their environment. These camera arrays are mounted on a stationary lander known as a Reef Immersion Observation Tower (Figure 2), which is also equipped with a CTD sonde (Textbox 1) and positioning beacon. This allows for precise deployment location on high-precision habitat maps produced from multibeam echosounder (Textbox 1) surveys, such as those available from Simrad or BioSonics. The application of full-spherical camera technology in marine environments has begun in earnest and is showing promise in resolving issues of repeat counts as well as biases in detection probability, relationships with true abundance, and relationships between fish and their environments (Campbell et al. 2018; Kilfoil et al. 2017).

Another common visual sampling approach involves mounting cameras aboard tow sleds. At the University of South Florida, researchers at the College of Marine Science began testing such a vehicle in 2013 called the Camera-Based Assessment Survey System (C-BASS; Figure 3) for use in assessing Gulf of Mexico reef fishes and their associated habitats up to 200 m depths (Lembke et al. 2017). The C-BASS is towed at 3–4 knots near the seafloor and has been equipped with six video cameras that are rigidly fixed to the front of the system; four cameras (two standard resolution and two high-definition cameras) face forward at a slightly downward angle and the remaining two standard definition cameras are mounted on the port and starboard sides of the tow body. When viewed together, the imagery from the six cameras creates a total field-of-view that is near 180°. The system is also equipped with a suite of scientific and performance sensors allowing for continuous measurements of turbidity, chlorophyll, temperature, salinity, depth, altitude, and attitude (Textbox 1) during deployment. The altitude measurements are especially important because they ensure that the C-BASS is kept between 2–4 m above the bottom as it is being towed.

Similar to stationary landers, this approach is especially useful in untrawlable habitats (e.g. marine reserves and/or reefs). However, the towed system differs in that it can be deployed for longer durations and moves at relatively fast speeds (3.5 to 4.0 knots), which allows for large tracts of seafloor to be sampled in a fairly short amount of time. Due to the downward camera orientation, estimating area sampled is a fairly simple process and can be approximated by multiplying the field-of-view by the distance covered per unit time. This means raw fish counts can be converted into density estimates that are scalable to the extents of mapped and characterized habitats. Because the C-BASS is towed near the seafloor, a proportion of benthic reef fishes is not accurately sampled as it is typically found slightly higher in the water column than where the system is towed. This is of particular concern for species that tend to stack (Textbox 1), such as Red Snapper *Lutjanus campechanus*, as well as those that form large schools which cannot be fully represented on C-BASS imagery.

There is also the issue of avoidance behavior by fishes, which may negatively react to the passage of the C-BASS by swimming away before being recorded. This would therefore lead to underestimates of these reef fish species. The C-BASS scientists are therefore trying to correct for missing proportions and better understand the magnitude of reactive behavior by pairing video collection with another piece of technology: a shipboard, calibrated, scientific echosounder (SIMRAD EK60; Figure 4). This sonar unit emits sound pulses at 38 kHz to collect water column data, concurrent to the C-BASS recording seafloor imagery during every deployment. These data are reflections of individual fish and fish schools from near the seafloor up to approximately 10 meters below the sea surface, and can be analyzed to estimate the densities of ensonified (Textbox 1) fishes using different echocounting and echointegration techniques. The results are then paired with georeferenced C-BASS data to compare fish densities determined from the echosounder data with those based on C-BASS video data. The goal for the C-BASS and echosounder data comparisons is to then determine how these two technologies complement one another and can be used in tandem to better characterize reef fish abundance throughout the West Florida Shelf and Gulf of Mexico.

Although both of the examples here were developed for use in offshore, marine environments, the technology is absolutely applicable to shallower, coastal marine systems as well as freshwater lakes. This has, in fact, already been done by researchers at the U.S. Geological Survey, who developed a towed camera system called the Deep ATRIS (Along-Track Reef-Imaging System), which could be used in water depths of up to 90 m (Zawada et al. 2008). In addition to applying these technologies to different environments, there are also ways to make the systems scalable to different budgets. The SphereCam already employs fairly low-cost technology with all of the cameras being GoPros, which produce high quality imagery. However, the instrumentation used in the paired sonar and towed system (Figure 4) was on the higher end of the cost spectrum; because the C-BASS was custom made and is fairly large and robust, the total cost to build and outfit it with all of the current instrumentation was approximately $200,000 and the EK60 echosounder ranges into the hundreds of thousands of dollars to purchase and install. A “ready-made” towed camera system does decrease costs (~$100,000) and it can purchased “plugin ready” from an underwater technology company. However, to decrease costs while retaining functionality and the ability to customize, one could downscale a towed camera system like C-BASS to make it more affordable. By the estimates of the C-BASS engineering team, a unit half the size of C-BASS with the same instrumentation but only two cameras could be built for approximately $125,000. Not only would overall cost decrease, but because the system would be physically smaller, it could be deployed from a smaller research vessel which affords users a lower day rate (the C-BASS currently weighs approximately 600 lbs in air and, as such, requires a large winch capable of deploying it). By pairing a smaller towed camera system with a lower cost fisheries sonar aboard a modestly sized research vessel, the same type of work as presented here with the EK60 and C-BASS could be replicated with a similar scope, but at a greatly reduced cost.

Though fisheries surveys will likely never escape various degrees of bias due to gear selectivity, variable detection abilities, and reactive behavior by the fishes themselves, there are ways to reduce and quantify their effects as demonstrated by these systems. What is also noteworthy about the two cases presented here is that the first example did not rely on prohibitively expensive equipment (e.g. GoPros) and in the second, the technology being used was not exceptionally novel (i.e. pairing sonars and cameras), which makes them applicable to a wide fisheries audience.

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