A Clearer Picture: How Digital Cameras and Other Technologies Have Changed Marine Life Surveys Over the Last Three Decades

Una Imagen más Clara: Cómo las Cámaras Digitales han Cambiado las Encuestas de Vida Marina en las Últimas tres Décadas

Une Image Plus Claire: Comment les Appareils Photo Numériques ont Changé les Relevés de la Vie Marine au Cours des Trois Dernières Décennies

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EXTENDED ABSTRACT

The rapid evolution of digital underwater imaging technology has resulted in a broad expansion of underwater photography among scuba divers. Such photography, once the domain of technical specialists, has allowed citizen scientists to record, identify, and inventory species well after their dive gear is dry. Reef Environmental Education Foundation (REEF) has maintained a citizen science fish survey program over 26 years, an interval of time that encompasses the advent of digital camera commercial availability. Underwater digital photography has changed the game for these diving citizen scientists, and photo documentation, in concert with social media applications, has led to a vibrant, interactive community of amateur natural historians. Through social media and other platforms, new species have been identified, and a better understanding of species-specific distributions, commonness, and habitat specialization has resulted.

The REEF Volunteer Fish Survey Project started in 1993 as a way for divers and snorkelers to report fish sightings. Each roving diver REEF survey (Schmitt and Sullivan 1996) includes a checklist of fish species positively identified, a log-scale estimate of abundance, and metadata about the survey including surveyor, location, date, start time, survey time, and other environmental information. The program started in Florida and the tropical western Atlantic and has since expanded to tropical and temperate waters world-wide. As of November 2019, 245,406 REEF surveys have been conducted at almost 15,000 sites by 16,000 volunteers (REEF 2019). The database includes sightings of more than 5,500 fish species and 10.7 million sightings records. Approximately 2/3 of the surveys have been conducted within the tropical western Atlantic, REEF's longest-running region. REEF survey data are processed with custom error-checking and quality assurance measures, and all data are made available to the public through reporting functions on the REEF website. Custom raw data files are provided upon request to researchers and government agencies. REEF surveyors can test through a series of experience levels. As with many citizen science efforts, there is a sub-set of volunteers who become "super-users" and the efforts of this relatively small sub-set of volunteers results in the majority of the data submitted. In the case of REEF, approximately 8% of the volunteers have conducted 80% of the surveys.

When the REEF program started in the early 1990s, a new regional fish field guide had just been published by Paul Humann and Ned DeLoach (REEF co-founders), *Reef Fish Identification: Florida, Caribbean, Bahamas*. It was unique in its targeting of divers and snorkelers and use of quality underwater photographs, and presented the information in a user-friendly, non-taxonomic format. It focused on the key characteristics visible to divers, and *in situ* identification (rather than from a dead specimen in a jar). At the time, very few divers dove with cameras and most divers only used lights at night. Through the years, new editions of the Humann and DeLoach book were published, expanding what was known about fish biodiversity in the region. The first edition published in 1988 had 374 species. In 2014, the fourth edition was published and included 683 species accounts.

Along with the growth in species accounts in this widely-used field guide over the decades, underwater cameras and lights have become smaller, cheaper, and easier to use, allowing divers to search for, find, and digitally capture images of species previously difficult to identify. In addition, the explosion of internet-based field guides and photo sharing has provided field naturalists an ever-expanding set of resources. Social media platforms, especially Facebook Groups, have connected communities and facilitated the leveraging of distributed knowledge and expertise in ways previously impossible. In 2017, REEF created regional fish ID Facebook groups for its members; these forums have become an invaluable resource to surveyors, providing detailed information on how to distinguish complexes of visually-similar species, thanks to the incredible macro functions on point and shoot underwater cameras. A fish taxonomist, Dr. Ben Victor, has also started awarding "Unicornfish Awards" for those who are the first to take an *in-situ*, live photo of a fish species. To date, 24 of these Unicornfish Awards have been issued, and many of those were first shared in the REEF Facebook Group. REEF members have also discovered several new species, collaborating with taxonomists to provide underwater photos, exact locations of sightings, and sometimes assistance with collection of voucher specimens (e.g. Allen et al. 2020).

As citizen scientist natural historians amass large digital libraries of species images, it is important that they follow best practices for photo curation, ideally including eXtended Image Format (XIF) metadata files that include taxon information, GPS location, date captured, and photographer. Long-term storage of images also needs to be considered to facilitate the use of these images for other potential uses, such as habitat evaluation (e.g. what's in the background of the photos) and training

datasets for deep-learning based identification tools (e.g Merlin from Cornell Lab of Ornithology and Seek from iNaturalist).

Citizen science programs such as REEF's Volunteer Fish Survey Project empower members of the public to generate monitoring data and promote active participation in resource management and science. The expansion of tools, technology, and innovation have enabled these natural historians to take advantage of "NextGen" methods (McKeon et al. 2020) that were previously limited to professionals. As a result, the collective impact of the REEF program and other citizen science efforts has increased dramatically in recent years and has helped advance the state of knowledge on biodiversity, species ranges, and status and trends.

KEYWORDS: Reef fish, species distribution, citizen science

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