Animal Mapping Using a Citizen-Science Web-Based GIS in the Bay Islands, Honduras

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Mapping animal distributions on a large spatial scale may be important for recognizing movement patterns not immediately apparent on smaller scales (Catlin-Groves 2012). Habitat health and distribution on a regional scale may be an important factor for spatial management of endangered species. One example is the historic and current distribution of the koala (*Phascolarctos cinereus*) in the New South Wales region of Australia (Lunney *et al.* 2000). Mapping the spatial extent of koalas and their habitat within this region using community based surveys has facilitated data-driven decision-making by the local government to incorporate habitat and distribution maps into their local environmental plan (Lunney *et al.* 2000). As an alternative to mapping sightings by hand, Geographic Information Systems (GIS) are changing how ecosystems and individual species are monitored, by providing easy access to long-term, wide-scale spatial views. However, some GIS programs are only accessible to researchers and can be complex without proper training. The Ocean Biogeographic Information System Spatial Ecological Analysis of Megavertebrate Populations (OBIS-SEAMAP) plots GPS data of turtle nesting sites and migrations using layers within a GIS (Halpin *et al.* 2009). Similarly, the Satellite Tracking and Analysis Tool (STAT) collects satellite-transmitted data and displays them in relation to various information layers (*i.e.*, bathymetry, chlorophyll abundance, and sea surface temperature) on a map (Coyne & Godley 2005). However, these systems, although freely accessible to anyone, are typically only used and manipulated by marine researchers.

The organization ECOCEAN uses a whale shark (*Rhincodon typus*) photo identification library populated by citizen-science sightings reports and photographs, to identify and track individual whale shark migrations throughout the world (Lenin 2013). Fox *et al.* (2013) have used the ECOCEAN database to successfully map and identify 95 individual whale sharks around the island of Utila, Honduras based on unique spot patterns. A similar database was established at the University of Hawaii by Whitney *et al.* (2012) for citizen-scientists to aid in collecting information and photographs on whitetip reef sharks (*Triaenodon obesus*) in Hawaii. Whitney *et al.* (2012) were able to use these data to map shark locations based on data gathered by citizen-scientists. To assess population recovery for the long-exploited basking shark (*Cetorhinus maximus*), Witt *et al.* (2012) used sightings populated by citizen-scientists from 1988 to 2008. After some data pre-processing, Witt *et al.* (2012) found three basking shark hot spots around Scotland, southwestern

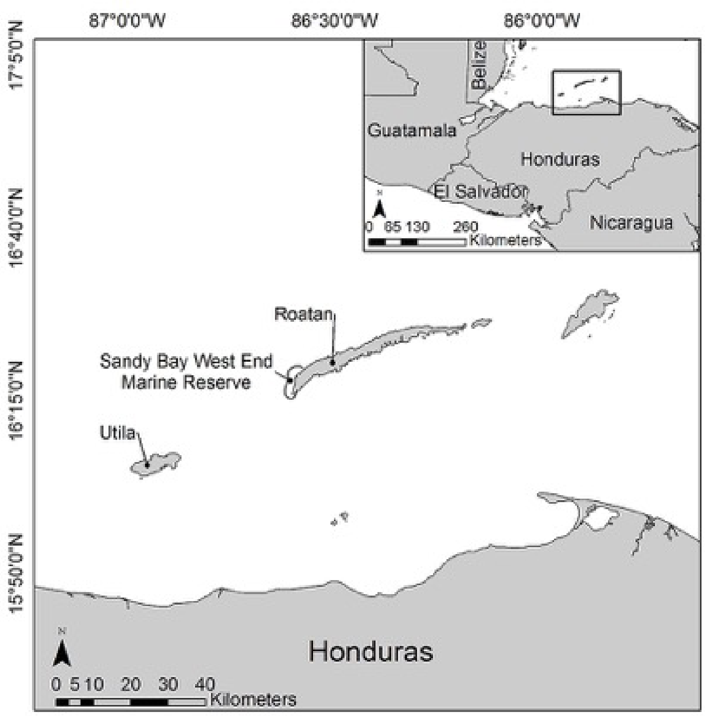

Figure 1. Map of the Bay Islands of Honduras showing Roatán and Utila. The area of the Sandy Bay West End Marine Reserve is outlined on the western end of Roatán. Inset map provides a regional view of Honduras.

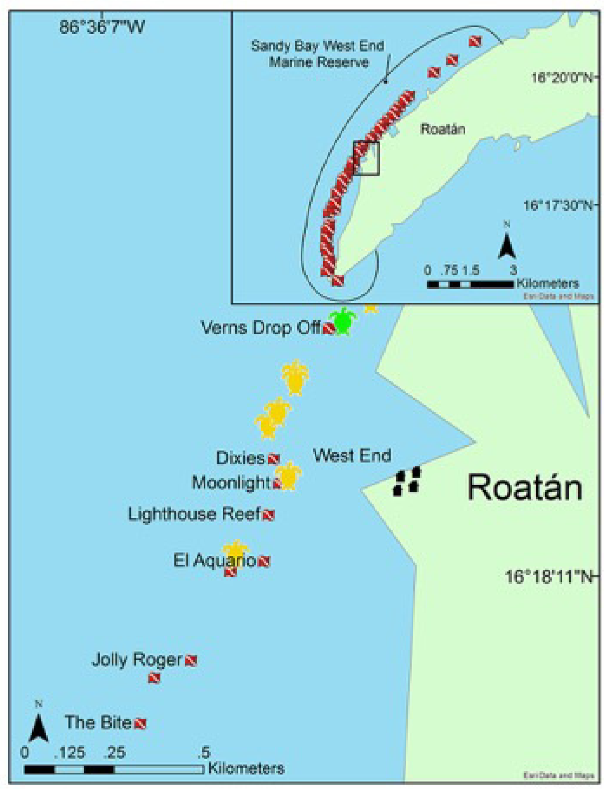

Figure 2. Turtle sightings map for the Sandy Bay West End Marine Reserve showing an example of dive sites and locations, represented by dive flags, within the boxed region of the inset map. Sea turtles colored by species (Green = green turtle; Yellow = hawksbill) represent currently logged turtle sightings by dive shops and individual volunteers.

England, and the Isle of Man. In each of these studies, researchers used information collected by citizen-scientists to map and explore the spatial extent of the data.

Representing data visually is important in designing a web-based GIS application to keep users involved and motivated (Newman *et al.* 2010). Allowing users to map their own data involves and informs contributors by immediately providing visual representations of the data. Azzurro *et al.* (2013) were able to utilize the citizen-science website, Seawatchers, to identify locations of the invasive sergeant major (*Abudefduf saxatilis*) in the Mediterranean using sightings and photos mapped by snorkelers.

Individual sea turtle identification may be important in monitoring foraging, movement, and gender specific behavior (Troëng *et al.* 2005; Van Dam *et al.* 2007). A widely used method for individual identification of turtles is the application of plastic or metal flipper tags, although metal tags are most commonly used (Balazs 1999). However, an alternative method for individual sea turtle identification involves using photographic identification (photo ID), which involves the use of identification software, requiring clear, high-resolution photographs (Reisser *et al.* 2008; De Zeeuw *et al.* 2010; Dunbar *et al.* 2014) .

Recent developments in web-based GIS provide easy access to the tools needed to create and use online citizen-scientist mapping systems. Researchers are now able to partner with citizen-scientists to collect large amounts of data on a variety of research topics by providing web-based mapping tools that are user-friendly and easy to navigate (Catlin-Groves 2012). Our study describes the development of a web-based GIS mapping tool using ESRIs ArcGIS online software to collect citizen-scientist sightings reports and photographs for identifying individual sea turtles.

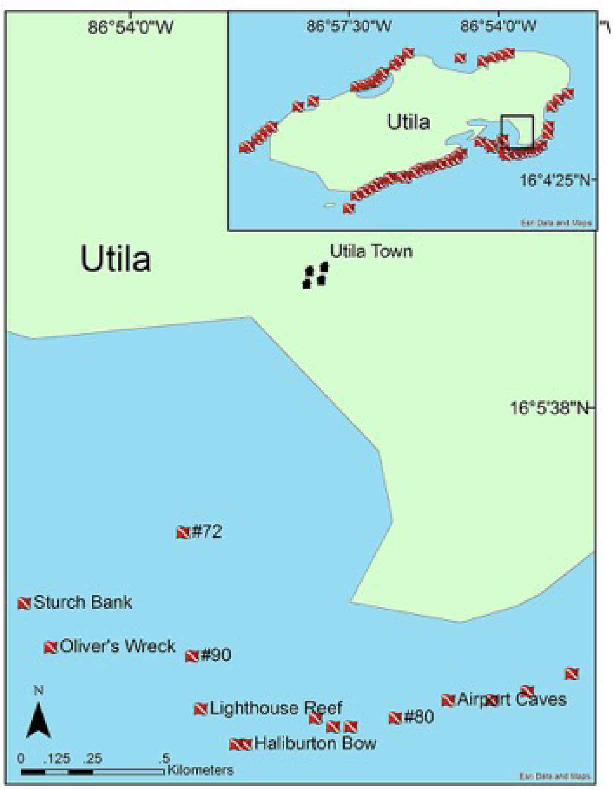

Figure 3. Utila dive site map showing an example of dive sites and locations, represented by dive flags, located within the boxed region of the inset map.

The island of Roatán lies approximately 60 km north of mainland Honduras (Fig. 1). The protected area of the Sandy Bay West End Marine Reserve (SBWEMR) is located on the west end of the 50-km island. Twenty-six dive shops are located along the SBWEMR that are frequented daily by dive tourists (Hayes *et al.* 2016). There are many opportunities for sighting turtles on a daily basis, due to resident populations of juvenile greens and hawksbills in the SBWEMR. The island of Utila lies approximately 34 km west of the SBWEMR and approximately 37 km north of mainland Honduras (Fig. 1). Off the town of Utila, resident juveniles and transient aggregations of adult hawksbills (typically observed during the breeding season) are encountered by divers.

We developed two interactive maps for logging in-water turtle sightings around the islands of Roatán and Utila. Latitude and longitude positions in degrees, minutes, seconds (DMS) of 98 dive site locations were collected and plotted for the island of Roatán (Fig. 2). For the island of Utila we plotted 74 dive site locations (Fig. 3). We then converted latitude and longitude positions from DMS to decimal degrees and mapped them displaying dive site names in ESRIs ArcGIS Online (ESRI, Redlands, CA). Another map layer was developed using ESRIs ArcMap software (ESRI ArcMap V. 10.3.1) in which we created the editable fields of Name, Depth, Time of Day, Weather Conditions, Visibility, Turtle Species, Turtle Gender, Approximate Size, and Date, along with the option to upload digital photographs (Fig. 4). The Turtle Species field was linked to turtle icons used for plotting sightings of species (hawksbill, green, loggerhead; see Fig. 4) and undetermined turtle species on the map. Eight towns around Roatán were mapped as reference points, while one town and two beaches were mapped for Utila. At two points on each map, instructions explaining how to log sightings are displayed as popup boxes under the Protective Turtle Ecology Center for Training, Outreach, and Research, Inc. (ProTECTOR

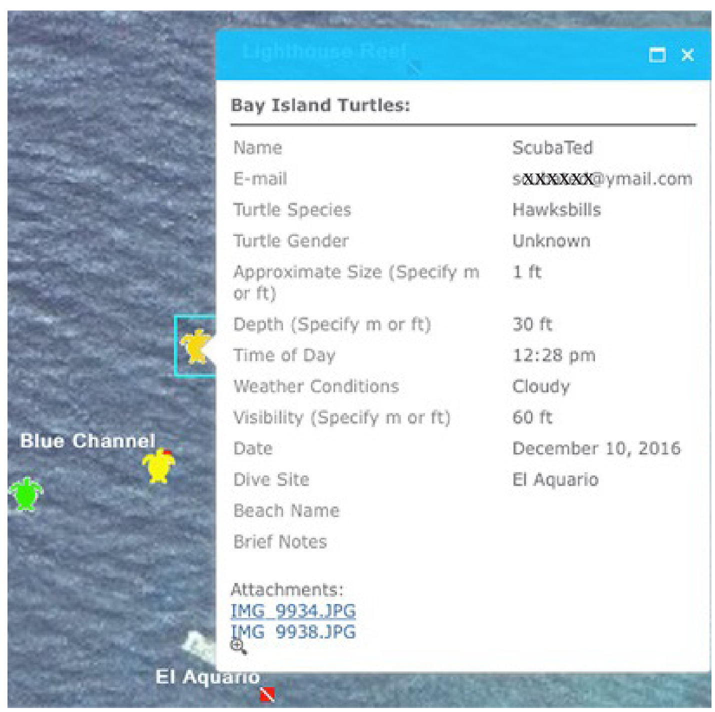

Figure 4. An example of a turtle sightings log with metadata and photographs of a hawksbill turtle sighting within the Sandy Bay West End Marine Reserve.

Inc.) logo, along with links to more information about each of the three species displayed by turtle icons. These interactive Roatán and Utila maps were then embedded on the ProTECTOR Inc. website (www.turtleprotector.org), and map links were distributed to dive shops in the SBWEMR for use in logging in-water turtle sightings. Finally, we also provided an e-mail address for users to communicate with us, in the event that map links malfunction.

The Roatán interactive map was distributed to twelve dive shops in the town of West End. Each dive shop was offered the opportunity to receive formal training by the authors on how to properly log turtle sightings using the interactive map. However, one did not have Internet access and three were uninterested in receiving training. One hundred and fifteen turtle sightings have been logged to date, with ProTECTOR Inc. volunteers and three dive shops being responsible for the majority of turtle sighting logs on Roatán. However, not all dive sightings had associated photos, either because divers did not have cameras while diving, or because sightings were recorded during training dives and thus, no photos were taken at the time. To date, no dive shops on Utila have received the interactive turtle sightings map. Previous sea turtle sightings for Roatán and access to the Utila map may be gained through their respective interactive maps by visiting the link: http://bit.ly/2kcPl7d

In this paper we report the launch of a user-friendly, web-based GIS mapping system that has been used to map in-water sightings of sea turtles within an MPA. Although it is common to use flipper tags for individual identification (Eckert & Beggs 2006), Balazs (1982) suggests that tags may not always be a reliable source of identification, as they are subject to degradation and loss. We propose the collection of photographs from divers, dive shops, or other scientists may be conducted with web-based GIS, which allow individuals to upload sightings data and photographs from their current location with ease and at their convenience.

Chassagneux *et al.* (2013) collected turtle sightings from divers, as implemented by Jean *et al.* (2010), to determine foraging locations of green and hawksbill turtles along Reunion Island, which may be useful for studying foraging habits of turtles. In future studies, citizen-scientist divers may be directed by researchers to collect photographs of facial scutes while turtles are foraging in order to track foraging habitat use on a long-term basis. Photo ID, in association with mapping in-water sightings and radio and satellite tracking methods, will assist researchers in tracking individual turtle movements and provide data for calculating population estimates using photographs uploaded by dive tourists into online databases.

Although some researchers have expressed concern over the quality of data that citizen-scientists report (Williams *et al.* 2015), data generated by experts appear very similar to those generated through citizen-science applications (Catlin-Groves 2012). Goffredo *et al.* (2010) used sport divers to participate in a global marine biodiversity assessment of flora and fauna and showed that sport divers recorded comparable data to those of a trained marine biologist. Similarly, Bell *et al.* (2009) used dive tourists and dive masters to record turtle sightings and visual measurements around the Cayman Islands. These authors found that a large quantity of data could be generated by dive tourists that were comparably as reliable and accurate as data collected by trained scientists. However, unless citizen-science websites and web mapping applications are formatted for their intended audiences, in some instances volunteers may lose interest, forget to log, or confuse their information, contributing to a loss of data or incorrect data submission. Thus, GIS web mapping applications, and the websites in which they are embedded, require elements that make logging records attractive, interactive, and educational for citizens to maintain motivation for collecting and logging data (Newman *et al.* 2010). The future development of integrating photo ID into our interactive web map, may expand the use of citizen-science data by researchers, with the aim of collecting large amounts of data records for logging sea turtle sightings.

Our results show the positive response of self-motivated dive shops to log the majority of turtle sightings within the first month of releasing the web-maps, followed by a growing number of voluntary sighting uploads. In order to expand the citizen-scientist user group, we intend to provide dive tourists at multiple dive shops in the towns of West Bay and Sandy Bay with the sightings map link, then gradually distribute this sightings map to dive tourists in other areas of Roatán. Due to restrictions of time and funding resources, we are unable to be present on Roatán during the entire year and thus, the creation of a poster or banner that describes the required information for uploading turtle sightings to the interactive web-map will be created. This step will allow dive tourists to have immediate access to instructions when logging turtle sightings from home. Empowering citizen-scientists to log turtle sightings may represent an untapped source for data collection. To assist this data collection, using a web-based GIS provides the ability for more dive tourists to participate in both sea turtle and general marine animal research on a global scale, with the result that gathering large amounts of data may be accomplished relatively quickly, and with little temporal and financial investment.

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