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CONSERVATION AND EDUCATION THROUGH ECOTOURISM: USING CITIZEN SCIENCE TO MONITOR CETACEANS IN THE FOUR-ISLAND REGION OF MAUI, HAWAII

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Pacific Whale Foundation (PWF) Eco-Adventures operates a fleet of nine ecotour vessels in Maui, Hawaii and has used these vessels as an opportunistic research platform since 2010. The researchers at PWF have utilized ecotour vessels as a platform of opportunity (PoP) to collect photo-ID data, through a program called Researcher-on-Board (ROB) and for the development of an application to log cetacean sightings, called Whale and Dolphin Tracker (WDT). In this article we compare the amount of data collected using these two methods and contrast to systematic research surveys taking place in the same location and same time period to demonstrate the value of citizen science. Both the ROB and WDT programs have been shown to be cost-effective alternatives to surveys aboard dedicated research vessels, with the additional benefit of having tour operations contribute directly to the management and monitoring of marine mammals.

Key words: Ecotourism; Cetaceans; Management; Platform of opportunity (PoP); Whale and dolphin tracker (WDT); Photo-ID

Introduction

Citizen science is a growing field worldwide and involves the public in science by allowing them to collect data for scientific purposes. Some notable examples of this type of scientific collaboration are Cornell Laboratory of Ornithology's Project FeederWatch (Trumbull, Bonney, Bascom, & Cabral, 2000) and Pacific Whale Foundation's Great Whale Count (Tonachella, Nastasi, Kaufman, Maldini, & Rankin, 2012). Many citizen science projects are opportunistic in nature and some make use of platforms of opportunity (PoPs), such as whale-watching boats, as a way to collect data. Recent discussions by the International Whaling Commission (IWC) have called for improved and streamlined methods for PoPs to collect information on cetacean distribution and relative abundance (IWC, 2015).

There are multiple clear benefits not only for the tourism industry but also for educators, wildlife managers, and researchers to collaborate with

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citizen scientists to incorporate PoP data collection. For researchers, studying cetacean populations, especially in isolated areas, can be costly, time consuming, and logistically difficult (Kiszka, Hassani, & Pezeril, 2004). As such, basic information such as abundance and distribution of some cetacean species is still poorly understood. Of the 75 species within the Balaenidae, Delphinidae, Iniidae, Phocoenidae, Physeteridae, Platanistidae, and Ziphiidae families evaluated for the International Union for the Conservation of Nature (IUCN) Redlist, 55% ($n = 41$) were considered data deficient (IUCN, 2015). In addition to traditional systematic research surveys, alternative data collection methodologies such as PoP could be employed to aid in data collection of these poorly studied species (Moura, Sillero, & Rodriques, 2012).

With thousands of marine tour operations worldwide, the tourism sector could make an invaluable contribution to cetacean data collection. Implementing a data collection application for citizen scientists, such as Whale and Dolphin Tracker, on various PoPs throughout the tourism sector could greatly enhance cetacean monitoring efforts and aid in quality control of such data (Carlson et al., 2016). Monitoring efforts are especially needed in areas where baseline data are lacking and limited funding is available (Kaufman et al., 2011). The focus of this article is to show the type and amount of data citizen scientists can contribute to the protection and enhanced understanding of cetacean species through data collection on PoP, and compare this to other data collection techniques. The three methods of data collection presented here were conducted over the same time period in Maui, Hawaii and the merits of each are discussed.

Methods

Systematic Research Surveys

Data were collected from a dedicated research vessel from January 1, 2013 to December 31, 2015 using systematic research surveys and line transect methodologies (Buckland et al., 2004). Observations were made by three dedicated observers while a fourth staff person acted as a data recorder. Data were collected on humpback whales if the initial sighting occurred within distance criteria described in Stack et al. (2013). Odontocete encounters initiated a focal follow, where photo-ID and behavioral data were collected. The following data were additionally recorded for all species: time and location (latitude and longitude) of sighting, vessel speed, age class, distance from boat, angle to group, and direction of travel. Environmental variables were also recorded at the beginning of each transect line and as they changed throughout the surveys.

Systematic surveys are widely used and prominent in cetacean research to estimate the density and/or abundance of wild animal populations with detailed methods described by Buckland, Rexstad, Marques, and Oedekoven (2015). This rigorous sampling design usually allows for greater inferences to be made with collected data. As such, researchers often use systematic transect surveys to assess population structure, life history characteristics, habitat preferences, and home ranges for cetaceans. These data can be used to guide species-specific management techniques to provide enhanced protection for the species, but are expensive and time consuming to conduct.

Platforms of Opportunity

Whale and Dolphin Tracker. Data were collected opportunistically using the application Whale and Dolphin Tracker from January 1, 2013 to December 31, 2015 onboard ecotourism vessels conducting whale watches and snorkel trips, which followed a nonsystematic track, and the user recorded whale and dolphin activity when sighted. In depth details on the build and data collection methodologies of Whale and Dolphin Tracker have been outlined in Kaufman et al. (2011) and Davidson, Currie, Stack, Kaufman, and Martinez (2014), respectively, with updates and basic information discussed below. The WDT application consists of a mobile web-based interface that can be accessed via a username and password. The data collection process involves a user, for example an ecotour guide/naturalist, who records opportunistic cetacean sightings using the Whale and Dolphin Tracker application downloaded to a mobile device. The user starts recording the GPS track at the start of the trip, adds sightings throughout the trip, and ceases the GPS tracking at the end of the trip. In addition to the species name, the following information is recorded with

each sighting: date and time of encounter, latitude and longitude, pod composition and behavior, environmental conditions, and vessel name. If photo identification or other usable behavior or morphological images are available during the encounter, photos can be taken with the mobile device and uploaded in the field, or the digital photo files can be uploaded and associated with the sighting at a later date. Each user maintains access to all their logged sightings and can easily export these data for analysis.

Whale and Dolphin Tracker has the ability to enhance the educational aspect of ecotourism by encouraging public participation. Ideally this can be achieved in two ways: (1) a naturalist-led discussion of data collection, explaining the type of data being recorded and importance of each parameter, which could also include some form of group participation (i.e., polling guests for animal count); (2) encouraging guests to create their own accounts and log sightings on current and future trips. The potential volume of data that could be collected using Whale and Dolphin Tracker highlights the large-scale contribution ecotourism could offer with minimal financial investment.

Researcher-on-Board. Data were collected from December to April 2013 to 2015 onboard ecotour whale-watching vessels by a dedicated researcher-on-board (ROB). The researcher went out on two trips per day and vessels traveled in a nonsystematic manner based on reported whale activity and the availability of opportunistic sightings. Detailed information on data collection and survey protocols are outlined in Currie, Stack, and Kaufman (2016), and a basic overview is provided here. A single observer scanned the surface of the water and, when within 500 m of a cetacean, collected sighting information and photographed the animals for photo identification. The following information was recorded with each sighting: time and location (latitude and longitude) of pod, vessel speed, pod composition and size, distance from boat, angle to pod, behavior, and weather information. Data from the ROB program can provide information on species abundance, habitat use, site fidelity, and interspecies interactions, contributing to conservation and management efforts.

The ROB program allowed the public to observe a researcher while they collected data and provided an additional educational resource to complement the normal narrative provided by an ecotour guide. This allowed passengers an accessible way to connect with marine science, enhancing the overall ecotour experience.

Results

Survey Effort

The systematic surveys had equal coverage of the area with overall lower total survey effort; the Whale and Dolphin Tracker surveys had dense coverage within the scheduled snorkeling and whale-watching trip routes with the highest total survey effort; and the ROB surveys had dense coverage of a small area within the scheduled whale-watching routes (Fig. 1).

Data Collection

Whale and Dolphin Tracker was able to record the highest number of species, survey the most distance, and spend the longest time at sea when compared to ROB and systematic research survey datasets (Table 1). During the same time periods, Whale and Dolphin Tracker surveyed 7.9 times the distance of systematic research surveys and 16.4 times the distance of ROB while recording 11.3 times the encounters reported using systematic research surveys and 6.2 times the encounters reported using ROB (Table 1).

Discussion

An aspect of species conservation often lacking in the marine environment is consistent long-term monitoring. The use of citizen science projects using tours as platforms of opportunity provides an avenue for long-term data collection and promotes citizen science by providing opportunities for the public to contribute to species conservation and management. As demonstrated in this article, tour vessels can serve as a scalable effective means of data collection recording high effort and encounter rates. Although beyond the scope of this article, the variations in the amount of data collected using

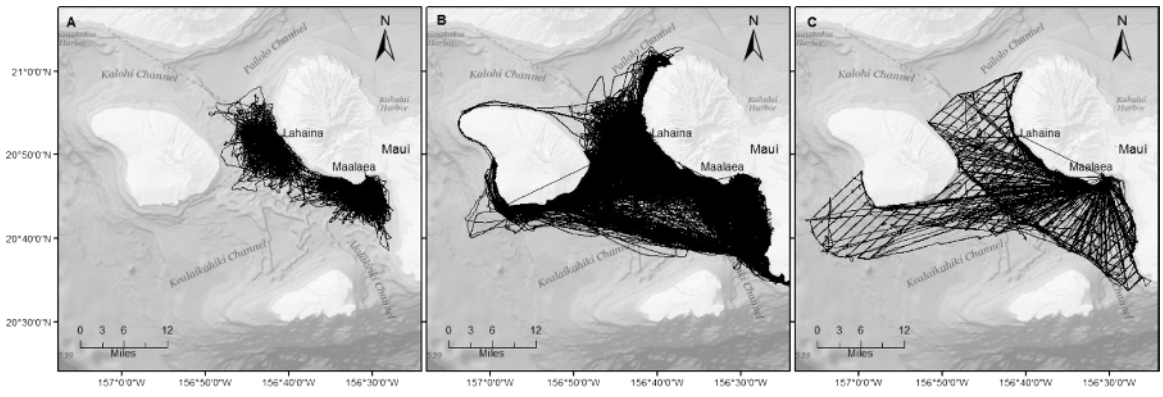

Figure 1. GPS survey effort recorded for (A) Researcher on Board, (B) Whale and Dolphin Tracker, and (C) Systematic surveys completed within the four-island region of Maui from January 1, 2013–December 31, 2015 depicting differences in spatial coverage for each method.

systematic research surveys, ROB, and Whale and Dolphin Tracker survey methods is in part due to survey specific biases such as vessel size, number of observers, and trip type. As such, it is important to note that Whale and Dolphin Tracker is not meant to replace systematic research surveys, but could be used as a means to supplement data collection and foster greater connectivity between citizen scientists, tour operators, and wildlife researchers and managers.

Both Whale and Dolphin Tracker and ROB surveys provide a similar benefit in terms of additional effort and sightings without the need for a dedicated research vessel. Collection of ROB data requires a dedicated researcher to go on trips and analyze the collected data. This method allows for the collection of specific data and has been employed for photo identification research on PoP (Allen, Carlson, & Stevick, 2011), but is difficult to scale for existing tourism operations. Given the increase in public participation of citizen science (Conrad & Hilchey, 2011), Whale and Dolphin Tracker could provide increased opportunities for individuals to engage in marine conservation-related activities and research. The utility of large-scale data collection by citizen scientists using Whale and Dolphin Tracker remains unknown, as typical biases of opportunistic and citizen science data collection apply (Isaac, Strien, August, Zeeuw, & Roy, 2014). However, the use of a standardized user-friendly method of tracking effort and recording sightings, as implemented with Whale and Dolphin Tracker, would help minimize data collection biases (Carlson et al., 2016; Vinding, Bester, Kirkman, Chivell, & Elwen, 2015). Further, the use of citizen science data as a potential source for increasing support for basic and applied science has received substantial attention in recent literature (Issac et al., 2014), and there is a clear benefit to crowdsourcing data collection in order to

Table 1
Comparison of Ecotour Vessel's Opportunistic Surveys and Research Vessel's Systematic Surveys Conducted From January 1, 2013 to December 31, 2015 Within the Four-Island Region of Maui, Hawaii

	Ecotour Vessel Researcher on Board	Ecotour Vessel Whale and Dolphin Tracker	Research Vessel Systematic Research
Distance surveyed (nm)	7,094	116,683	14,735
Number of encounters	1,476	9,113	807
Number of species encountered	7	11	7
Days on water	281	1,094	232

contribute to species management and conservation-based research (Theobald et al., 2015).

Whale and Dolphin Tracker could serve as the method for citizen science data collection, particularly from platforms of opportunity such as whale-watching vessels, owing to its ease of use and scalability. This would allow citizen scientists to contribute to the protection and enhanced understanding of the species they are watching. Regular use of Whale and Dolphin Tracker could encourage collaboration between tour operators, citizen scientists, and research groups, yielding several benefits such as: improved connection between scientists and members of the public, enhanced educational opportunities, and contributing to viable long-term wildlife monitoring. These data would contribute directly to the body of knowledge on a particular species and, by extension, towards the conservation and management of cetaceans.

The data collected onboard marine ecotours utilizing Whale and Dolphin Tracker have been used to develop and evaluate responsible whale and dolphin viewing guidelines called Be Whale Aware and Be Dolphin Wise (Pacific Whale Foundation, 2017). Using information collected on vessel speeds and initial sighting distances, a voluntary speed limit of 15 knots was suggested for vessels operating during humpback whale season in Maui; December–April. The impacts of reduced speed guidelines were easily monitored using Whale and Dolphin Tracker on vessels that opted to follow the reduced speed guidelines, where one could see a reduction in encounters at close distances when vessels maintained a speed of 15 knots or less. Whale and Dolphin Tracker data on the high frequency of humpback whale mother–calf encounters further led to the development of a voluntary time restriction of 30 min for vessels viewing mother–calf pods. The continued monitoring of cetacean populations with Whale and Dolphin Tracker allows for the evaluation of newly implemented conservation measures to determine if effective guidelines have been set. Furthermore, the Whale and Dolphin Tracker dataset ensures there is continuous monitoring, which can be used as a baseline to measure unforeseen changes or stressors to a population. Currie, Stack, McCordic, and Roberts (2018) utilized Whale and Dolphin Tracker sighting data to determine trends in humpback whale mother–calf pod use within the Maui four-island region, Hawaii presenting opportunistic platforms as an alternative method of long-term, cross-seasonal monitoring of this population.

The use of citizen scientists and PoPs have the potential of making valuable contributions to the understanding of cetacean populations by providing alternate, long-term sources of information (Kiszka et al., 2004; Moore et al., 1999; Williams, Hedley, & Hammond, 2006). Despite some biases inherent with PoP surveys and citizen scientist data collection, the information gathered can be used to provide basic metrics on cetacean ecology (Moura et al., 2012) and distribution (e.g., Felix & Botero-Acosta, 2011; Moore et al., 1999), but represent an underutilized resource (Theobald et al., 2015). These data can feed into species management and conservation plans contributing to the protection of marine resources (e.g., Constantine, 2001; Evans & Hammond, 2004; Felix & Botero-Acosta, 2011; Timmel, Courbis, Sargeant-Green, & Markowitz, 2008).

PoPs and the use of citizen scientists should not replace systematic surveys for the management of species, but should be evaluated as an option to enhance data sets, particularly in areas where the financial or personnel resources to conduct systematic studies are lacking. PoPs can provide methods of data collection during a greater window of time, providing considerable effort that is not possible with systematic surveys alone. Recent advances in analytical techniques have proven effective for data collected on PoPs; for example, species distribution models to quantify habitat use in marine ecosystems (Guisan & Thuiller, 2005; Redfern et al., 2006).

Conclusion

In 2018 Whale and Dolphin Tracker was developed into a native application (app), which is freely available for both Android and iOS devices. The goal of developing this application was to make a free and easy to use program that other researchers and citizen scientists could use to improve the global body of knowledge about cetacean populations. Data collection using Whale and Dolphin Tracker would ensure consistent data collection between individuals and be relatively

easy to implement as the only equipment required is a smartphone. Further, this would allow for the collection of data across a wide range of species and locations, providing long-term monitoring efforts and increasing sightings histories for various species. The use of Whale and Dolphin Tracker to collect cetacean sighting information presents unique challenges with inherit biases in data collection, but also great potential to advance marine and coastal conservation, particularly in areas where populations are understudied due to resource limitations.

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Biographical Notes

Jens Currie is Senior Research Analyst at Pacific Whale Foundation. His research focuses on distance sampling, modeling cetacean population dynamics, and cetacean interactions with marine debris.

Stephanie Stack is Senior Research Biologist at Pacific Whale Foundation. Her research focuses on population ecology, behavior, patterns of residency, associations between individuals, and animal health.

Gregory Kaufman died in February 2018 and this was the last manuscript he co-authored before his passing (see the In Memoriam article in this issue). He was the Founder of Pacific Whale Foundation. Through his work at Pacific Whale Foundation he committed the organization to educating the public from a scientific perspective about whales and their ocean habitat.

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