

AN ABSTRACT OF THE THESIS OF

Courtney Hann for the degree of Master of Science in Marine Resource Management presented on November 20, 2015.

Title: Citizen Science Research: A Focus on Historical Whaling Data and a Current Marine Mammal Citizen Science Project, Whale mAPP

Abstract approved: _____

Leigh G. Torres

Citizen science work has built the foundation of much of our knowledge on regional-scale large cetacean spatial patterns through historical whaling data. Historical whaling data on sperm whales was used as an example to show the type of ecological questions large-scale, long-term citizen science datasets can address. Results from the study revealed a seasonally driven association of sperm whales with shallow, presumably biologically productive, seamounts off northeastern New Zealand. Similar modeling work could be presumably accomplished with current marine mammal citizen science efforts, such as the mobile application Whale mAPP. Yet, the success of Whale mAPP is dependent on if the citizen science project is effective at recruiting volunteers, maintaining volunteers, providing an educational environment, interpreting biases apparent in the dataset, and producing data that can be used for research. Thereby, the spatial, species, and user biases associated with collected Whale mAPP data were evaluated by using home range estimates for expert and novice data, and comparing the results to previous marine mammal studies. Results suggest that both expert and novice users' had greater survey effort near towns, the recruitment center, and common travel routes. Species bias was found to be different between marine mammal ecological distribution groups, requiring varying sample sizes to accurately predict their home ranges. Furthermore, two surveys were used to evaluate if the educational components added to Whale mAPP achieved various informal education goals.

Surveys were also used to interpret user perception and motivation for participating, and suggested revisions for the citizen science project. Overall, volunteers were motivated to participate based on pre-existing interests in marine mammals and the ocean, and enjoyed the added educational components. Yet, these added components were not enough to change users' marine mammal conservation knowledge, only to improve novice users' identification skills. The top revisions, adding detailed behavioral descriptions and allowing users to revise past sightings, are now being implemented and integrated into the new version of Whale mAPP, which will be released in January 2016. Overall, results from these studies will provide insight to future Whale mAPP development, data analyses, and can be applied broadly to other citizen science and marine mammal studies as well.

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Citizen Science Research: A Focus on Historical Whaling Data and a Current Marine Mammal
Citizen Science Project, Whale mAPP

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Dean of the Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Courtney Hann, Author

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1 CHAPTER 1: INTRODUCTION

Globalization, climate change, land alteration, and human population growth are presenting major conservation challenges that require understanding processes that occur at population level scales. The dynamic nature of these processes requires annual monitoring to identify current trends and impending threats, a task that has been successfully accomplished for the monitoring of global bird populations through the citizen science project eBird (Sullivan *et al.* 2014). Interpreting such trends also requires a long-term dataset to acquire baseline data from which changes in biodiversity can be measured against (Magurran *et al.* 2010). This study focuses on how such techniques can be applied to the marine realm, in particular marine mammals. Results from this study provide an example of using both historical and current marine mammal citizen science data for research, elaborating on the benefits, challenges, and recommendations for the development of future marine mammal citizen science projects.

1.1 Need for regional-scale spatial and temporal marine mammal data

Marine mammals have significant effects on the distribution and abundance of prey species and structure of marine communities (Estes 1980; Perez and McAlister 1993; Kenney *et al.* 1997; Croll *et al.* 1998). Knowledge of the distribution, abundance, and foraging habitats of marine mammals is an essential element of any pelagic ecosystem study because many are top predators or keystone species, and consume significant amounts of prey (Estes 1980; van Franeker 1992). In addition, understanding individual species distribution patterns in relation to their environment is crucial when describing their distribution (Kéry *et al.* 2010). Such distribution patterns vary according to scale (Levin 1992). Scale is more often designated based on technological or logistical constraints, resulting in a majority of studies focused on individual- or location-specific questions (Baker *et al.* 1985; Witteveen *et al.* 2008; Rosa *et al.* 2012).

Yet, population- and region-scale studies are required to answer many of today's applied research questions. For instance, a rise in humpback whale abundance over the past half century (Calambokidis *et al.* 2008) has been associated with increase ship strikes, net entanglements (Reilly *et al.* 2008), and fisheries interactions in Southeast Alaska (Straley *et al.* 2010).

Spreading sea otter populations in this region have led to dispute over sea otter's impact on commercial fisheries (Boyle 2013). Furthermore, prey removal due to cetacean consumption approaches or exceeds removals due to commercial fisheries in Alaska (Laws 1977; Laevastu and Larkins 1981; Bax 1991; Markussen *et al.* 1992; Nordoy *et al.* 1995; Kenney *et al.* 1997). Trites *et al.* (1997) estimated that dolphins and porpoises exhibit a 50% overlap in diet with commercial fisheries, while pinnipeds and sea otters average a 60% overlap. Understanding marine mammal population trends is needed to highlight areas of high marine mammal-human overlap and provide information to mitigate conflict with fisheries, ship activity, tourism, and industry (Gregs and Trites 2001; Hamazaki 2002; Redfern *et al.* 2006; Torres *et al.* 2011). Fluctuation in marine mammal populations since the cessation of whaling (Calambokidis *et al.* 2008), coupled with changing environmental conditions and anthropogenic activities, highlights the need to monitor marine mammal distribution, especially in a high vessel traffic and multi-use area such as Southeast Alaska.

1.1.1 Old and new marine mammal research techniques

Overall, marine mammal data collected over large spatial and temporal scales is rare, and requires extensive collaboration and funding (Calambokidis *et al.* 2008; Dahlheim *et al.* 2009). A majority of marine mammal research is conducted over limited time frames (weeks to months) and on local spatial scales, requiring the data to be extrapolated out to understand regional patterns (Baker *et al.* 1985; Rosa *et al.* 2012). As a result, ecological modeling and other analyses are limited by geographic and temporal scale (Hamazaki 2002; Redfern *et al.* 2006).

Furthermore, the seasonality of many species such as humpback whales, fin whale, Dall's porpoise, and harbor porpoise in Southeast Alaska (Dahlheim *et al.* 2009) cannot be taken into consideration when interpreting the data. As a result, many studies rely on a combination of opportunistic sightings and variable surveys methods to acquire enough data for scientific analysis (Baker *et al.* 1985; Dahlheim *et al.* 2009; Rosa *et al.* 2012). Embracing these non-standardized methods with potentially higher bias, allow scientists to investigate larger-scale trends. Citizen science research takes this approach one step forward, by relying completely on

often non-standardized, biased data. Opening doors to this new avenue of science enables the investigation of population and regional level processes.

This is most evident in historical whaling datasets, which have been important for highlighting regional and global marine mammal distributions and abundance estimates (Gregor and Trites 2001; Torres *et al.* 2011). Representing the first form of citizen science data for marine mammal research, these historical whaling records overcome countless user and spatial biases by the sheer number of records and the fact that no other datasets are as vast as these. Replicating such datasets today is not fiscally feasible with traditional research methods, but distribution data is still vital for understanding how populations have changed over time and how they are responding to large-scale climate and anthropogenic changes. Modern day citizen science research may be the solution to collecting such baseline data.

1.2 Citizen science research

Citizen science research represents an emerging field in which volunteers, called citizen scientists, help researchers collect, process, and/or analyze scientific data (Hames *et al.* 2002; Cooper *et al.* 2006). The dawn of citizen science projects is often associated with the first 1900 Christmas Bird Count. Now citizen science work covers a range of taxa (from local to global scales) of plants, fungi, earthworms, insects, crabs, fish, mammals, amphibians and reptiles (Dickinson *et al.* 2010). The past decade has experienced an expansion of citizen science projects (Silvertown 2009; Conrad and Hilchey 2011; Thiel *et al.* 2014), and numerous peer reviewed publications (Kelling *et al.* 2013; Raddick *et al.* 2010b).

1.2.1 Benefits

Citizen science projects can provide a vast array of benefits, ranging from traditional research and knowledge gain to social and education remunerations as well. From an ecologists' viewpoint, citizen science projects provide a low cost method for gathering abundance and distribution data in a short time frame, and over a large geographic area (Goffredo *et al.* 2010; Raddick *et al.* 2010a). Participating volunteers contribute more sightings data than scientists could feasibly achieve given average budget and time (Goffredo *et al.*, 2010; Hochachka *et al.*

2012; Kelling *et al.* 2013; Paul *et al.* 2014). For instance, eBird volunteers collected 2-3 million new species-data-location records monthly across the entire planet (Hochachka *et al.* 2012), and Divers for the Environment: Mediterranean Underwater Biodiversity Project collected data in four years what would have cost a single professional 45 years and more than US \$4,758,000 (Goffredo *et al.* 2010). Conducting research with assistance from the public, however, can be far more complex than traditional methods; thereby evaluating data quality is critical to the success of such projects. Recent evaluation of the quality of citizen science data has revealed that opportunistic citizen science data can be similar in accuracy and spatial prediction compared to scientifically collected data (Paul *et al.* 2014; Jackson *et al.* 2015).

Citizen science research also appeals to applied studies. Government organizations and NGOs are using citizen science data for estimating species occurrences on both public and private landholdings, as well as completing environmental impact statements (Sullivan *et al.* 2014). Furthermore, public engagement has been deemed necessary for connecting the public to scientific governance (Stilgoe *et al.* 2014). Citizen science represents a unique method for combating this challenge, and has been shown to facilitate increase in content knowledge and an opportunity for changes in attitude towards science and the environment (Conrad and Hilchey 2011; Crall *et al.* 2012; Raddick *et al.* 2010a).

1.2.2 Combating data limitations

Citizen science data is often sighted for statistical limitations. Data fragmentation, uncertainty regarding the data accuracy, and limited applicability for research must be overcome to have a successful project (Koss *et al.* 2009; Conrad and Hilchey 2011). In addition, unlike traditional scientific studies that use standardized transects and survey methods, citizen science project often do not regulate the “survey area” or range covered by an individual. As a result, spatial bias is inevitable. Studies have shown data to be over-reported in high use areas (Bird *et al.* 2014) and for uncommon species (Paul *et al.* 2014). Sampling error can also occur when observers differ in their ability to detect, identify and quantify species or events (Bird *et al.* 2014), leading to the misidentification of species (Bray and Schramm 2001; Galloway *et al.* 2006; Thiel *et al.* 2014). Species bias, often a result of variability in species detection rates,

distributional patterns, and habitat use raises further concern (Gaston 1996; Reese *et al.* 2005; Fitzpatrick *et al.* 2009; Milberg *et al.* 2008; Kéry *et al.* 2010). Sample size, coupled with species' ecological and detection differences can alter the performance of distribution models (Reese *et al.* 2005). Failure to measure and acknowledge these biases associated with citizen science data will lead to false results that do not accurately describe the species distribution.

However, these variations in sampling effort can be combated by collecting data on surveying effort (Dickinson *et al.* 2010) and keeping species lists accurate and location-specific (Sullivan *et al.* 2014). Recognizing and accounting for spatial variation, due to greater effort near cities or places of interest, is also important (Bart *et al.* 1995; Lawler and O'Conner 2004; Niemuth *et al.* 2007; Goffredo *et al.* 2010). Data quality can be improve by standardizing and simplifying data collection methods (Couvett *et al.* 2008; Conrad and Hilchey 2011; Silvertown 2009; Newman *et al.*, 2012; Hochachka *et al.*, 2012), calibrating user expertise (Silvertown, 2009; Raddick *et al.* 2010a), and providing proper training for the specific project (Koss *et al.* 2009). Accounting for sample size is also important, as different species require various sample sizes to accurately predict realistic species distributions (Reese *et al.* 2005). Understanding these biases associated with citizen science projects is important so that the project design can be implemented to combat such limitations.

1.3 Citizen science data and its application for large-scale ecological research

Citizen science methods have been adopted as a low-cost, feasible method for gathering abundance and distribution data in a short time frame, and over a large geographic area (Goffredo *et al.* 2010; Raddick *et al.* 2010). Using citizen science projects for such research has been successful for examining species abundance and distribution data (Goffredo *et al.* 2010; Crall *et al.* 2012; Hochachka *et al.* 2012; Kelling *et al.* 2013), as well as measuring species richness and diversity (Koss *et al.* 2009). For example, citizen science research has documented pole-ward range shifts for numerous taxa across the world (Hickling *et al.* 2006; Parmesan and Yohe 2003; Walther *et al.* 2002), and changes in avian migrations (Thomas and Lennon 1999; Huppopp and Huppopp 2003), providing some of the strongest evidence that species are responding to recent climate change. Such research has only briefly been applied to marine mammal

research based on historical whaling data (Torres *et al.* 2013) and tracking data (Hazen *et al.* 2013), and is greatly needed to interpret the health of our oceans and marine megafauna.

1.4 A marine mammal citizen science mobile application: Whale mAPP

One example of a growing marine mammal citizen science project is Whale mAPP (www.whalemapp.org). This modern-day citizen science app is the only globally accessible marine mammal citizen science mobile application, and has the potential to truly impact how marine mammal research is conducted. Whale mAPP was originally developed by Dr. Lei Lani Stelle of the University of Redlands and Melodi King of Smallmelo Geographic Information Services, and was modified for this project with added educational components specific for Southeast Alaska. The revised beta mobile application was developed in spring 2014, and used by volunteers to collect marine mammal sighting data from June 20th to September 30th 2014 in Southeast Alaska. Success from the revised beta version helped initiate the revision of the entire Whale mAPP application to include the added educational marine mammal *fun facts*, the marine mammal protection act statement, recording visibility, and the marine mammal identification guide. The upgraded version of Whale mAPP will be release in 2016.

1.4.1 How Whale mAPP works

Volunteers can easily sign up to be a Whale mAPP data collector online (www.whlaemapp.org), providing them with access to the mobile application on an Android device. Although, the beta version of Whale mAPP used for this study was manually downloaded to users' Android devices during the summer 2014 field season. Once downloaded, the user started a new "marine mammal survey" by selecting the blue whale tale Whale mAPP icon on their device. Prior to beginning a survey trip, the user filled out a brief user profile, including their vessel name and type of vessel (private, commercial recreation, commercial fisheries). This data was used to connect the data to specific users. Next, the user was notified of the 1972 Marine Mammal Protection Act that prohibits anyone from approaching marine mammals within 100 yards, and required to agree to these regulations. Upon completing these

details, the user was presented with a map view (Figure 1.1) to visualize their survey track line and sightings recorded throughout their trip.

When a user sees a marine mammal, they click the binoculars icon in the upper right corner of the map screen. This takes them to a form where they first click on the appropriate group (whales, dolphins/porpoises, or seals/sea lions/sea otters), and fill in the required data of species type, count, weather conditions, the presence of a calf, and a five star confidence rating (with one star being low confidence and five being high confidence in all data entered) (Figure 1.2). Optional data entry includes recording the animal's behavior, including a photo, and adding additional notes. The users' responses are then displayed prior to submitting the data, allowing them to fix mistakes in their observation details before submission. Upon submission, the user is brought back to the original map view, and the sighting was noted with an animal icon (Figure 1.3). To end a trip, users select the anchor icon, and all data is stored in the SQLite database in the phone until cell service is received. In addition, the My Data View section of the application allows users to view basic information about their trip, such as the number of sightings recorded, the data of past survey trips, and if their data was correctly uploaded.

1.5 Objectives and formatting of thesis

Overall, citizen science is a growing field, one with potential to have a strong impact on marine mammal research. Thereby, as the oldest form of marine mammal citizen science data, historical whaling data provides a plethora of data that has shaped most of what we know about large-scale cetacean patterns today (Smith *et al.* 2006; Gregr 2011; Smith *et al.* 2012; Torres *et al.* 2013). From historical whaling data to current citizen science projects, such as Whale mAPP, there is much to be gained and learned from citizen science data. This thesis' objectives and formatting are described below.

The first goal is to analyze historical whaling data to provide an example of how a long-term, regional-scale marine mammal dataset can be used to answer relevant conservation and management questions, such as how sperm whales are associated with seamounts. Thereby, Chapter 2 focuses on using historical whaling data to interpret sperm whale associations with seasonality and seamounts off the northeast coast of New Zealand.

The second goal is to investigate data from a current marine mammal citizen science project, Whale mAPP, and decipher some of the benefits and challenges associated with expert and novice citizen science data for predicting species' home ranges. Thereby, Chapter 3 interprets the research benefits and biases associated with a new marine mammal citizen science dataset.

The third goal is to look at the same marine mammal citizen science project presented in Chapter 3, but instead focus on the educational benefits, motivations, and user experience associated with participating in the project. Thereby, Chapter 4 examines some of the educational benefits and motivations behind the users participating in the same new marine mammal citizen science project.

The final goal is to summarize Whale mAPP user feedback, and present the information to the Whale mAPP team for designing future revisions to the mobile application. Thereby, Chapter 5 provides a report on user-suggested revisions to the new marine mammal citizen science project, Whale mAPP. Lastly, Chapter 6 ends with general conclusions, highlights key findings, and presents ideas for future research.

1.6 Appendix A

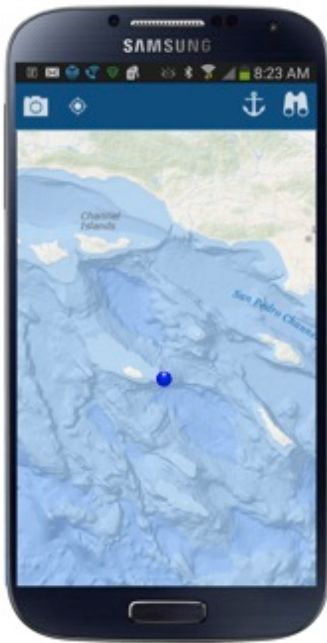


Figure 1.1. Map view displayed on Whale mAPP

Whale mAPP map view shown to the user throughout their trip using the Whale mAPP Android application (Image credit: Dr. Lei Lani Stelle). The upper right icons allow users to record sightings (binocular icon) or end a trip (anchor icon). The upper left icons allow users to take a photo (camera icon) or zoom into a location (bulls eye icon).

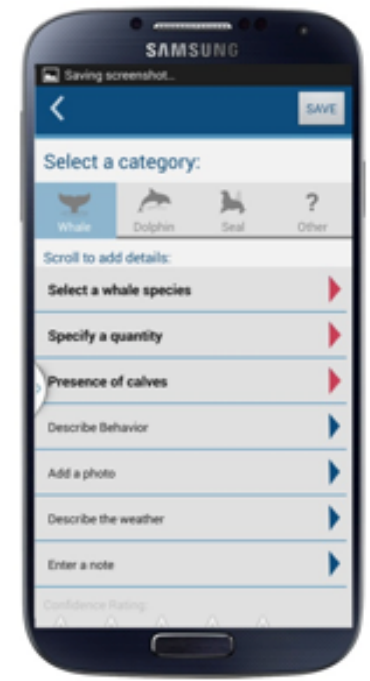


Figure 1.2. Whale mAPP screen for recording a marine mammal sighting.

View of the Whale mAPP screen, with the marine mammal icons at the top indicating the three categories of marine mammal: whales, dolphins/porpoises, and seals/sea lions/sea otters (Image credit: Dr. Lei Lani Stelle).

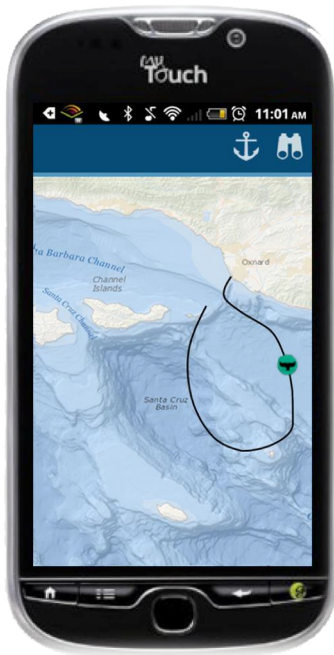


Figure 1.3. Whale mAPP screen displaying a vessel track line and sighting.

Whale mAPP view showing a vessel track line shown with the black line, and whale sighting indicated by the blue whale tail icon (Image credit: Dr. Lei Lani Stelle).

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2 CHAPTER 2: SPERM WHALES *PHYSETER MACROCEPHALUS* AND SEAMOUNTS:
EXPLORING SEASONAL AND SPATIAL RELATIONSHIPS

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Scientists and fisherman have reported anecdotal observations of greater sperm whale *Physeter macrocephalus* (Berzin & Rovnin 1966) and squid abundance (Clarke 1996c) above seamounts. Clarke (2007) suggests that sperm whales may forage on cephalopod species that drift or swim to seamounts for spawning, or possibly feeding. Yet, there is conflicting quantified evidence regarding sperm whale association patterns with seamounts. Using habitat models, Waring *et al.* (2001) and Skov *et al.* (2008) found significant positive relationships between sperm whales and seamounts. Wong and Whitehead (2014) described seasonal sperm whale presence at one seamount in the North Atlantic. In comparison, habitat modeling by Torres *et al.* (2011) and non-modeling work by Morato *et al.* (2008), found no association between sperm whale distribution and seamounts. This discrepancy between studies may be due to variation in scale and sample size, size of the study area (and amount of inherent bathymetric variation), and the resolution of data. For instance, encounter rates from Skov *et al.* (2008) indicate scale-dependent variability of the modeled distribution of sperm whales in relation to bathymetry. Furthermore, Torres *et al.* (2011) recommended a more refined examination of seamount influence on sperm whale presence that accounts for the variation in seamount characteristics as a proxy for prey availability to whales. The distribution of sperm whales has been associated with other abiotic features such as bathymetry (Jaquet & Whitehead 1996, Gregr & Trites 2001) and cross-seamount fronts (Skov *et al.* 2008), both of which are tightly linked with seamount presence. Thus, patterns of association between sperm whales and seamounts merit further investigation.

An estimated 14,000 (Kitchingman *et al.* 2007) to 33,000 (Yesson *et al.* 2011) seamounts (> 1000 m elevation) are distributed around the world, mainly formed at mid-ocean ridges or hotspots (Kitchingman *et al.* 2007). Water flow over seamounts in the euphotic zone can stimulate upwelling and phytoplankton growth, while retaining much of the organic material produced over seamounts (e.g. Taylor cone formation) to support secondary productivity (Pitcher & Bulman 2007). Higher trophic levels can also be supported by the horizontal flux and topographic blockage of zooplankton and organic

matter at seamounts from tidally forced circulation, internal waves, and turbulent mixing (Mienis *et al.* 2007, Kvile *et al.* 2014). The level of productivity varies across seasons, tides, and geomorphology of seamounts (Pitcher & Bulman 2007, White *et al.* 2007). Seamount depth, is a proxy for a range of environmental variables, and particularly impacts the community structure present (Rogers *et al.* 2007, Morato *et al.* 2008, Lavelle & Mohn 2010). Seamounts permeating the euphotic zone, categorized in this paper as those seamounts with a summit depth less than 400 meters from the surface, may provide habitats suitable for an abundance of benthic organisms (Rogers *et al.* 2007), fish and cephalopod species (Clarke 2007, Morato & Clarke 2007), and foraging pelagic predators (Morato *et al.* 2008).

Marine mammals, marine birds, and their prey (fish and cephalopods) have been documented near seamount slopes (Clarke 2007, Kaschner 2007, Morato & Clarke 2007, Morato *et al.* 2008). In particular, the steep slopes of seamounts are potential foraging sites for sperm whales (Clarke 2007) due to their cephalopod dominated diet (Gaskin & Cawthorn 1967a, Clarke 1996a, Evans & Hindell 2004) and their ability to exploit prey over a wide range of depths; the mean dive depth of sperm whales is estimated at 500 m, although deeper dives up to 985 m have been recorded (Whitehead 2003, Watwood *et al.* 2006). Off the coasts of New Zealand and southern Australia, sperm whale diet is dominated by the squid *Onychoteuthid* sp. (Gaskin & Cawthorn 1967c, Evans & Hindell 2004), which often occur below 200 m around seamounts (Clarke 1996c). Sperm whales in this region also exhibit a northward migration in autumn and distinct north-south distribution patterns based on demography, with female and calf groups limited to areas above 50° S, and lone, adult males ranging down to Antarctica (Gaskin 1973).

In this study we use a unique, large-scale dataset of sperm whale presence and absence data derived from 19th century whaling records to investigate association patterns between sperm whales and seamounts in the pelagic waters off eastern New Zealand. The seafloor geomorphology of New Zealand, including seamount depth, density, and size varies greatly (Rowden *et al.* 2005), making biological productivity due to seamounts

difficult to link and describe. We hypothesize that the distribution of sperm whales relative to seamounts is not absolute, but rather a function of seamount height, depth, size, and density, local mean bathymetry or season. Bathymetry is defined as a measurement of the mean depth of the seafloor, logged with every sperm whale presence/absence recording. We expect to see positive association with seamounts under conditions that enhance prey availability.

We obtained daily observations from American whaling vessels within our study region east of New Zealand (168°W to 130°E, and 10°S to 55°S; Fig. 1) from logbook records collated by Maury (1852) and the Census of Marine Life (www.coml.org/) using methods described in Smith *et al.* (2012). Whalers recorded their location daily and indicated when sperm whales were encountered. These data amounted to 28,485 daily records of vessel location over the period 1823 to 1888 (1,015 presence locations; 27,470 absence locations; Fig. 1). Mean vessel location error is estimated to be 0.22° latitude and 0.54° longitude (Smith *et al.* 2012). Therefore, using a WGS 1984 World Mercator projection, we applied a spatial scale of 70 km² for analyses. We grouped data by season for analysis to account for seasonal changes in environmental patterns and whale ecology: spring (September, October, November; n presence = 144, n absence = 6,359), summer (December, January, February; n presence = 367, n absence = 11,338), autumn (March, April, May; n presence = 353, n absence = 7,067), and winter (June, July, August; n presence = 151, n absence = 2,706). Although these data are historic, and recorded at a relatively large spatial and temporal scale, the dataset is appropriate to test our hypothesis because it includes presence and absence locations, and is widely distributed across time (seasons and years) and a highly heterogeneous bathymetric seascape (Rowden *et al.* 2005, Yesson *et al.* 2011). Such a large and diverse dataset is necessary to assess the relationship between sperm whales and seamounts to capture, and tease apart, the inherent variability in whale distribution and environmental patterns. By using these historic data, we make the assumption that sperm whale spatial ecology in the New Zealand region has not altered over the last century.

Within a 100 km buffer of the whaling data extent, seamount peak location, height, depth and size information were extracted from Yesson *et al.* (2011). The depth, height, and area of the nearest seamount to each sperm whale location was calculated, along with the distance to the nearest seamount, and the density of seamounts at 70 km² resolution. This data was used in a Principal Component Analyses (Jolliffe 2002). Subsequently, the following data classifications were used in binary logistic regression models. The 3,567 seamounts were grouped once by summit depth, again by summit height, and again by summit size to yield nine primary classes of seamounts (Table 1.1). The divisions of each class by depth, height and size were determined based on Jenks classification, which is a data clustering method that seeks to reduce the variance within classes and maximize the variance between classes (Jenks 1967). Further sub-divisions of the shallow depth seamount group were classified based on groupings used by previous studies of seamount ecology (Table 1.1; Clarke 2007, Morato & Clarke 2007, Rogers *et al.* 2007, Morato *et al.* 2008). In total, eleven classes of seamounts based on height, depth, and size were examined relative to sperm whale presence and absence (Table 1.1). The Euclidean distance from the base area of all seamounts in each class was calculated within the study region to yield eleven ‘distance from seamount’ rasters. All presence and absence locations sampled these eleven layers, as well as a layer of bathymetry derived from the General Bathymetric Chart of the World (GEBCO: <http://www.gebco.net/>) and resampled to a 70 km² resolution. A layer of seamount density of 70 km² resolution and a search radius of 150 km was also included. All spatial analyses were conducted in ArcGIS v 10.2 (Esri, Redlands, CA).

To examine our hypothesis, binary logistic regression models were developed to examine the relationships between whale occurrence and proximity to seamounts of different classes and densities, and temporal variability and bathymetry in waters east of New Zealand. A preliminary Principal Component Analysis was conducted to determine which explanatory variables should be included in the models (Jolliffe 2002). A Pearson’s Correlation Coefficient was used to reveal correlations between explanatory

variables, and hence the need to include any interaction terms in the model (Reynolds 1977). Four seasonal binary logistic regression models applied presence/absence of sperm whales as the dependent variable, and distance from seamount geomorphology, seamount density, and bathymetry as independent variables (Moses & Finn 1997). Empirical logit plots were initially used to identify important explanatory variables and those variables that needed to be transformed (Ramsey & Schafer 2012). No transformations were needed due to negative linear relationships between logits and explanatory variables. Wald's test was used to determine the significance of specific variables. Using the logistic regression models and methods by Ramsey and Schafer (2012), we calculated the expected change in sperm whale presence with any 100 km step toward the seamount. All analyses were conducted in R (R Development Core Team 2013) with packages FactoMineR (Husson *et al.* 2015), factoextra (Kassambara 2015) and vegan (Oksanen *et al.* 2007). Graphical representation of presence/absence histograms were chosen based on suggestions from Smart *et al.* (2004) using the package popbio (Stubben *et al.* 2008).

Results from the Principal Component Analysis reveal seven principal components, of which ~79% of data variance can be explained by PC1, PC2, PC3, and PC4. These four principal components were included in the model based on selecting suggestions by Jolliffe (2002), which included the following variables: depth, height, and base area size of nearest seamounts, seamount density, bathymetry, and year. Approximately 49.27% of variation within the dataset can be explained by PC1 (depth, height, and base area size of nearest seamounts) and PC2 (the distance to the nearest seamount and seamount density) (Fig. 2). Another 15.58% of the variance can be explained with PC3 (bathymetry) and an additional 14.15% of variation is explained by adding PC4 (year). Comparison of PC1 to PC2 illustrates that both sperm whale presence and absence data were distinctly clumped by seasons, with presence data having larger standard errors relative to absence data (Fig. 2). Therefore, binary logistic regression models were divided by season, equating to four models total. None of the distributions

landed exactly on either axes; therefore all seasonal presence and absence data demonstrate a relationship with PC1 and PC2. Pearson's chi-squared test revealed no correlations between any two explanatory variables; therefore interaction terms were not included in the models.

Models reveal that sperm whales were most broadly associated with shallow seamounts with 200 to 400 m summit depths (Table 2; Fig. 3). With every 100 km step toward a shallow seamount (200 to 400 m summit depth) the mean presence of sperm whales increased by ~12% in spring, by ~8% in summer, and by ~8% in autumn (Wald's test, $p = 0.009, 0.022, 0.021$ respectively). Sperm whales were also associated with slightly deeper shallow seamounts, as the mean presence of sperm whales increased by ~23% with every 100 km step toward a less shallow seamount (400 to 1464 m summit depth) in spring, and by ~17% in summer (Wald's test, $p = 0.030, 0.035$ respectively). In autumn, the mean presence of sperm whales increased by ~18% with every 100 km step toward a very shallow seamounts (200 to 400 m summit depth) (Wald's test, $p = 0.024$).

In the spring model, the mean presence of sperm whales also increased by ~48% with every 100 km step toward a small area seamount (Wald's test, $p = 0.044$). Therefore, sperm whales showed a positive association with shallow (200 to 400 m and 400 to 1464 m) summit depths and small area seamounts in spring, and no associations with seamount heights (Fig. 4). Other trends shown were a strong summer sperm whale association with year (Table 2), likely due to greater sperm whale presence/absence data collected between 1835 and 1850 (Smith *et al.* 2012). In addition, sperm whales exhibited a positive association with shallower bathymetry and short height seamounts in autumn (Table 2), reflecting a potential shift in their distribution towards shallower foraging grounds in autumn where short height seamounts may reach a height at which productivity can occur. Come winter, sperm whales show no association with any of the geological features measured, indicating potentially reduced sperm whale foraging at seamounts in eastern New Zealand during colder seasons.

We conclude that relationships between sperm whale presence/absence and seamount summit depth represents the most consistent and informative geographic factor measured for anticipating sperm whale presence. Sperm whale presence was positively associated with shallow seamount summit depths during spring, summer, and autumn seasons. In comparison, the importance of the seamount height and base area appears to be less relevant across seasons. Unlike seamount height that is measured relative to variable bathymetric relief, the sea surface is a relatively constant reference position, making seamount summit depth measured from the surface a consistent metric to describe relationships between seamounts and sperm whales. For instance, a seamount of 1000 m height may be considered shallow in waters with bathymetry < 2000 m, but deep in areas with bathymetry > 4000 m (Fig. 5). Therefore, we consider summit depth to be a more relevant and easily interpretable metric for comparison to sperm whale presence/absence.

Furthermore, the lack of significant associations between sperm whales and various height classes exposes the inappropriate nature of seamount height as a reliable metric of association due the confounding effect of bathymetry on height values (Fig. 5) and the complex bathymetry in this region (Yesson *et al.* 2011). In addition, although base area inevitably influences the physical oceanography and potential productivity at a given seamount (Read 2015), its degree of influence is not consistent and therefore is a poor parameter for estimating relative biological productivity at a seamount. Due to the limited significance of seamount base area on predicting sperm whale presence across seasons, we suggest using readily available and more significant seamount summit depth for explaining large-scale associations with sperm whales. At our large-scale of analysis, seamount density was not a driving factor for predicting sperm whale presence, indicating the greater importance of seamount productivity over seamount abundance for driving potential regional-scale foraging patterns.

Ecologically, this association between sperm whales and shallow summit depth seamount is likely due to enhanced productivity at seamounts (White *et al.* 2007) that

facilitate concentration of pelagic fish and cephalopods (Clarke 2007, Morato & Clarke 2007), important prey items for sperm whales (Gaskin & Cawthorn 1967a, Clarke 1996a, Evans & Hindell 2004). While our results align with previous studies showing enhanced marine predator occurrence at seamounts (Morato *et al.* 2008), our study also highlights the potential causes of previous inconsistent findings between sperm whales and seamounts: lack of consideration for seasonal patterns or seamount characteristics, or low sample size.

Seasonal sperm whale and seamount association patterns have been previously recorded in the Sargasso Sea (Wong and Whitehead 2014). In our study region, reduced association between sperm whales and seamounts in winter suggests that sperm whales may spend less time foraging in this region or in association with seamounts during the cooler months, as noted previously by Gaskin (1973). This reduced association may be due to cooler water temperatures, reduction in prey availability, or reduced whaling effort during stormy winter months. Additionally, social patterns of sperm whales may impact the detected distribution patterns with greater female and calf presence in warmer waters (Gaskin 1973, Ivashin 1981) and the distribution of males extending further south (Gaskin 1973).

In summary, we conclude that not all seamounts are created equal from a sperm whale's perspective, which is supported by the diverse and heterogeneous classifications of seamounts around New Zealand (Clark *et al.* 2011) that sustain disparate levels of biodiversity (Morato *et al.* 2015). Additionally, positive associations between sperm whales and shallow seamounts during spring, summer, and autumn demonstrated the seasonal influence on these relationships. These findings have important management implications for the region as environmental managers in New Zealand attempt to regulate growing resource extraction activities at its offshore seamounts for fish and minerals (O'Driscoll & Clark 2005, Clark *et al.* 2010, Leduc *et al.* 2015). Our results indicate that a refined grouping of seamount characteristics, especially one that accounts for seamounts with summits less than 400 m deep, will likely contribute to the predictive

power of sperm whale habitat and distribution models, particularly during the spring, summer, and autumn months.

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2.2 Appendix B

Table 1.1. Seamount classes and sample sizes, by summit depth and seamount height.

Summit depth (m)		Range	n
Shallow	Very shallow	< 200	284
	Shallow	$200 \text{ to } \leq 400$	97
	Less shallow	$400 \text{ to } \leq 1464$	866
Medium		$1465 \text{ to } \leq 2906$	1230
Deep		$< 2906 \text{ (to } 5983)$	1090
Seamount height (m)		Range	n
Short		$1001 \text{ to } \leq 1680$	2093
Medium		$> 1680 \text{ to } \leq 2637$	1059
Tall		$> 2637 \text{ (to } 4978)$	415
Seamount area (m ²)		Range	n
Small		≤ 643	766
Medium		$> 643 \text{ to } \leq 893$	1372
Large		$> 893 \text{ to } 1162$	1374

Table 2.2. Seasonal logistic regression model results

Results from seasonal logistic regression models between sperm whale presence/absence and distance to various seamount characteristics, bathymetry and year. For each explanatory variable, the arrow indicates whether there is a positive (upward pointing) or negative (downward pointing) relationship with sperm whale presence. The percent change in expected sperm whale presence with any 100 km step toward a seamount, and associated p-value is also given. A dash mark indicates that the variable was not significant.

	Spring	Summer	Autumn	Winter
Intercept	—	↓100% p = 0.004	—	—
Year	—	↑vary large p = 0.003	—	—
Bathymetry	—	—	↑1.97% p = 0.003	—
Seamount density	—	—	—	—
Tall seamount height	—	—	—	—
Medium seamount height	—	—	—	—
Short seamount height	—	—	↑40% p = 0.013	—
Deep summit depth	—	—	—	—
Medium summit depth	—	—	—	—
Shallow (<200 m) summit depth	—	—	↑18% p = 0.024	—
Shallow (200-400 m) summit depth	↑12% p = 0.009	↑8% p = 0.022	↑8% p = 0.021	—
Shallow (> 400 m) summit depth	↑23% p = 0.030	↑17% p = 0.035	—	—
Big summit area	—	—	—	—
Medium summit area	—	—	—	—
Small summit area	↑48% p = 0.044	—	—	—

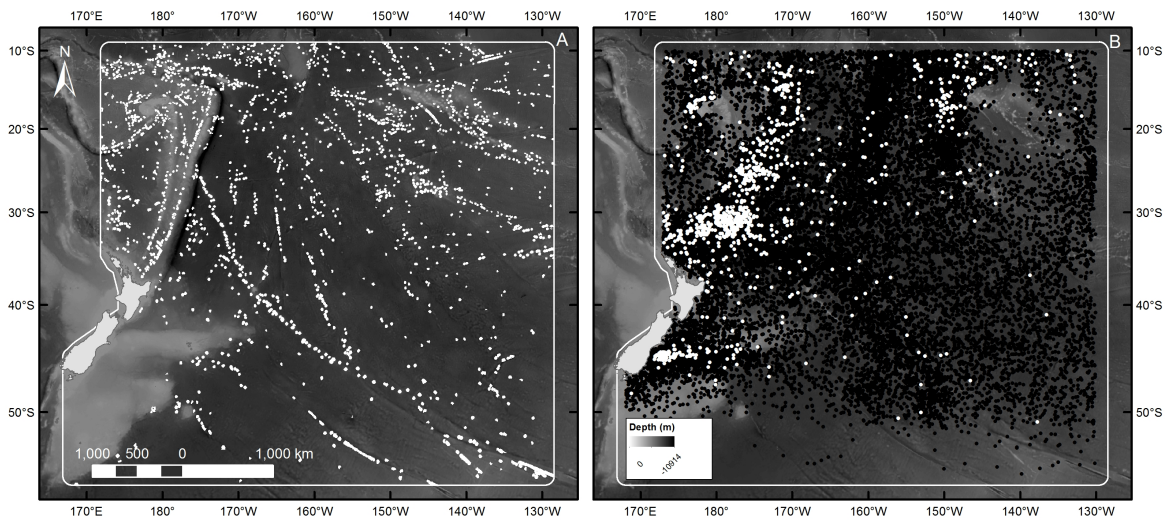


Figure 2.1. Study area and sperm whale presence/absence

Study area east of New Zealand showing regional bathymetry and distribution of (A) all seamount base areas, and (B) sperm whale presence (white dots) and absence (black dots) data derived from 19th century whaling records.

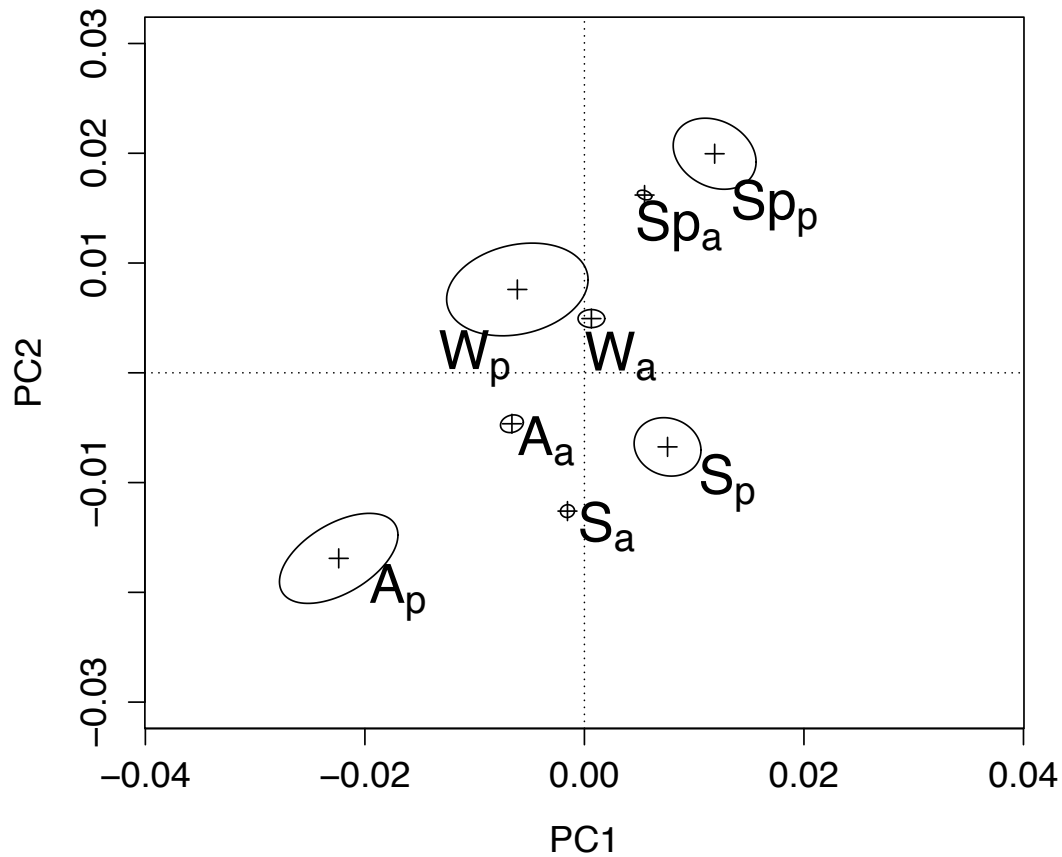


Figure 2.2. Sperm whale data in relation to PC1 and PC2

Distribution of sperm whale data in environmental space as described by principal component 1 (seamount height, area, and summit depth) versus principal component 2 (distance to the nearest seamount and seamount density). Data grouped by season and by presence or absence, totaling to eight subsets: spring/absence data (Sp_a), spring/presence data (Sp_p), summer/absence data (S_a), summer/presence data (S_p), autumn/absence data (A_a), autumn/presence data (A_p), winter/absence data (W_a), and winter/presence data (W_p). The plus sign indicates the mean variance of each subset, while the circle around the plus shows the standard error of the variance.

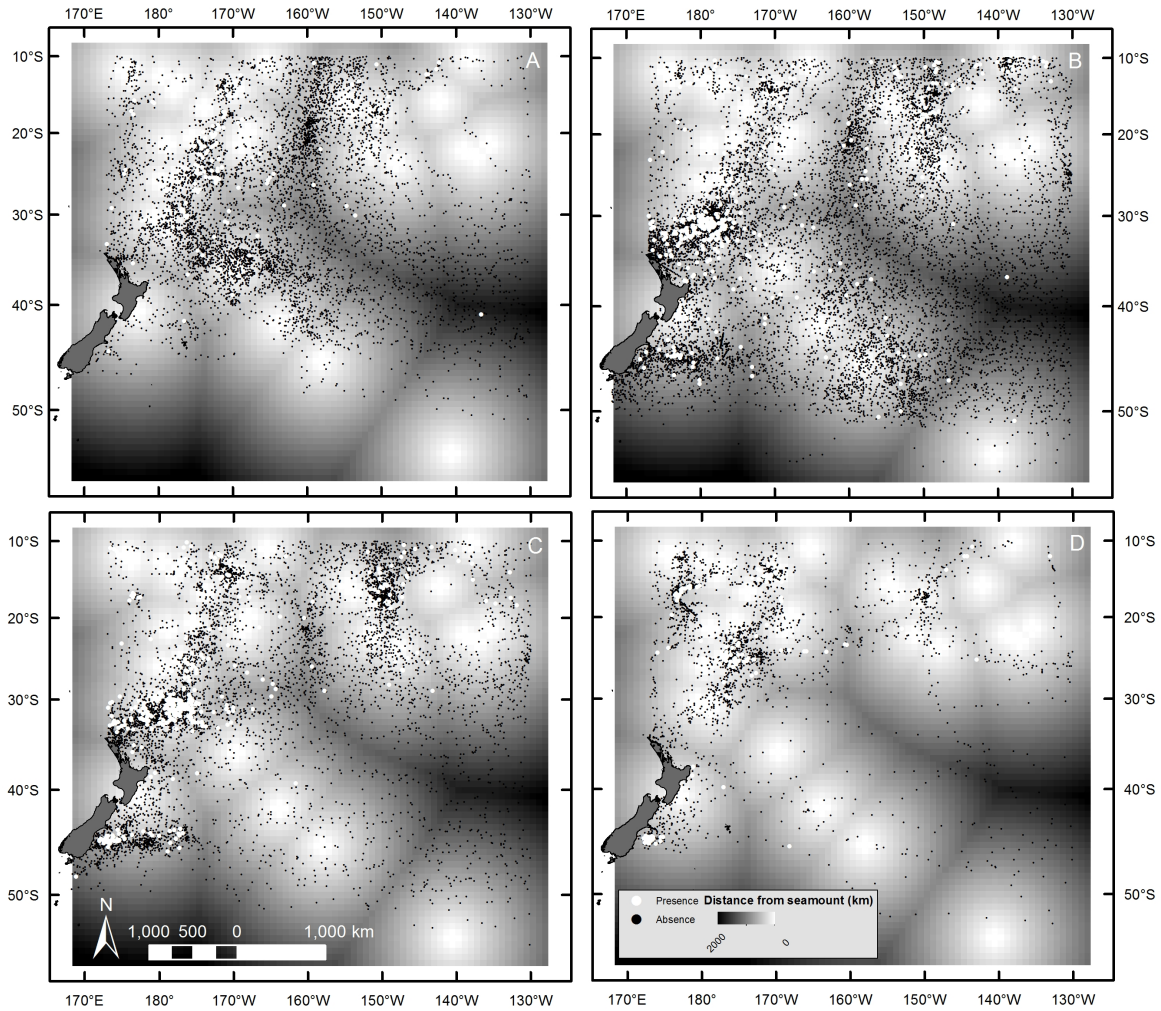


Figure 2.3. Sperm whale presence/absence relative to shallow summit depth seamounts

Distribution of sperm whale presence and absence location data derived from 19th century whaling records relative to the distance from seamounts with shallow summit depth (< 400 m from the surface) during (A) spring, (B), summer, (C) autumn, and (D) winter.

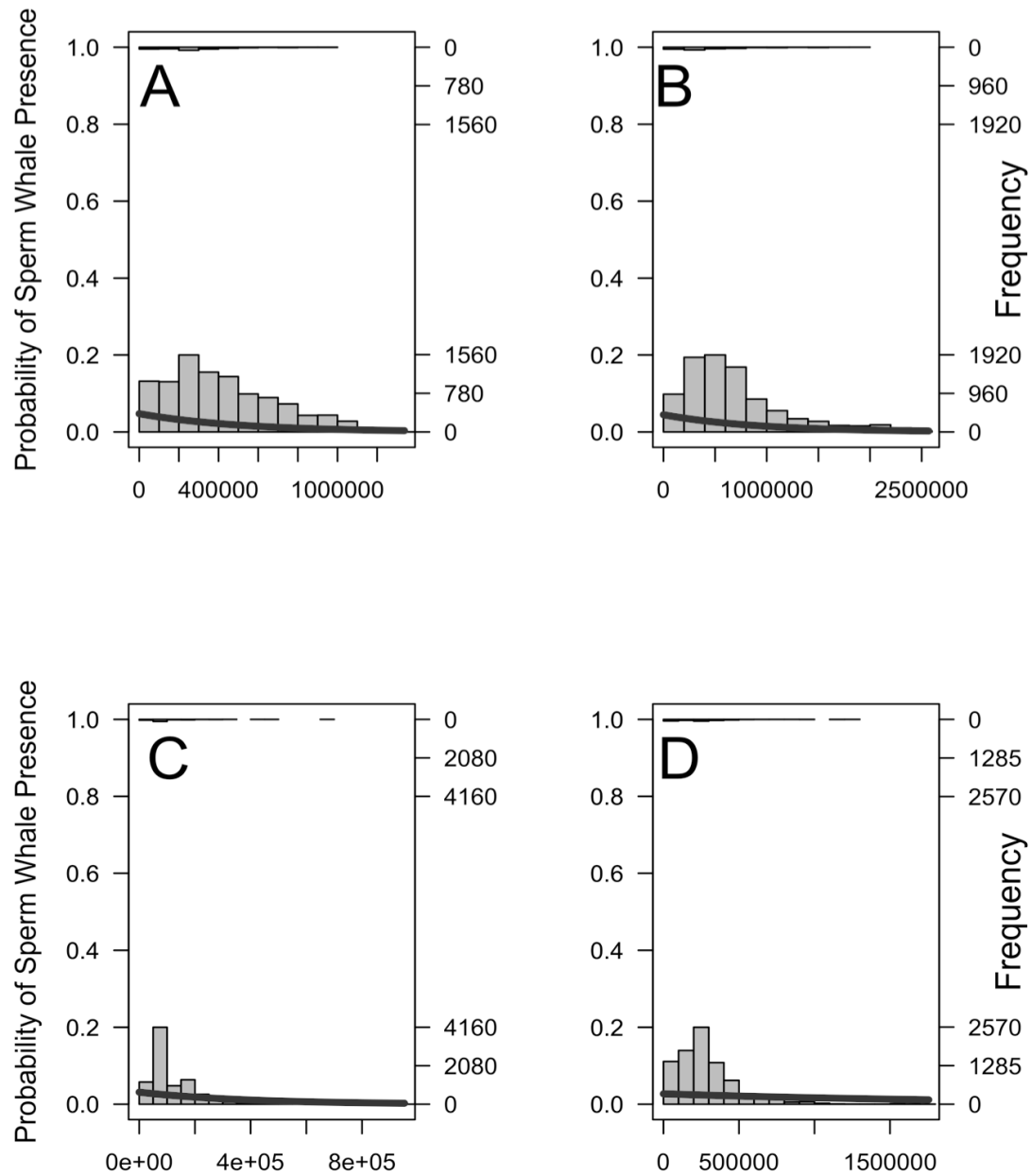


Figure 2.4. Sperm whale absence/presence versus distances to various seamount categories

Relationships between sperm whale presence and absence relative to the distance to A) shallow (< 400 m) summit depth, B) shallow (200 – 400 m) summit depth, C) small summit area, and D) medium summit area seamounts. Absence and presence data frequencies are shown by the bottom and top bar charts respectively. The black line illustrates the overall trend, where an increase indicates more sperm whales presence than absence.

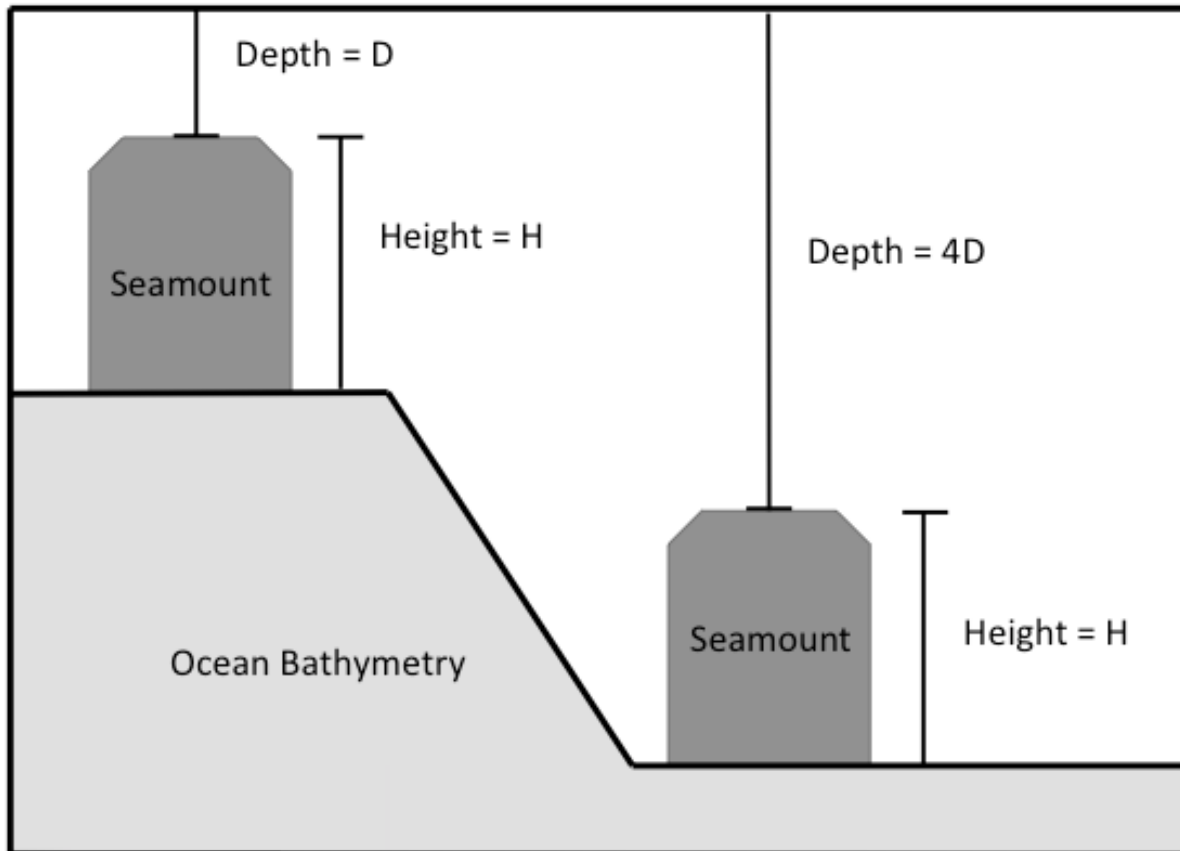


Figure 2.5. Seamount schematic

Schematic of a two seamounts with the same summit height (H) but different summit depths (D), due to variable bathymetry.

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3 CHAPTER 3: SPECIES, SPATIAL, AND USER BIAS: ACCOUNTING FOR VARIABILITY IN A MARINE MAMMAL CITIZEN SCIENCE DATASET

Journal to be submitted to *Biological Conservation*

Abstract

Citizen science represents a growing field where citizens participate in various phases of scientific research. In the marine mammal realm, such projects have been focused on recording beached marine mammals or photo-identification studies. This project investigates using a mobile application as a citizen science tool for collecting opportunistic sighting data on seven marine mammal species in Southeast Alaska. Different forms of error within the dataset, including spatial biases, user biases, and species biases were evaluated for data collected by expert and novice users. These user groups had similar spatial bias patterns, with greater user effort near major towns and common travel routes. Furthermore, results suggest that species' unique ecological distributions are driving much of the differences in the novice and expert datasets, requiring higher sample sizes for highly migratory and discontinuously distributed marine mammals. In comparison, marine mammals with clustered distributions (harbor porpoise and Dall's porpoise) exhibited comparable core- and intermediate-use areas as determined by expert and novice data despite their small sample sizes. For all marine mammals, expert and novice datasets were more similar when predicting restricted core-use 25% home range areas than broader 95% home range areas. Results illustrate the potential application of Whale mAPP collected marine mammal citizen science data towards research, and the need to consider spatial and species biases when evaluating citizen science data.

3.1 Introduction

An estimated 37% of all marine mammals, including species with insufficient data, are at risk of extinction (Davidson *et al.* 2011). Modern-day threats include accidental mortality in fishing operations, pollution, habitat loss, shipping, and global climate change (Allen and Angliss 2015). Understanding the basic biology and ecology of marine mammals is vital for assessing the correlates and causes of depletion, and implementing solid management decisions. Yet, this basic information remains poorly understood for most marine mammal species (Davidson *et al.* 2011; Kovacs *et al.* 2012). For instance, conservation efforts to pinpoint and reduce ship strikes for large cetaceans are limited by information on their migration routes and distributions (Torres *et al.* 2013; Irvine *et al.* 2014). In addition, the effects of climate change and

rising ocean temperatures on marine mammals are associated with core and basin-scale changes in biodiversity (Hazen *et al.* 2013). Monitoring these population-level changes often requires data across long-term temporal scales and regional to global spatial scales (Magurran *et al.* 2010; Torres *et al.* 2013).

A majority of marine mammal research projects focus on location or individual-specific questions, and therefore analyze data collected over several weeks to months, and in geographically limited areas (Baker *et al.* 1985; Witteveen *et al.* 2008; Rosa *et al.* 2012). Several longer-term studies across regional scales exist (Calambokidis *et al.* 2008; Dahlheim *et al.* 2009, 2015), but these are highly resource-intensive and therefore are rare for marine mammal research. Tagging is another method scientists use to study marine mammals over broad scales. These studies shed light on the large scale movement patterns of individuals, but capture only a small portion of the population studied, can be expensive, are invasive, and provide only a snapshot in time (Mate *et al.* 1999; Cotté *et al.* 2011; Womble and Gende 2013). As a result, many applied and basic ecological questions are left unanswered as they occur at geographic scales beyond the reach of traditional research methods (Dickinson *et al.* 2010).

One approach to combat the paucity of large spatial and temporal scale marine mammal data is to embrace citizen science research as an alternative method. Currently, one of the greatest breadths of large cetacean data comes from historical whaling data, the oldest marine mammal citizen science dataset used today (Smith *et al.* 2006; Gregr 2011; Smith *et al.* 2012; Torres *et al.* 2013; Hann *et al.* 2015 Chapter 2). Although citizen science data collection is not a new concept, the past decade has experienced an expansion of such projects (Silvertown 2009; Conrad and Hilchey 2011; Thiel *et al.* 2014). In terrestrial ecosystems, citizen science research has become accepted as a powerful tool to collect multi-year and regional-scale data (Kelling *et al.* 2013; Thiel *et al.* 2014). Projects recruit volunteers to assist in collecting, processing, and in some cases analyzing scientific data (Hames *et al.* 2002; Cooper *et al.* 2006). Many projects involve the recording of opportunistic sightings of plants, fungi, and animals (Dickinson *et al.* 2010) and results from such studies have led to an expansion of peer-reviewed literature derived from citizen science data (Kelling *et al.* 2013; Raddick *et al.* 2010b; Thiel *et al.* 2014). Various

citizen science projects have collected abundance and distribution data (Goffredo *et al.* 2010; Crall *et al.* 2012; Hochachka *et al.* 2012; Kelling *et al.* 2013) and measured species richness and diversity (Koss *et al.* 2009). Citizen science work has also expanded to include marine mammal monitoring, particularly focused on recording cetacean strandings (Thiel *et al.* 2014).

Citizen science research has become more prevalent due to its low cost approach for gathering data in a short time frame and over a large geographic area (Goffredo *et al.* 2010; Raddick *et al.* 2010a). Numerous studies have found spatial agreement between citizen science and traditional scientific datasets (Paul *et al.* 2014; Jackson *et al.* 2015). Furthermore, volunteers can collect data relatively quickly (Paul *et al.* 2014) and contribute more data than scientists could feasibly achieve with an equivalent budget and timeframe (Goffredo *et al.* 2010; Hochachka *et al.* 2012; Kelling *et al.* 2013). In addition to research benefits, citizen science projects have provided informal education to the public (Goffredo *et al.*, 2010) that facilitates an increase in content knowledge and an opportunity for changes in attitude towards science and the environment (Conrad and Hilchey 2011; Crall *et al.* 2012; Raddick *et al.* 2010a; Hann *et al.* 2015 Chapter 3).

This study compares the correspondence between expert and novice marine mammal citizen science data collected in Southeast Alaska to better understand user, spatial, and species biases associated with citizen science datasets. User biases can result from observer variation in their ability to detect, identify, and quantify species or events (Bray and Schramm 2001; Galloway *et al.* 2006; Bird *et al.* 2014). Spatial biases can occur from unequal survey effort, often with a positive bias in sampling effort around larger cities or roads (Bart *et al.* 1995; Lawler and O’Conner 2004; Niemuth *et al.* 2007; Goffredo *et al.* 2010). Finally, species biases can result from differences in abundance (Gaston 1996; Milberg *et al.* 2008; Kéry *et al.* 2002), sample size (Wisz *et al.* 2008; Fitzpatrick *et al.* 2009), detectability (Kéry *et al.* 2010), and habitat preference (Fitzpatrick *et al.* 2009) between species. In addition, the sample size required for accurate representation of distribution patterns varies between species and needs to be considered when using the same model for different species (Reese *et al.* 2005) to avoid data

fragmentation and complications when interpreting results (Koss *et al.* 2009; Conrad and Hilchey 2011).

For this study, data were collected on a mobile application, Whale mAPP (www.whalemapp.org), which takes advantage of advancing smart phone technology to provide an electronic protocol for recording citizen science marine mammal data. Whale mAPP utilizes this technology to record marine mammal sightings and behavior, environmental conditions, confidence ratings, and track vessel paths that transmit to an online geodatabase. Although the app is currently in-use with over 100 users, the applicability of the resulting data for research has not yet been evaluated. This study compares expert versus novice data estimations of species' broad-use (95% home range), intermediate-use (50% home-range), and core-use (25% home range) area sizes and geographic overlap. Home range estimations were evaluated because it is a common technique applied to management strategies and in understanding general distribution patterns, habitat use, and behavioral relationships of species (Zeller 1997; Meyer *et al.* 2000; Eristhee and Oxenford 2001; Parsons *et al.* 2003; Heupel *et al.* 2004; Frère *et al.* 2010; Fujisaki *et al.* 2014; Irvine *et al.* 2014). As a primary form of examining species distributions, home ranges represent an ideal method to examine various biases that may skew perceived distribution patterns derived by expert and novice data sets.

3.2 Methods

3.2.1 Study Area

Volunteers used Whale mAPP to collect marine mammal sighting data throughout Southeast Alaska from June 20th to September 30th, 2014 (Figure 3.1). The study area's convoluted coastline, many bays, inlets, and islands (Weingartner *et al.* 2009) support an abundance of marine mammals (Dahlheim *et al.* 2009; Allen and Angliss 2013). Common marine mammals in Southeast Alaska include the humpback whale *Megaptera novaeangliae*, killer whale *Orcinus orca*, Steller sea lion *Eumetopias jubatus*, harbor seal *Phoca vitulina*, sea otter *Enhydra lutris*, Dall's porpoise *Phocoenoides dalli*, and harbor porpoise *Phocoena phocoena* (Dahlheim *et al.* 2009; Allen and Angliss 2013). Only common marine mammal

species were included in the data analysis. These seven species have different species' ecology and were broken into the following three ecological groups: 1) widely dispersed species including humpback whales and killer whales (Dahlheim *et al.* 2009); 2) discontinuously distributed species including harbor seals, Steller sea lions, and sea otters (Garshelis and Garshelis 1984; Calambokidis *et al.* 1986; York *et al.* 1996; Hastings *et al.* 2004; Small *et al.* 2004; Womble *et al.* 2005); and 3) species with clustered distribution including harbor and Dall's porpoises (Chivers *et al.* 2002; Dahlheim *et al.* 2009, 2015). Widely dispersed species are those categorized as spending a majority of their time traveling and foraging throughout Southeast Alaska (Saulitis *et al.* 2000; Dahlheim *et al.* 2009). Discontinuously distributed species are defined as non-migratory with local movements, often primarily sighted at haul out locations for pinnipeds (Garshelis and Garshelis 1984; Hastings *et al.* 2004; Small *et al.* 2004). Clustered distribution is defined as larger, clumped distributions with core-use areas covering a larger area than that of discontinuously distributed species (Chivers *et al.* 2002; Moore *et al.* 2002; Hobbs and Waite 2010; Dahlheim *et al.* 2009, 2015).

3.2.2 Recruitment of volunteers and data collection

Volunteers were recruited at the Alaska Whale Foundation's Coastal Research and Education Center (CREC) in Warm Springs Bay, Alaska (57.09°N, -134.84°W; Figure 3.1). Most volunteers were provided in-person training, while a few volunteers received only the user manual due to time limitations. The in-person CREC training involved a 15 to 30 minute tutorial on how to use the mobile application, scientific technique and rationale for the approach, and data collection methods. When time allotted, participants completed a test run using Whale mAPP to collect artificial sighting data. The user manual provided background information on the project, data collection protocols, contact information, and step-by-step instructions on how to use Whale mAPP. Both training methods were assumed to support similar user performance as they both provided user instructions, emphasized using Whale mAPP only when completing a "marine mammal survey", and noted that a session should be terminated when either the vessel or scanning effort stop. Furthermore, all users were provided with a region specific marine mammal identification guide to assist in identifying marine mammals.

Whale mAPP automatically recorded the volunteers' boat location, while the volunteers documented any marine mammals sighted, the approximate distance and direction to the animal(s), the animal's behavior, weather conditions, and a five star confidence rating scoring the user's own confidence in the accuracy of the data s/he entered for each sighting. Since many areas of Southeast Alaska do not support cellular reception, the Southeast Alaska Whale mAPP version was designed to store data locally on a disconnected base map of Southeast Alaska. Once cellular reception was reached, the data were automatically transmitted to a geodatabase.

3.2.3 Accounting for user, spatial, and species bias

Data analysis precautions were developed to minimize user bias. The successes of such measures were evaluated in this study. A standardized and straightforward data entry system, recommended by other citizen science studies (Couvét *et al.* 2008; Silvertown 2009; Conrad and Hilchey 2011; Hochachka *et al.* 2012), was developed by highlighting common species with an asterisk to minimize error and user confusion. As suggested by Bonney *et al.* (2009), preliminary training was provided and included a user guide and a marine mammal identification sheet. Advice was also taken from Silvertown (2009) and Raddick *et al.* (2009), in which volunteers were calibrated as expert or novice users prior to participating. Users took a marine mammal identification test and those who scored 100% for identifying common Southeast Alaskan marine mammal species were categorized as experts, otherwise the user was classified as a novice unless prior knowledge of their expertise was known. In addition, greater participation in citizen science projects occurs when activities parallel regular user activities (Goffredo *et al.* 2010; Kellings *et al.* 2013). Therefore, volunteers collected data based on their preferred travel route rather than project-specified survey transects.

Only sightings data with a confidence rating of 4 or 5 were included in data analysis. The importance of this separation was measured by comparing home range geographic overlap for high confidence (4 or 5 rating) to low confidence (1, 2, or 3 rating) data for both expert and novice users. In addition, weather conditions were recorded for each sighting. Since visibility and weather is often a primary limiting factor for detecting marine mammals in Southeast Alaska (Dahlheim *et al.* 2015; Neilson *et al.* 2015), only sightings recorded in "unlimited visibility"

conditions were used for analysis. In addition, duplicate data or data noted as a “mistake” in the *notes section* were removed. Sightings that listed the number of individuals as *unknown* were not included, unless the number was identified in the *notes section* of the entry. All user datasets in which the user could not be identified as a novice or expert were removed. Most of the track lines (~75%) were not recorded due to a technological error in the app. As a result, vessel track line data were not included in this analysis. Only sightings north of latitude 54°, where a majority (91.6%) of the sightings were located, were analyzed.

Differences in expert and novice spatial bias were evaluated by comparing the home range size and overlap for all expert versus all novice sighting data. In addition, expert and novice Whale mAPP home ranges were compared to previously described marine mammal distributions in the region, and relative to major towns and travel routes. Differences in species bias were evaluated by comparing expert versus novice species-specific size and overlap of home ranges (see below). Sample size, detection probability, ecology, and habitat use of specific species were also considered when interpreting species bias.

3.2.4 Using home ranges to identify core-, intermediate- and broad-use areas for each species

Home ranges for each species were calculated to identify core- to broad-use areas. All analyses were conducted in R (R Core Team 2015). Given the irregular boundaries and abundance of islands in Southeast Alaska, a lattice-based density estimator (Barry and McIntyre 2011) was used to generate estimates of 25%, 50%, and 95% home ranges. Similar methods have been used when estimating marine species distributions in areas with complex shorelines and islands (Citta *et al.* 2014; Legare *et al.* 2015). The lattice-density method first distributes nodes evenly throughout the study region. Next, nodes are connected to adjacent nodes to form a spatial lattice. Location density is estimated using a random walk process, where the length of the random walk, k , and the probability that the random walk moves to the neighboring node, M , controls the smoothness of the density. The probability that the random walk stayed in the same location, M , was set in accordance with previous studies to be 0.5 (Barry and McIntyre 2011; Citta *et al.* 2014). The estimation of the optimal smoothing parameter, k , was determined using cross-validation in the package ‘latticeDensity’ (Barry and McIntyre 2011) for each species. We

used node spacing of 50 m, which was sufficient for delineating the coastlines while still allowing computer computation of the complex study area. Core-use areas were defined as the 25% home range (Citta *et al.* 2014). Intermediate core-use and broad-use areas were defined as the 50% and 95% home ranges respectively (Parsons *et al.* 2003; Heupel *et al.* 2004; Fujisaki *et al.* 2014). Similarity and contrast between novice and expert data sets were compared through assessment of the size and overlap of each home range using the following methods based on previous work by Eristhee and Oxenford (2003) and Legare *et al.* (2015).

- (1) The size of core, intermediate, and broad-use areas for novice and expert users was calculated and a paired t-test of 95%, 50%, and 25% home range sizes was calculated; statistical significance was accepted at $P < 0.05$.
- (2) Geographic overlap for core, intermediate, and broad-use areas for novice and expert users was examined using a paired t-test to compare the presence or absence of the defined home range at each geographic location; statistical significance was accepted at $P < 0.05$. In addition, to assess the impact of sample size, humpback whale data was randomly subsetted to mimic killer whale expert and novice sample sizes, after which the above analysis of geographic overlap was completed.
- (3) Geographic overlap for core, intermediate, and broad-use areas for high and low confidence sightings was examined using a paired t-test to compare the presence or absence of the defined home range at each geographic location for both expert and novice data; statistical significance was accepted at $P < 0.05$.

3.3 Results

Altogether, 16 expert users and 23 novice users collected a total of 1232 sightings, with variable sighting counts per species (Table 3.1). The total water study area used to estimate home ranges was 15,630 km², with each node located 0.05 km apart.

3.3.1 User bias

To examine user bias in the data collection phase, all volunteers were (1) categorized as either expert or novice users with a marine mammal identification test, and (2) required to rate their confidence level for every sighting. The division between expert and novice users, with the assumption that expert users had little to no error in identifying species, enabled the comparison between a dataset with presumably no species misidentified to another dataset more likely to have misidentified species. When examining low versus high confidence novice data, 95%, 50%, and 25% home range overlaps were significantly different (Paired t-test, $P = 0.002$, $P < 0.001$, $P < 0.001$ respectively). Similarly, when examining low versus high confidence expert data, 95%, 50%, and 25% home range overlaps were significantly different (Paired t-test, $P < 0.001$, $P < 0.001$, $P < 0.001$ respectively). This test was completed to interpret the difference between high and low confidence data, and justified the removal of low confidence data.

3.3.2 Geographic overlap comparison of home ranges

When all sightings data were grouped together, expert and novice 95%, 50%, and 25% home ranges overlapped, with no significant difference (Table 3.3; Figure 3.3). The evaluation of home range overlap and overall patterns of core-use area distributions was further examined by species. One similarity was seen amongst all species: expert and novice home ranges became increasingly similar with decreasing home range sizes from larger (95% home range) to core-use (25% home range) areas (Table 3.3; Figure 3.10).

Harbor and Dall's porpoises with clustered distribution had comparable sample sizes and number of core-use areas to each other. (Table 3.2; Figure 3.8-3.9). In addition, both species' 25% and 50% home ranges were not significantly different between expert and novice users (Table 3.3).

In comparison, the widely dispersed species, humpback whales and killer whales, had a medium number of core-use areas (Table 3.2; Figure 3.3-3.4). This group was harder to directly compare because humpback whales' sample size was over ten times that of killer whales. With a high sample size, humpback whale expert and novice 25%, 50%, and 95% home range estimates

were not significantly different (Table 3.3). Yet, when humpback whale data were randomly subsetting to mimic killer whale sample sizes, all home range estimates were significantly different between expert and novice users, which correspond with the killer whale results (Table 3.3).

Finally, discontinuously distributed species of Steller sea lions, harbor seals, and sea otters had the highest number of small core-use areas (Table 3.2; Figure 3.5-3.7) and more variable results when comparing the geographic overlap of home ranges between user groups. Only Steller sea lion and sea otter core-use areas (25% home range) were not significantly different between expert and novice users (Table 3.3).

Overall, similar patterns between the three defined ecological groups of discontinuously distributed species, widely dispersed species, and species with clustered distribution were seen (Figure 3.3-3.10).

3.3.3 Spatial bias and comparison of expert and novice home ranges to previous marine mammal distributions and town locations in Southeast Alaska

Home range sizes for expert and novice users were not significantly different for all data, suggesting similar patterns of spatial bias for both user groups (Table 3.2). Overall, both expert and novice datasets had good coverage near towns and along common travel routes such as Chatham Strait, Peril Strait, Fredrick Sound, and Stephens Passage (Figure 3.2). Reduced coverage was seen in more remote and/or restricted access areas, such as along offshore facing coastlines, Lynn Canal, Glacier Bay, and south by the Prince of Whales Island and Wrangell (Figure 3.2-3.9).

Previous studies have primarily taken place in Glacier Bay (Calambokidis *et al.* 1986; Womble *et al.* 2005; Mathews *et al.* 2006; Dahlheim *et al.* 2009; Esslinger and Bodkin 2009; Hobbs and Waite 2010; Dahlheim *et al.* 2015; Neilson *et al.* 2015), with moderate coverage in Lynn Canal (Chivers *et al.* 2002; Womble *et al.* 2005; Dahlheim *et al.* 2009; Hobbs and Waite 2010), and Icy Strait (Dahlheim *et al.* 2009; Hobbs and Waite 2010; Dahlheim *et al.* 2015; Neilson *et al.* 2015). Cetacean and variable pinniped and sea otter studies exist for Chatham Strait (Small *et al.* 2003; Womble *et al.* 2005; Dahlheim *et al.* 2009, 2015), Stephens Passage

((Womble *et al.* 2005; Dahlheim *et al.* 2009), and Fredrick Sound (Womble *et al.* 2005; Dahlheim *et al.* 2009; Dahlheim *et al.* 2015). Species-specific studies have taken place in the southern region of Southeast Alaska (Chivers *et al.* 2002; Dahlheim *et al.* 2009; Esslinger and Bodkin 2009; Hobbs and Waite 2010; Larson *et al.* 2013; Dahlheim *et al.* 2015) with sea otter (Esslinger and Bodkin 2009; Larson *et al.* 2013), Steller sea lion (Womble *et al.* 2005), and harbor porpoise (Hobbs and Waite 2010) ariel surveys covering coastlines exposed to offshore water.

Comparisons of expert and novice citizen science data to these previous studies showed similar distribution patterns for all species, except sea otters due to no past survey data, in Chatham Strait, Peril Strait, and in by the towns of Stika, Petersburg, Juneau, and the Warm Springs Bay recruitment center (Figure 3.1- 3.10). Results also showed good citizen science coverage in Fredrick Sound and Stephens Passage for all cetaceans and Steller sea lions. High coverage along these main passageways and towns indicates that survey bias is more concentrated in higher human-use areas. In comparison, poor spatial coverage for all citizen science data occurred in the less traveled southern section of Southeast Alaska (south of Fredrick Sound) for all cetacean species and sea otters. For example, high detection rates at haul-out sites is evident in areas of high citizen science survey effort, where ~ 84.6% of Steller sea lion haul out sites identified by Womble *et al.* (2005) were identified by both expert (identified 7 rookeries) and novice (identified 8 rookeries) users. In comparison, in areas of low citizen science survey effort, only ~ 30.8% of Steller sea lion haul out sites identified by Womble *et al.* (2005) were identified by both expert (identified 2 rookeries) and novice (identified 3 rookeries) users.

The greatest difference between expert and novice spatial coverage was seen in northern Southeast Alaska (Figure 3.2-3.9). For instance, novice data showed similar home range occurrences in Glacier Bay as other studies for humpback whales, sea otters, Steller sea lions, and harbor porpoises, and for Steller sea lions, harbor seals, and Dall's porpoises in the southern section of Lynn Canal. Expert users did not record the same sightings in these areas as novice users. Furthermore, the recognition of previously defined killer whale, humpback whale, and

harbor porpoise distributions in Icy Strait was better described by novice data than expert data. Thus, demonstrating that although these differences may not be statistically significant, visual comparison with documented distribution patterns shows that novice users had better survey coverage in the northern section of Southeast Alaska. Track-line data would enable a quantitative assessment of these spatial biases, and should be included in future studies.

3.4 Discussion

To adopt citizen science data collection methods for marine mammal research, appropriate data validation is necessary (Bruce *et al.* 2014) and the constraints of these data must be considered in context of introduced bias. Our study suggests that spatial and species biases were present regardless of user expertise, while species identification and detection bias likely differed between expert and novice users as noted by differences in geographic home range overlap. Species bias found to be similar within each ecological species group, but differed between the groups. When certain biases cannot be reduced with equal survey effort and/or adequate sample size, then analysis should be restricted to interpreting core-use areas or species with clustered distributions. This has been seen in previous scientific studies (Fitzpatrick *et al.* 2009; Kéry *et al.* 2010), but has not been as commonly addressed for citizen science research.

Species bias, resulting from variable sample sizes and ecological distribution patterns, plays a key role in the Whale mAPP dataset, and likely other citizen science datasets as well. For instance, larger and more abundant marine mammals, such as humpback whales, may have a higher detection probability by users, but require a larger sample size due to their widely dispersed distribution. Species with more concentrated distributions, such as hauled-out pinnipeds and sea otter rafts, increase the likelihood of expert and novice datasets spatially overlapping relative to widely dispersed humpback and killer whale data that have fewer and larger core-use areas. The likelihood of expert and novice datasets overlapping is even greater for species with very few, dense, and larger patchy distributions, such as those of clustered Dall's and harbor porpoises. Discontinuously distributed species have generally reduced expert and novice overlap differences compared to killer whales, but greater differences compared to clustered distribution species. Thereby, suggesting that species with clustered patterns require the

smallest sample size to accurately predict home range distributions, while a bigger sample size is required for discontinuously distributed species, and the largest sample size is required for widely dispersed species. When optimal sample size cannot be obtained, results from this study suggest limiting citizen science data interpretation to core-use areas, which showed greater similarity between expert and novice datasets. This pattern is evident because animals occur more consistently in core-use areas, and therefore more likely to be detected and noted by citizen science observers.

Perhaps some of the disparities seen between citizen science datasets and previous marine mammal studies, as well as the differences between expert and novice datasets themselves, are due to inadequate survey effort in northern, southern, and western exposed sections of Southeast Alaska. A positive survey bias was seen around towns and along the main seascape “highways” connecting those towns. Similar positive biases in sampling effort around larger cities or roads have been seen in other citizen science studies as well (Bart *et al.* 1995; Lawler and O’Conner 2004; Niemuth *et al.* 2007; Goffredo *et al.* 2010). Navigation limits, due to area closures to certain vessel types or depth and maneuverability restrictions, can alter spatial bias. Furthermore, sea conditions and user travel routes limit area coverage, as demonstrated by limited offshore and southern extent data.

Overall, species and spatial biases existed regardless of user expertise, and therefore should be considered for all future Whale mAPP data collectors. Future studies should focus on recruiting a variety of volunteers and including vessel track lines to better measure variability in survey effort, enabling the integration of spatial bias into home range estimates.

3.5 Conclusion

Our results highlight the importance of accounting for the interaction between sample size and a species’ ecological distribution patterns when evaluating bias in citizen science datasets. More common biases, including spatial and user bias, were also present in the Whale mAPP dataset. Thereby, verifying the importance of measuring for such biases, and grouping species distributions appropriately for data analyses of new citizen science dataset. When adequate sample size and survey coverage cannot be obtained, citizen science datasets can still

be useful to describe distribution patterns if results are restricted to higher use, core areas. This is especially true for non-migratory species that spend most of their time around these smaller, core-use areas (Eristhee and Oxenford 2001; Parsons *et al.* 2003). Expanding this theory to terrestrial species, as well as across various habitats and sample sizes will provide more information on how to properly estimate the sample size needed to account for species variance.

Overall, our study suggests the importance of measuring and considering spatial bias likely associated with all forms of citizen science data collection. Future citizen science analyses should continue to use only high confidence data, compare expert to novice datasets before using all sighting data for species distributions, and include knowledge of the study area and species ecology.

3.6 Appendix B

Table 3.1. Sample sizes, optimal smoothing parameter, and home range size comparison

Species sample sizes for expert and novice users, optimal smoothing parameter (k) applied, and p-values for a paired t-test comparing the size of core-use (25% home range), intermediate-use (50% home range), and broad-use (95% home range) areas between expert and novice data. Species are listed from greatest to smallest sample size.

	n (Expert, reduced)	n (Novice, reduced)	k	P-value
All Species	671	561	0.05 km ²	0.120
Humpback Whale	251	167	0.05 km ²	0.971
Sea Otter	61	43	0.15 km ²	0.155
Harbor Seal	58	44	0.5 km ²	0.270
Steller Sea Lion	51	22	0.1 km ²	0.264
Killer Whale	21	26	0.5 km ²	0.157
Dall's Porpoise	11	15	0.5 km ²	0.599
Harbor Porpoise	7	17	0.5 km ²	0.336

Table 3.2. Size of home ranges and number of core-use area

The size (km^2) of core-use (25% home range), intermediate-use (50% home range), and broad-use (95% home range) areas for expert (E) and novice (N) users, and for each species, listed from greatest to smallest sample size.

	E	N	E	N	E	N	E	N
	Broad (km^2)		Intermediate (km^2)		Core (km^2)		Number of core-use areas	
All Species	9.9	9.8	2.3	2.1	0.8	0.7	--	--
Humpback Whale	6.7	7.0	1.6	1.3	0.5	0.4	10	11
Sea Otter	6.6	5.4	1.6	1.1	0.6	0.4	17	9
Harbor Seal	6.9	4.4	1.6	0.7	0.5	0.2	14	4
Steller Sea Lion	5.3	2.8	1.1	0.6	0.4	0.2	12	7
Killer Whale	8.5	6.1	2.4	1.4	0.9	0.4	6	5
Dall's Porpoise	5.2	6.2	1.5	1.4	0.6	0.5	5	5
Harbor Porpoise	4.5	7.5	1.0	1.5	0.3	0.4	2	5

Table 3.3. Home range geographic overlap assessment

Compared home range geographic overlap between expert and novice data using a paired t-test comparing the presence (1) or absence (0) of the species at each geographic location. The sample size (n) is also reported for expert (E) and novice (N) data.

	n	Home range		
			P-value	
		Broad	Intermediate	Core
All species	E-671, N-561	0.765	0.518	0.862
Humpback Whale	E-251, N-167	0.290	0.163	0.414
Sea Otter	E-61, N-43	0.002	0.023	0.117
Harbor Seal	E-58, N-44	< 0.001	< 0.001	0.003
Steller Sea Lion	E-51, N-22	< 0.001	0.009	0.144
Killer Whale	E-21, N-26	< 0.001	< 0.001	0.011
Dall's Porpoise	E-11, N-15	0.011	0.651	0.223
Harbor Porpoise	E-7, N-17	< 0.001	0.051	0.336

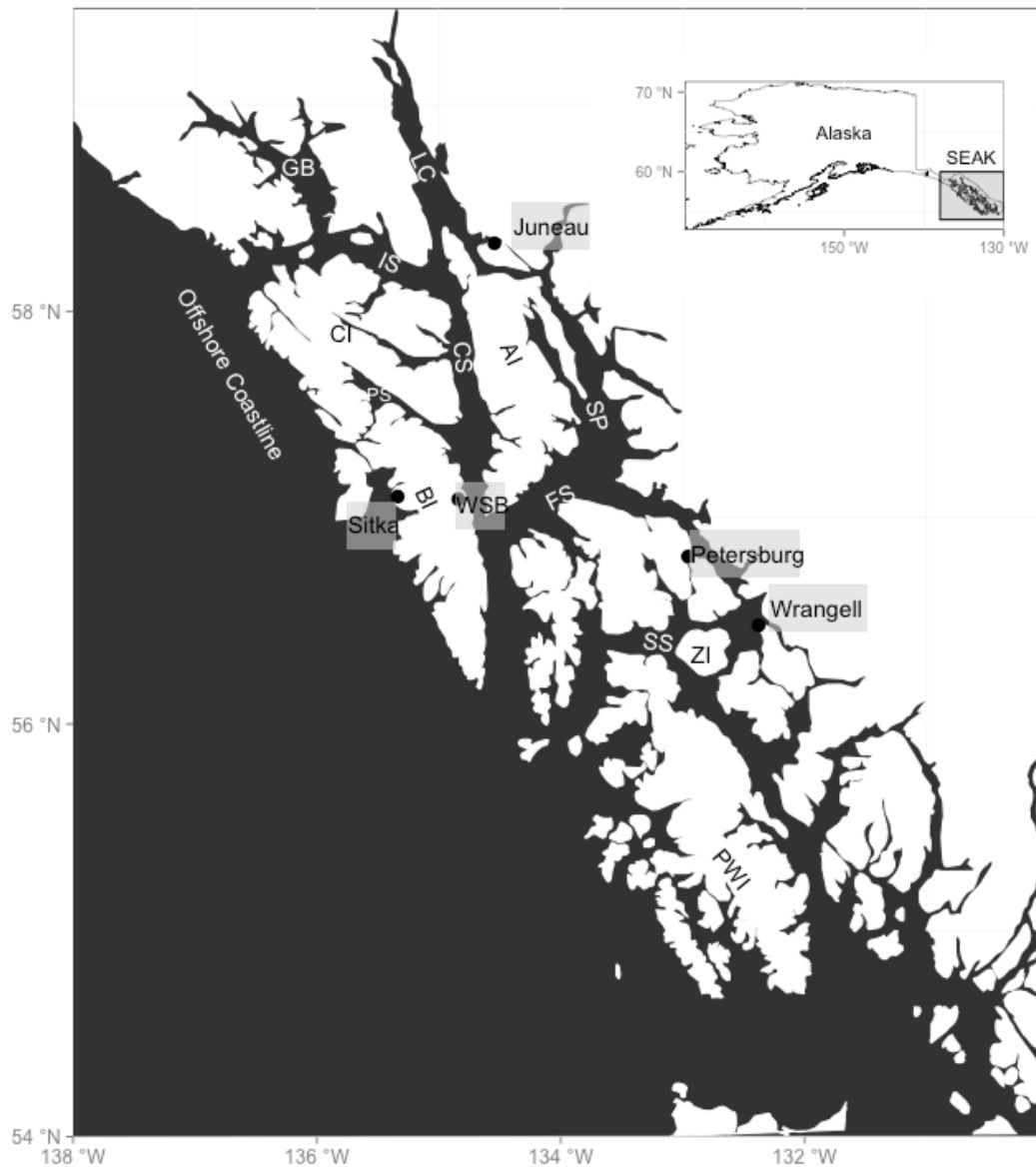


Figure 3.1. Study area

The study area of Southeast Alaska, highlighting larger towns of Sitka, Juneau, Petersburg, and Wrangell, the recruitment center at Warm Springs Bay (WSB), major bodies of water including Chatham Strait (CS), Fredrick Sound (FS), Stephens Passage (SP), Peril Strait (PS), offshore facing coastline, Icy Strait (IS), Glacier Bay (GB), Lynn Canal (LC), Sumner Strait (SS), and islands discussed in this paper including Chichigof Island (CI), Baranof Island (BI), Admiralty Island (AI), the Prince of Wales Island (PWI), and Zarembo Island (ZI).

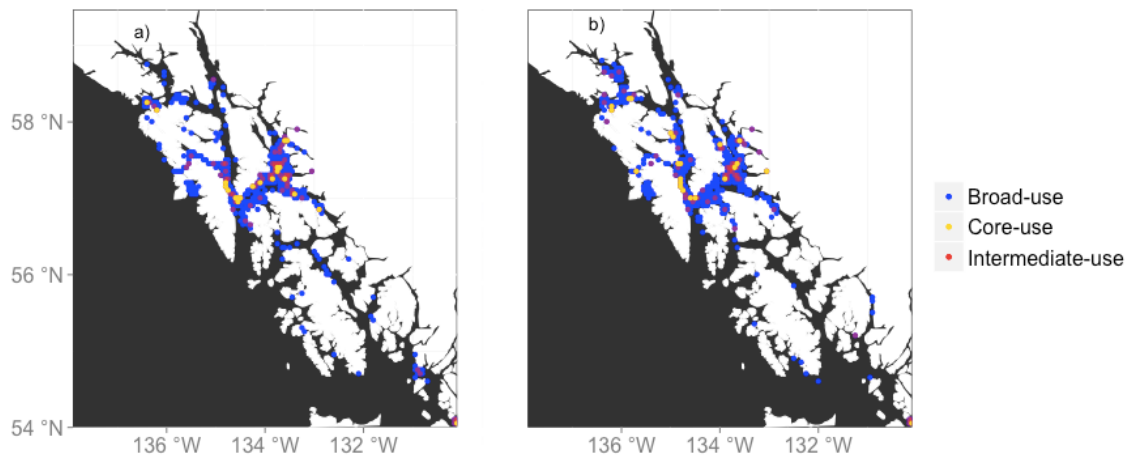


Figure 3.2. Home ranges for all sighting data

Core-use (25% home range, yellow), intermediate-use (50% home range, red), and broad-use (95% home range, blue) areas for expert a) and novice b) users for all sighting data. A total of 1232 ($n = 671$ expert users; $n = 561$ novice users) sighting points were recorded from June 20th to September 30th 2014.

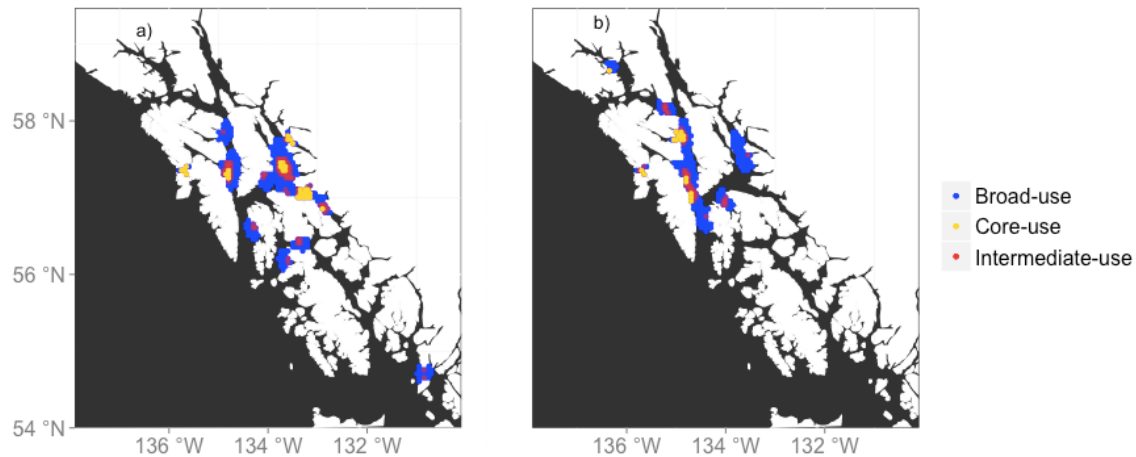


Figure 3.3. Home ranges for humpback whales

Humpback whale core-use (25% home range, yellow), intermediate-use (50% home range, red), and broad-use (95% home range, blue) areas for expert a) and novice users b). A total of 418 ($n = 261$ expert users; $n = 167$ novice users) sighting points were recorded from June 20th to September 30th 2014.

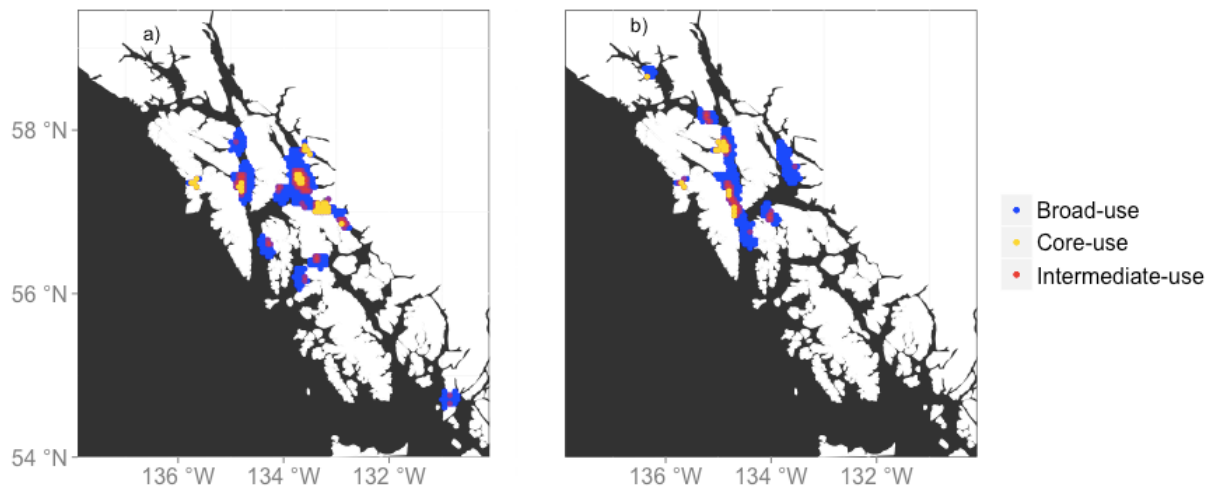


Figure 3.4. Home ranges for killer whales

Killer whale core-use (25% home range, yellow), intermediate-use (50% home range, red), and broad-use (95% home range, blue) areas for expert a) and novice users b). A total of 47 ($n = 21$ expert users; $n = 26$ novice users) sighting points were recorded from June 20th to September 30th 2014.

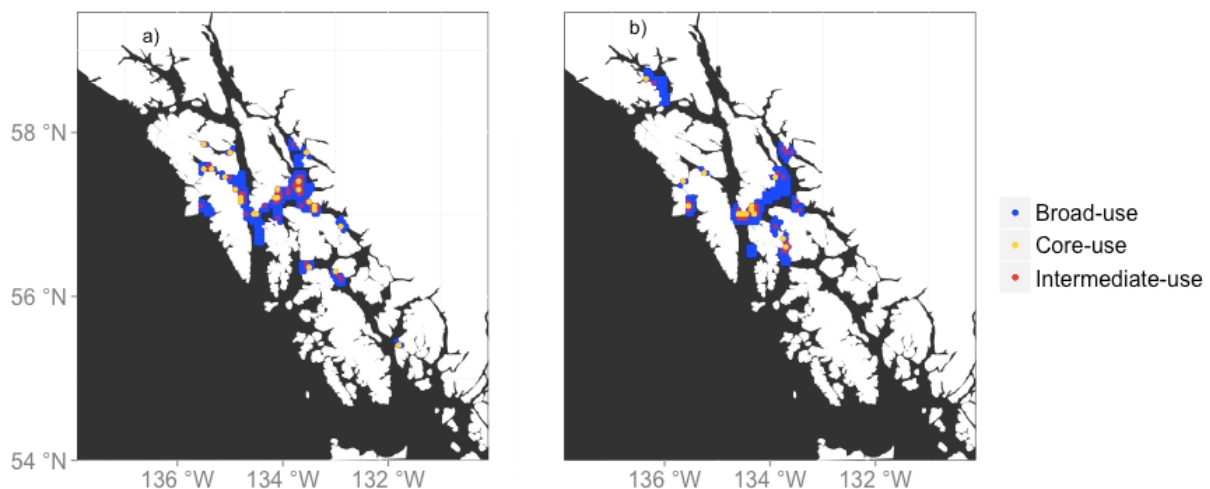


Figure 3.5. Home ranges for sea otters

Sea otter core-use (25% home range, yellow), intermediate-use (50% home range, red), and broad-use (95% home range, blue) areas for expert a) and novice users b). A total of 104 ($n = 61$ expert users; $n = 43$ novice users) sighting points were recorded from June 20th to September 30th 2014.

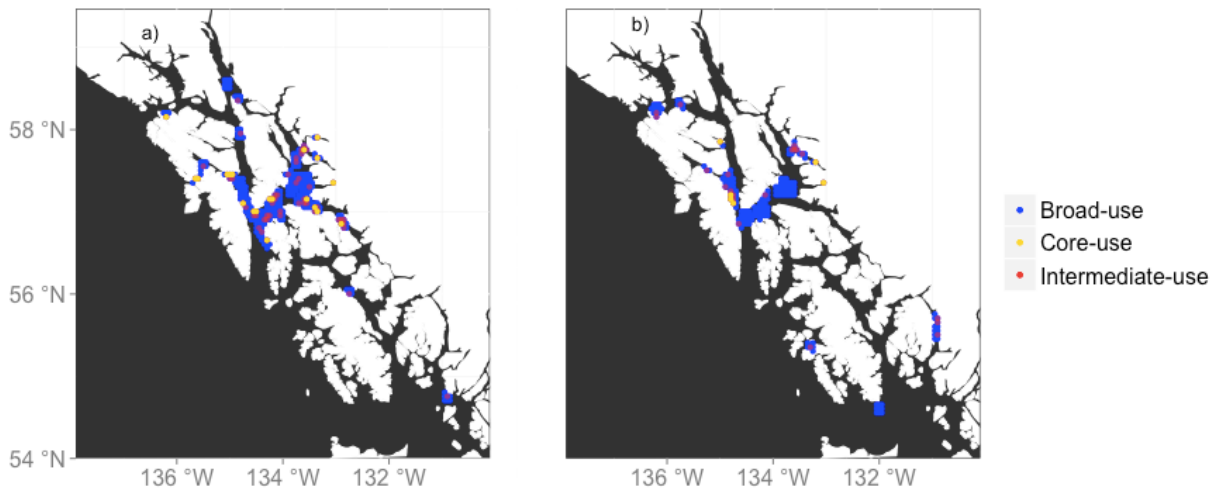


Figure 3.6. Home ranges for harbor seals

Harbor seal core-use (25% home range, yellow), intermediate-use (50% home range, red), and broad-use (95% home range, blue) areas for expert a) and novice users b). A total of 102 ($n = 58$ expert users; $n = 44$ novice users) sighting points were recorded from June 20th to September 30th 2014.

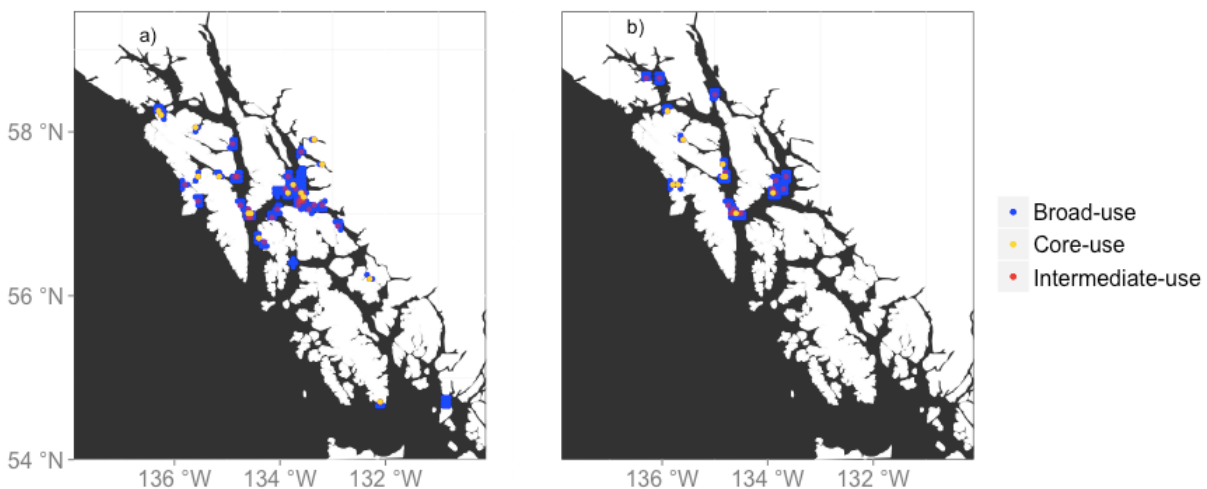


Figure 3.7. Home ranges for Steller sea lions

Steller sea lion core-use (25% home range, yellow), intermediate-use (50% home range, red), and broad-use (95% home range, blue) areas for expert a) and novice users b). A total of 73 ($n = 51$ expert users; $n = 22$ novice users) sighting points were recorded from June 20th to September 30th 2014.

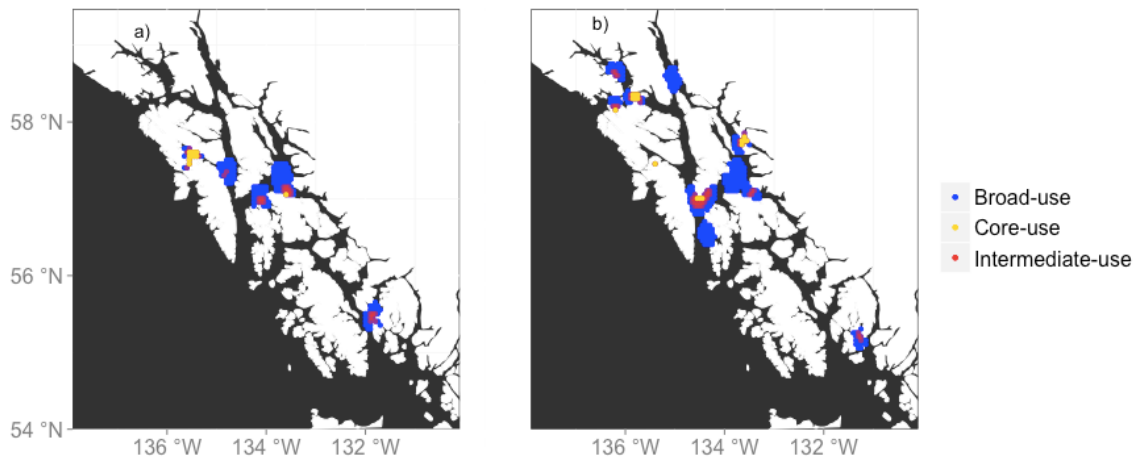


Figure 3.8. Home ranges for harbor porpoises

Harbor porpoise core-use (25% home range, yellow), intermediate-use (50% home range, red), and broad-use (95% home range, blue) areas for expert a) and novice users b). A total of 24 ($n = 7$ expert users; $n = 17$ novice users) sighting points were recorded from June 20th to September 30th 2014.

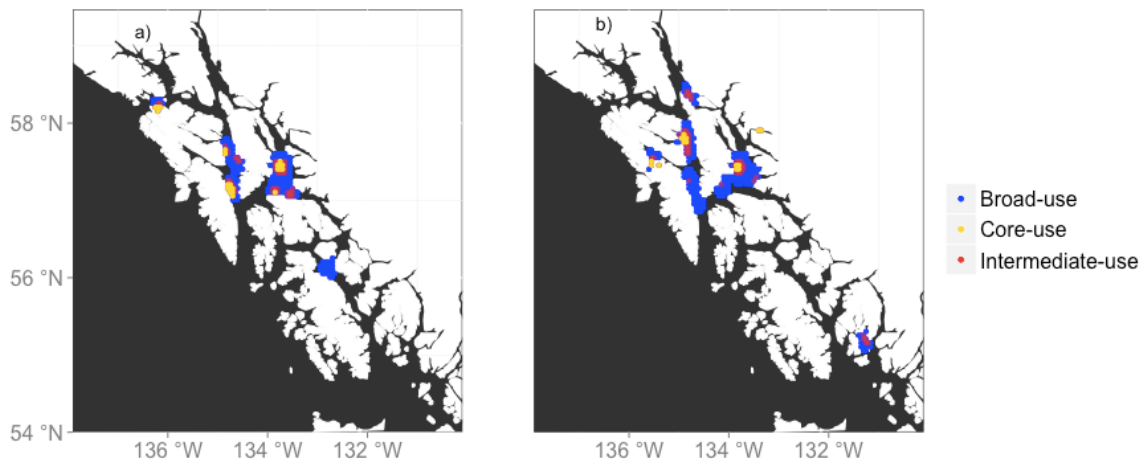


Figure 3.9. Home ranges for Dall's porpoises

Dall's porpoise core-use (25% home range, yellow), intermediate-use (50% home range, red), and broad-use (95% home range, blue) areas for expert a) and novice users b). A total of 25 ($n = 11$ expert users; $n = 15$ novice users) sighting points were recorded from June 20th to September 30th 2014.

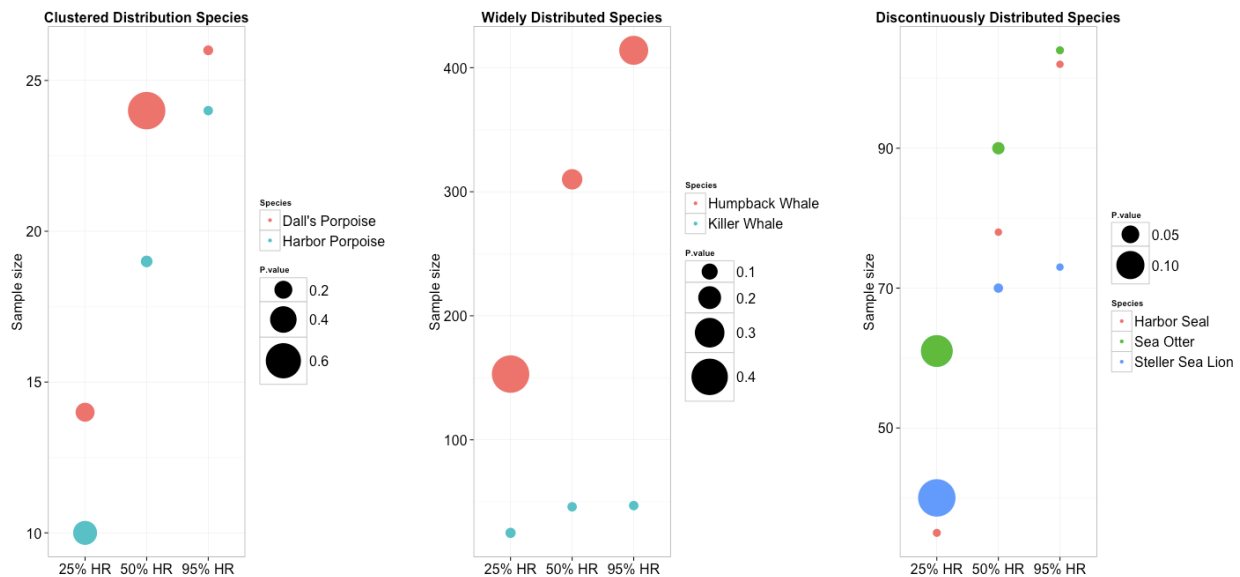


Figure 3.10. Differences in expert and novice datasets based on sample size and home range

Visualization of sample size versus 25%, 50%, and 95% home ranges (HR) for discontinuously distributed species (harbor seal, sea otter, Steller sea lion), widely dispersed species (humpback whale, killer whale) and clustered distribution species (Dall's porpoise, harbor porpoise). The size of the dot indicates the p-value, which varies for each plot, but shows an overall trend of a smaller p-value, or dot size, with an expanding home range. For each plot, color indicates the species.

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4 CHAPTER 4: CONNECTING BACK TO THE USERS: CITIZEN SCIENTISTS'
PERSPECTIVES ON A MARINE MAMMAL CITIZEN SCIENCE APP

Journal to be submitted to *Citizen Science: Theory and Practice*

Abstract

Citizen science research represents a growing field, one especially popular for studies interested in collecting large regional and temporal scale species distribution data. One citizen science project, Whale mAPP, invites volunteers to help record opportunistic marine mammal sighting data with a mobile application. The outcomes of adding education and site-specific components to the mobile application, along with user motivations and experience, were evaluated with two surveys administered during the summer field season in Southeast Alaska. Differences in expert and novice volunteer responses were also evaluated. Results suggest that both user groups were motivated based on a pre-existing interest in marine mammals and/or the ocean, and in general were impelled to keep using Whale mAPP. Novice users had slightly more technological problems, and would have preferred less data entry. In comparison, expert users had few problems, and wanted the data collection to expand to include behavioral descriptions. While using Whale mAPP, both user groups actively sought outside knowledge to learn more about marine mammals, and enjoyed the added educational components of Whale mAPP. In addition, novice users significantly improved their marine mammal identification skills, while neither group developed further content knowledge on marine mammal conservation topics. Overall, the added educational components were successful at teaching novice users preliminary skills of species identification and inspiring volunteers to seek outside knowledge. Further educational development, including expanded content knowledge and changes in attitudes towards the environment, would require additional learning and engagement components to be built into the citizen science program.

4.1 Introduction

Citizen science research represents an upcoming field in which volunteers, called citizen scientists, help researchers collect, process, and/or analyze scientific data (Hames *et al.* 2002; Cooper *et al.* 2006). This field has become increasingly popular as a low cost method for gathering abundance and distribution data in a short time frame, and over a large geographic area (Goffredo *et al.* 2010; Raddick *et al.* 2010). In addition, citizen science projects can educate the public in an informal learning environment (Goffredo *et al.* 2010), facilitating increased content

knowledge and an opportunity for changes in attitude towards science and the environment (Conrad and Hilchey 2011; Crall *et al.* 2012; Raddick *et al.* 2010b).

The expansion of citizen science projects over the past decade (Silvertown 2009; Conrad and Hilchey 2011; Thiel *et al.* 2014) and technological advances have facilitated new citizen science projects that collect data with mobile applications (Maisonneuve *et al.* 2009; Newman *et al.* 2012; Herodotou *et al.* 2014). Mobile applications provide a standardized platform and greater flexibility than paper or group-led citizen science projects when collecting data from episodic volunteers (Martin 2013). Evaluating such projects as they develop is crucial to understanding how to accomplish various research and education goals. Raddick *et al.* (2009) notes that one of the keys to a successful citizen science project involves studying who participates, what motivates them, and what they are learning through the process.

4.1.1 Application toward marine mammal research

Traditional marine mammal research is highly resource and time intensive, often leading to small sample sizes, spatial scales, and temporal ranges (Witteveen *et al.* 2008; Rosa *et al.* 2012). Data required for analyzing long-term patterns of distribution, seasonal occurrence, and regional scale trends are costly and logistically challenging (Calambokidis *et al.* 2008; Dahlheim *et al.* 2009). Citizen science may provide a low-cost alternative method for gathering marine mammal abundance and distribution data in a short time frame and over a large geographic area, something that has proved to be true for numerous species (Goffredo *et al.* 2010; Raddick *et al.* 2010a).

Location-based, real-time mapping services available on smartphones provide an easy to use and accessible method for collecting GPS-based citizen science data (Maisonneuve *et al.*, 2009; Newman *et al.*, 2012). One such application, Whale mAPP, utilizes this technology to allow volunteers to record marine mammal sightings and behavior, environmental conditions, and track vessel paths that transmit to a geodatabase. This information is then available to the user online via an interactive map on the Whale mAPP website (www.whalemapp.org).

In this study, a beta version of Whale mAPP that was programmed to provide users with educational material through the presentation of marine mammal specific information was

distributed to volunteers in the summer of 2014 in Southeast Alaska. Surveys were used to evaluate Whale mAPP user motivations, and potential educational outcomes. Results from these surveys, along with user feedback regarding their experience with Whale mAPP and their suggestions as to how the application can be improved, are presented in this case study.

The primary questions addressed were:

1. What were the demographics and motivations for the Southeast Alaskan Whale mAPP users? Do they vary between expert and novice users?
2. Were the following informal science learning goals enhanced with this citizen science project: 1) participants' developing interest in science; 2) participants' understanding of science knowledge and, 3) participants' engagement in scientific practices (Bell *et al.*, 2009)? Did expert and novice users differ in their degree of accomplishing these three informal science goals?

4.2 Methods

From June 20th to September 30th 2014, volunteers were recruited to participate in a citizen science project focused on recording marine mammal sighting data with a beta version of Whale mAPP (Appendix E). Only species found in Southeast Alaska were included in the beta version of Whale mAPP, and common species were highlighted with an asterisk (i.e. humpback whale, killer whale, harbor seal, Steller sea lion, and sea otter). Users were required to rate their confidence in the accuracy of the data they entered.

Educational information was incorporated in Whale mAPP and presented to users as *fun facts*, which were short facts about a marine mammal that displayed after an animal sighting was recorded (Appendix F). Additionally, volunteers were provided with a single-page marine mammal identification guide to assist them in identifying marine mammals in the field and provide information on current conservation topics.

4.2.1 Recruitment and training of participants

Volunteers were recruited primarily through active advertisement at a remote research facility (the Coastal Research and Education Center; CREC) in Warm Springs Bay, Southeast Alaska, and by targeting known ecotourism operators in the area. Participants included guests and crew aboard commercial recreational charters, private vessel operators, and commercial fishermen. Volunteers were recruited to collect data throughout Southeast Alaska, a region of high marine mammal diversity and abundance (Dahlheim *et al.* 2009; Allen and Angliss, 2013).

The majority of volunteers were provided with in-person training, which involved a 15 – 30 minute tutorial on how to use the mobile application, scientific technique and rationale for the approach, and data collection methods. These methods were designed to standardize data collection among users and provide a brief background on the scientific outcome of collecting data with Whale mAPP. Similar training techniques have been used in other citizen science projects (Boney *et al.* 2009). In a few instances where training was not possible, volunteers were provided with a training manual as a substitute (Appendix G). All users were also provided with the marine mammal identification guide to assist in identifying marine mammals (Figure 4.1).

4.2.2 Surveys

Volunteers were asked to participate in two surveys to evaluate user motivations, assess educational benefits, and gain feedback for Whale mAPP. Permission to collect data on volunteers over the age of 18 was granted by the Oregon State University 5234 Institutional Review Board, study number 6273 (Appendix E).

Survey 1 was distributed prior to using Whale mAPP and included a marine mammal identification test and questions about marine mammal threats and conservation (Appendix H). Survey 1 was primarily distributed in-person at CREC, but also via email. The identification test required users to match images to correct species common names, and subsequently ranked the user as an expert or novice based on their score (experts correctly identified more than 80% of the species, while novice users did not). When survey 1 was not taken prior to using Whale

mAPP, user ranking was assumed to be novice unless prior knowledge of their expertise was known.

Survey 2 was distributed two to four weeks after using Whale mAPP, to assess three science-learning goals for this project (see below), user motivation for participating in the study, and feedback on the functionality of Whale mAPP (Appendix I). Survey 2 was predominately distributed via email, although several users returned to the CREC and completed a hard copy. Expert versus novice user motivations and educational outcomes were compared in for both surveys, and used to provide suggestions to improve the citizen science project.

Three informal learning goals presented by Bell *et al.* (2009) were applicable to this study. The three informal learning goals investigated for this project included 1) participants' developing interest in science; 2) participants' understanding of science knowledge and, 3) participants' engagement in scientific practices (Bell *et al.* 2009). The first goal, interpreting participants' developing interest in science, was assessed by identifying user interests (Q8 – 9, Appendix I) and any actions they took to learn more about marine mammals (Q11, Appendix I). The second goal, evaluating participants' understanding of science knowledge, focused on interpreting the user's growth in marine mammal content knowledge. To assess content knowledge, participants responded to questions regarding marine mammal identification and knowledge (Q5 – 7, Appendix I). Responses from the post-use survey were compared to those of the preliminary survey to identify improvement in content knowledge. The third goal, determining participants' engagement in scientific practices, was assessed through participant's ability to identify patterns in where or why they saw marine mammals when they did (Q12, Q13, Appendix I). These questions were used to identify educational benefits of this citizen science project.

To evaluate user motivation, participants responded to questions on why they chose to participate in the project and if they will continue to use Whale mAPP (Q8 – 10, Appendix I). User attention and variability was determined by recording the time spent scanning the water and looking for marine mammals compared to focusing on other activities (Q15, Appendix I). The usefulness of the marine mammal identification guide (Q16, Appendix I) and opinion of

collecting data with Whale mAPP (Q17, Appendix I) was used to rank the importance of each component of Whale mAPP. Furthermore, volunteer enjoyment of using Whale mAPP (Q19, Appendix I) and ranking of potential Whale mAPP revisions (Q18, Appendix I) were used to provide feedback for improving the educational components of Whale mAPP and user experience.

4.2.3 Evaluation

Both surveys were designed in Qualtrics and data was stored in Excel. All statistical analyses were performed using the program R (R Core Team 2015). Since the data were not normally distributed, a Wilcoxon rank sum test was used to calculate differences between expert and novice responses, and directly compare responses to specific questions. A paired Wilcoxon rank sum test was used to measure a significant change between Survey 1 and Survey 2 responses.

4.3 **Results**

From June 20th to September 30th 2014, 39 participants recorded 1256 marine mammal sightings (Figure 4.5) from the northern portion of Southeast Alaska (58.82°N, 136.40°W) to Seattle, Washington (43.22°N, 23.34°W). A total of 664 humpback whale, 145 sea otter, 142 harbor seal, 116 Steller sea lion, 75 killer whale, 49 harbor porpoise, 42 Dall's porpoise, 12 Pacific white-sided dolphin, 5 California sea lion, 2 minke whale, 2 elephant seal, 1 fin whale, and 1 gray whale sightings were recorded. An abundance of humpback whale sightings resulted in a majority (~52.9%) of marine mammal *fun facts* presented to the user related to humpback whales.

4.3.1 Participant Demographics

Participants were categorized as either expert/control users or novice users based on their marine mammal identification test score from Survey 1 (Table 4.1). This division was made to compare expert and novice users; a common method used in other citizen science projects as well (Paul *et al.* 2014; Jackson *et al.* 2015; Hann 2015, Chapter 3). Eight of the novice users

were placed in the novice group because they did not take the marine mammal identification test prior to recording data, and prior knowledge of their marine mammal expertise was unknown. Further data division beyond expert and novice based on user and vessel characteristics was not useful because of the small resulting sample sizes (Table 4.1). Expert and novice users had a high survey response rate, ~68.7% and ~56.5% respectively. User effort also varied between individuals as two individuals collected ~ 52% of the total sighting data (Table 4.1).

At the end of this study in September 2014, most volunteers were either still using Whale mAPP (~25% of expert, ~21% novice users) or stopped because they left Alaska (~75% of expert users, ~36% of novice users). Some novice users stopped using the app because they encountered technology problems (~14%), thought it required too much time (~21%), and/or for another reason (~7%) (Table 4.2). Responses did not differ significantly between expert and novice users.

4.3.1.1 User dedication and attention toward collecting marine mammal data

Participants spent the majority of their time scanning the water for marine mammals while using the app (~77% expert users, ~62% novice users); however, they also reported driving a vessel (~49% expert users, ~52% novice users) and talking (~36% expert users, ~27% novice users) (Table 4.3). For both user groups, these activities overlapped while using Whale mAPP, indicating that users were multitasking while collecting marine mammal sighting data.

4.3.2 Assessing informal learning educational goals from Bell et al. (2009)

4.3.2.1 Participants' motivation and developing interest in science

Approximately 73% of expert users and ~46% of novice users were motivated to use Whale mAPP due to their interest in marine mammals, collecting data, and/or science (Table 4.4). For both expert and novice users, ~27% participated in the project to improve their organization's association with citizen science projects (Table 4.4). There were no significant variations between expert and novice responses.

Pre-existing interests also likely influence user motivations and their learning development. Strong pre-existing interests in marine mammals, the ocean, using Whale mAPP, and collecting marine mammal data for both user groups was reported in survey results (Table 4.5). Participants' growing interest in marine mammals was also interpreted through their self-initiated actions they took to learn more about marine mammals. For both expert and novice users, the top three learning activities included reading a book (~25% expert users, ~72.7% novice users), talking to a peer (~41.7% expert users, ~72.7% novice users), and talking to a scientist (~16.7% expert users, ~54.5% novice users) (Table 4.6). There was no significant difference between expert and novice responses.

4.3.2.2 Participants' change in marine mammal knowledge

The second goal, evaluating participants' understanding of science knowledge, was focused on improved marine mammal knowledge. Novice users' marine mammal identification skills significantly improved after using Whale mAPP (paired Wilcoxon rank sum test, p-value = 0.039). Expert users showed no significant change likely due to their already high test score. The number of marine mammal conservation topics users noted as being knowledgeable pre- and post- Whale mAPP use was not statistically different for either user group.

4.3.2.3 Participants' engagement in scientific practices

The third goal, determining participants' engagement in scientific practices, was assessed through participants' noting of reoccurring patterns associated with when and where they saw marine mammals. Most participants noted changes in marine mammal distribution patterns based on their location in Southeast Alaska (Table 4.6). Significantly more novice users than expert users attributed change in marine mammal distributions to weather (Wilcoxon rank sum test, p-value = 0.02). While many participants attributed their sightings to various environmental factors, a mean of ~82% of expert and ~83% of novice participants identified no change in the abundance of marine mammals spotted after starting to use Whale mAPP.

4.3.3 User experience and suggested revision to Whale mAPP

The enjoyment of key components of Whale mAPP was ranked to provide more information on the user's engagement and experience in the project. Overall, both expert and novice users enjoyed using Whale mAPP, will continue to use the app, and would recommend it to a friend (Table 4.7). They also enjoyed the added educational components of the marine mammal *fun facts* and identification guide (Table 4.7). While users found Whale mAPP easy to use, both groups did not actively go out on the water to use the app and novice users, in comparison to expert users, significantly believed the app required too much data entry (Wilcoxon rank sum test, p-value = 0.006; Table 4.7). In addition, expert users had significantly stronger positive views in recommending Whale mAPP to a friend than did novice users (Wilcoxon rank sum test, p-value = 0.0019). Further examination of the opinions of the educational marine mammal guide revealed that expert and novice users found all components helpful, and ranked information on the size of the animal and behavior, as well as fluke, blow, and full body drawings as the most beneficial (Table 4.8).

4.4 Discussion

The growth of citizen science projects over the past three decades, and anticipated increasing trend of its application, elicits the need to evaluate their effectiveness in meeting educational goals (Thiel *et al.* 2014). Results of this study suggest an overall positive user experience with Whale mAPP, the added *fun facts*, and the marine mammal identification guide. While user enjoyment is important, citizen science studies should also consider learning outcomes as most learning occurs outside the classroom, in informal learning environments such as citizen science programs (Groffman *et al.* 2010). While both expert and novice users actively sought out more information on marine mammals, a more engaging, in-depth, or unique approach is required for them to learn a measurable amount about conservation topics.

The most evident difference in expert and novice user experiences was the desire for a more simplified data entry and technology system by novice volunteers. The need to simplify

recording the direction to a marine mammal sighting, improve the descriptions of animal behaviors, and perhaps eliminate taking a photo of the animal was evident, as one user noted:

“Generally fun to use and careful searching added to interest during cruising...Hard to know exactly when to record distance and direction of an observation as the relative direction and distance changed constantly as the boat (and animal) moved.”

User fatigue was also reported by both expert and novice users. As one novice user noted:

“I was generally afraid that I would miss a sighting while taking so much time to enter information about the last one...[In addition,] I had technological problems with my personal device, which would shut it off before I could finish entering data. Because of that and also because I didn't want to miss a sighting and give inaccurate "empty space" data during trips, I would usually only start a trip when I first made a sighting, not when I first started looking...”

Reducing user fatigue and simplifying Whale mAPP could be accomplished by removing the requirement to enter distance and direction data, the presence of calves, a photo, and behavioral data. These revisions are currently being programmed into a revised Whale mAPP mobile application that has two versions, a detailed expert app and a simplified novice app. Both revisions will be released in January 2016 and available online (www.whalemapp.org). Future funding should focus on developing an iOS version, as many interested citizens could not participate because they owned an iPhone, not an Android.

While the app may need to be modified for expert and novice users, recruitment efforts should remain consistent for both novice and expert users due to equivalent preexisting interests and/or knowledge on marine mammals. Similar trends in user motivations have been seen in previous citizen science studies (Koss *et al.* 2009; Nov *et al.* 2011; Crall *et al.* 2012, Raddick *et al.* 2010b). Future Whale mAPP recruitment efforts could focus on advertising to groups who likely have similar interests in marine mammals and the ocean, such as environmental/conservation groups, aquariums, and marine-specific outreach centers.

Although educational components added to Whale mAPP, including marine mammal *fun facts* and an identification guide, likely improved the users' understanding and interest in marine mammals, they did not change pre-existing knowledge of marine mammal conservation topics.

This could have been due to the users' overall high pre-existing interest and perhaps knowledge on marine mammals and the ocean, disinterest in the topic, and/or lack of fully reading and remembering the conservation topics addressed in the marine mammal guide and *fun facts*. The marine mammal guide and experience identifying marine mammals with Whale mAPP were probably the primary reasons why novice users improved their content knowledge of marine mammal identification skills, a common educational benefit of citizen science projects (Crall *et al.* 2013). A more challenging, and often long-term, educational benefit is inspiring volunteers to engage in further learning outside of the citizen science project (Conrad and Hilchey 2011), a task that few citizen science projects have reportedly accomplished (Crall *et al.* 2012). The first steps to this are seen in our volunteers who took action to learn more about marine mammals outside of participating in the project.

Furthermore, expert and novice users' associated marine mammal distributions in Southeast Alaska with prey location and time of day. These associations of marine mammal location with spatial and temporal changes represents one of the most fundamental associations made in spatial ecology (Goffredo *et al.* 2010; Crall *et al.* 2012; Hochachka *et al.* 2012; Kelling *et al.* 2013). Even if this association was more intuitive than intellectual, users still acknowledged the importance of recognizing variable species detectability when interpreting animal distribution patterns (Fitzpatrick *et al.* 2009; Kéry *et al.* 2010). Whale mAPP could build upon this skill by developing interactive maps available on the website and on the app by pointing out how to identify various marine mammal spatial patterns.

Overall, results suggest that Whale mAPP is providing simple content learning in the form of species identification for novice users and species distribution pattern recognition for both user groups. Additionally, users are actively pursuing more knowledge outside of the program. There is still a need for alternative techniques other than the marine mammal identification guide and *fun facts* for teaching volunteers about marine mammals. Even the most abundant species recorded, humpback whales that had the greatest number of *fun facts* read by volunteers, did not elicit change in user expertise on humpback whales. Future educational techniques could include providing more detailed behavioral and species descriptions on their

range, ecology, and threats imbedded within the application itself. Making these educational components more interactive, such as including some type of learning game, may also be a good solution. Future strategies should focus on connecting Whale mAPP users around the world, as online forums and chat groups have been very successful for other citizen science projects (Khatib *et al.* 2011).

4.5 Conclusion

As a developing citizen science program, Whale mAPP demonstrates preliminary educational benefits with the potential to improve the mobile application based on user feedback. As one ecotourism captain wrote:

“I loved being able to use the app, and our passengers loved that I was sending information to you. It gives us and our guests a better sense of purpose and that the things we see might help you collect data”

Improving the technology used to interact with participants is key to growing the data-collecting community (Sullivan *et al.* 2014). Furthermore, having a mobile application associated with Whale mAPP is advantageous as informal learning systems, including museums and science centers, are increasingly using technology to leverage their traditional techniques and engage more of their visitors (DiPaola and Akai 2006). Continuing on this route will likely lead Whale mAPP in a progressive direction.

In this study, we found that using Whale mAPP resulted in specific content learning gains, a developing interest in science, and engagement in scientific practices. It is important to note that these educational benefits only applied to specific topics addressed in the surveys, and a more complete study involving participant interviews would provide additional insight into some of our findings, but collection of these data was beyond the scope of this study.

4.6 Acknowledgement

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4.7 Appendix C

Table 4.1. Demographic data from the two surveys

The table displays the number of expert, novice, and total participants in each of the three user groups. The number of individuals and percent of user group who recorded data for both expert and novice users is displayed in columns five and six.

	Expert	Novice	Total	Expert – recorded data	Novice – recorded data
Private vessel owner	6	12	18	5 users recorded 83.3% of data	7 users recorded 58.3% of data
Commercial recreation	9	9	18	6 users recorded 66.7% of data	8 users recorded 88.9% of data
Commercial fisheries	1	2	3	1 user recorded 100% of data	0 users

Table 4.2. User status on Whale mAPP use

Mean percent of expert and novice users with various Whale mAPP use statuses as of September 30th 2014, at the end of the data collection period, and the p-value based on the Wilcoxon rank sum test of the differences in expert versus novice responses.

Status on Whale mAPP use	Expert N=11	Novice N=12	p-value
Still using	25.0%	21.4%	1
Stopped; left Alaska	75.0%	35.7%	0.091
Stopped; the app required too much time	0%	21.4%	0.077
Stopped; technology issue	0%	14.3%	0.186
Stopped; boring	0%	0%	-
Stopped; not engaging	0%	0%	-
Stopped; other reason	0%	7.2%	0.363

Table 4.3. Activities users participated in while using Whale mAPP

The mean percent of time expert and novice users devoted to each activity, and the p-value based on the Wilcoxon rank sum test of the differences in expert versus novice responses.

Activity:	Expert N=11	Novice N=12	p-value
Scanning the water looking for marine mammals	76.6%	61.5%	0.063
Driving the vessel	49.3%	51.9%	0.951
Talking	36.3%	27%	0.337
Fishing	16.3%	12.7%	0.506
Inside the cabin	8.3%	29.1%	0.017
Reading	3.1%	6.9%	0.289

Table 4.4. Whale mAPP user motivation

The mean percentage of expert and novice users who were interested in the various topics, and the p-value based on the Wilcoxon rank sum test of the differences in expert versus novice responses.

Motivation due to an interest in:	Expert N=11	Novice N=11	p-value
Marine mammals	72.7%	45.5%	0.218
Collecting marine mammal data	72.7%	45.5%	0.218
Science	72.7%	45.5%	0.218
Company association with the project	27.3%	27.3%	1
Helping a graduate student	27.3%	18.2%	0.651
Technology	18.2%	9.1%	0.581
Other	9.1%	9.1%	1

Table 4.5. Whale mAPP user interests

The mean response of expert and novice users' interests in various topics, ranked on a scale of 0 (no interest) to 5 (very interested). The p-value based on the Wilcoxon rank sum test of the differences in expert versus novice responses is also listed.

Interest in:	Expert N=11	Novice N=11	p-value
Marine mammals	4.9	4.8	0.635
The ocean	4.7	4.9	0.546
Using Whale mAPP	4.5	4.0	0.116
Collecting marine mammal data	4.4	3.7	0.110
Android technology	3.4	2.9	0.494

Table 4.6. Various marine mammal patterns identified by users

The mean percent of expert and novice users who described marine mammal distribution based on various patterns such as a reoccurring location, monthly distribution patterns, and distribution based on weather, prey location, or time of day. The percent of users who did not think marine mammal distribution was determined from some pattern and the associated Wilcoxon rank sum test p-value that compares expert and novice responses is also shown.

Marine mammal pattern identified	Expert N=9	Novice N=12	P-value
No	25%	22.2%	0.9233
Yes; location	75%	66.7%	0.7167
Yes; month	33.3%	11.1%	0.2685
Yes; weather	0%	33.3%	0.0202
Yes; prey location	9.1%	12.5%	0.8767
Yes; time of day	8.3%	11.1%	0.889

Table 4.7. Action taken by volunteers to learn more about marine mammals

The mean percent of expert and novice users who noted “yes” to having completed one of the actions listed to learn more about marine mammals. The p-value based on the Wilcoxon rank sum test of the differences in expert versus novice responses is also listed.

Action taken to learn more about marine mammals:	Expert N=11	Novice N=12	p-value
Read a book	25%	72.7%	0.028
Talked to a peer	41.7%	72.7%	0.152
Talked to a scientist	16.7%	54.5%	0.068
Went on a wildlife tour	8.3%	9.1%	1
Went to a museum	0%	18.2%	0.147

Table 4.8. Volunteer evaluations of Whale mAPP

The mean expert and novice user responses to various statements ranging from -2 (strongly disagree) to 2 (strongly agree), with 0 representing no opinion. The Wilcoxon rank sum test p-value indicates the difference between expert and novice responses, while the mean response is a verbal representation of the numbered mean value.

Volunteer opinions of the following statements:	Expert N=9	Novice N=12	p-value	Mean response
Enjoyed using Whale mAPP	1.67	1.08	0.08722	Agree
Will continue to use Whale mAPP	1.11	0.50	0.1432	Agree
Would recommend Whale mAPP to a friend	1.67	1	0.01923	Agree
Enjoyed the marine mammal <i>fun facts</i>	1.44	0.83	0.08943	Agree
Enjoyed the species guide	1.44	0.83	0.08943	Agree
Enjoyed viewing the vessels' track line on the app	1.22	0.92	0.4503	Agree
Purposefully went out to use Whale mAPP	-0.56	-0.67	0.9706	Disagree
Too much information to enter	-1.11	0.5	0.006059	Disagree
Whale mAPP was easy to use	1.33	0.83	0.1727	Agree

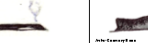
Table 4.9. Volunteer opinions of participating in the citizen science project

List of volunteer agreement to the following statements about Whale mAPP for all users (N = 23).

Statement	Strongly Agree	Agree	No Opinion	Disagree	Strongly Disagree	Summary of Results
Enjoyed using Whale mAPP	10	8	3			~ 85.7% enjoyed using Whale mAPP
Will continue to use Whale mAPP	6	9	2	3	1	~ 71.4% would continue to use Whale mAPP
Would recommend Whale mAPP	8	11	2			~ 90.5% would recommend Whale mAPP to another person
Enjoyed the <i>fun facts</i>	8	7	6			~ 71.4% enjoyed the <i>fun facts</i>
Enjoyed using the species guide	8	7	6			~ 71.4% enjoyed using the species guide
Enjoyed viewing the vessel track	8	6	7			~ 66.7% enjoyed viewing the vessel track
Purposefully travelled to use Whale mAPP	2	1	6	6	6	~ 57.1% did not purposefully travel to use the app
Too much data to enter	3	3	7	3	5	~ 38.1% thought there was not too much entry data, 33.3% have no opinion, and 28.6% thought there was too much data to enter
Easy to use	6	11	3	1		~ 81.0% found the app was easy to use

Whale mAPP Marine Mammal Identification Guide – Baleen Whales

Humpback Whale (<i>Megaptera novaeangliae</i>)	Gray Whale (<i>Eschrichtius robustus</i>)	Sperm Whale (<i>Physeter macrocephalus</i>)	Fin Whale (<i>Balaenoptera physalus</i>)	Minke Whale (<i>Balaenoptera acutorostrata</i>)
				
Most Common – most likely to be seen in inland waters	Rare – most likely to be seen in outside waters near Sitka	Rare – most likely to be seen in southern Chatham Strait	Rare – mainly near open water	Rare – mainly near Glacier Bay/Icy Strait
Size – medium (<45')	Size – medium (<40')	Size – medium/large (<60')	Size – large, occasional breach (<80')	Size – small, breach and aerial behavior (<30')
Fluke – present when diving	Fluke – present when diving	Fluke – present, triangular	Fluke – flukes when diving	Fluke – rarely seen
				
Dorsal fin – arched back	Dorsal fin – no dorsal fin	Dorsal fin – blunt, triangular	Dorsal fin – hooked	Dorsal fin – hooked
				
Blow – tall, bushy	Blow – moderate, busy	Blow – tall, 45° angle	Blow – very tall, columnar	Blow – small, usually absent
				
Threats – gear entanglement, ship strikes, sonar and boat noise	Threats – collision with vessels, gear entanglement, habitat degradation, boat noise, disturbance from tourism	Threats – net entanglements, fisheries interactions (sperm whales have been recorded feeding off long-line gear)	Threats – oil/gas activities and increased shipping in higher latitudes	Threats – net entanglements, ship strikes, climate change affecting their prey distribution

Dall's Porpoise (<i>Phocoenoides dalli</i>)	Killer Whale (<i>Orcinus orca</i>)	Harbor Porpoise (<i>Phocoena phocoena</i>)	Pacific White-sided Dolphin (<i>Lagenorhynchus obliquidens</i>)
			
Most Common	Common	Occasional	Rare
Size – small (<7')	Size – large (<30')	Size – small (<6')	Size – small, sleek (<8')
Behavior – small groups, rooster's tail, often bow ride, no acrobatic tricks	Behavior – groups, several breaths followed by a long dive	Behavior – alone, quiet and elusive, can be difficult to spot	Behavior – groups, very social with frequent bow-riding and acrobatics
Dorsal fin – triangular, black & white	Dorsal fin – huge and black	Dorsal fin – triangular, all black	Dorsal fin – hooked, black and white
			
Acrobatic – no	Acrobatic – no	Acrobatic – no	Acrobatic – yes, leaps & flips
Threats – net and gear entanglement	Threats – net entanglement, long line fishing interactions	Threats – habitat loss, predation, disease, and pollution	Threats – habitat loss, predation, and disease

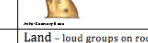
Harbor Seal (<i>Phoca vitulina</i>)	Steller Sea Lion (<i>Eumetopias jubatus</i>)	Sea Otter (<i>Enhydra lutris</i>)	California Sea Lion (<i>Zalophus californianus</i>)	Northern Fur Seal (<i>Callorhinus ursinus</i>)
				
Common – near haul outs	Common	Common	Rare – outside waters	Rare
Size – small seal (<6')	Size – large (<8' (F) 10' (M))	Size – small sea otter (<5')	Size – medium (<6' (F) 8' (M))	Size – smaller sea lion (<6')
Behavior – shy, alone or in groups on ice, rocks, or beaches	Behavior – alone or on rocks in groups, very loud	Behavior – alone or floating in groups close to shore	Behavior – alone or in groups in the water	Behavior – alone, likely foraging for food
Water – short muzzle, will only see the head, near shore	Water – loud and active in groups, slap flippers	Water – floating on back, alone or in large 'rafts'	Water – loud and active in groups, slap flippers	Water – may see flippers
				
Land – quiet, on ice or rocks in sheltered shores, round, spotted	Land – loud groups on rocks or beaches	Land – quiet, elusive, rare on land	Land – on rocks or beaches, walk with flippers	Land – rarely on shore in Alaska
				
Threats – gear and net entanglements, pollution	Threats – competition for food, predation, and pollution	Threats – oil spills, disease	Threats – net entanglement, disease, predation	Threats – net entanglement, depletion of food, oil spills

Figure 4.1. Marine mammal identification guide

Marine mammal survey guide including information on the fourteen marine mammals that could be sighted in Southeast Alaska, if the species is common or rare, and the animals approximate size, behavior, visibility above water, and threats.

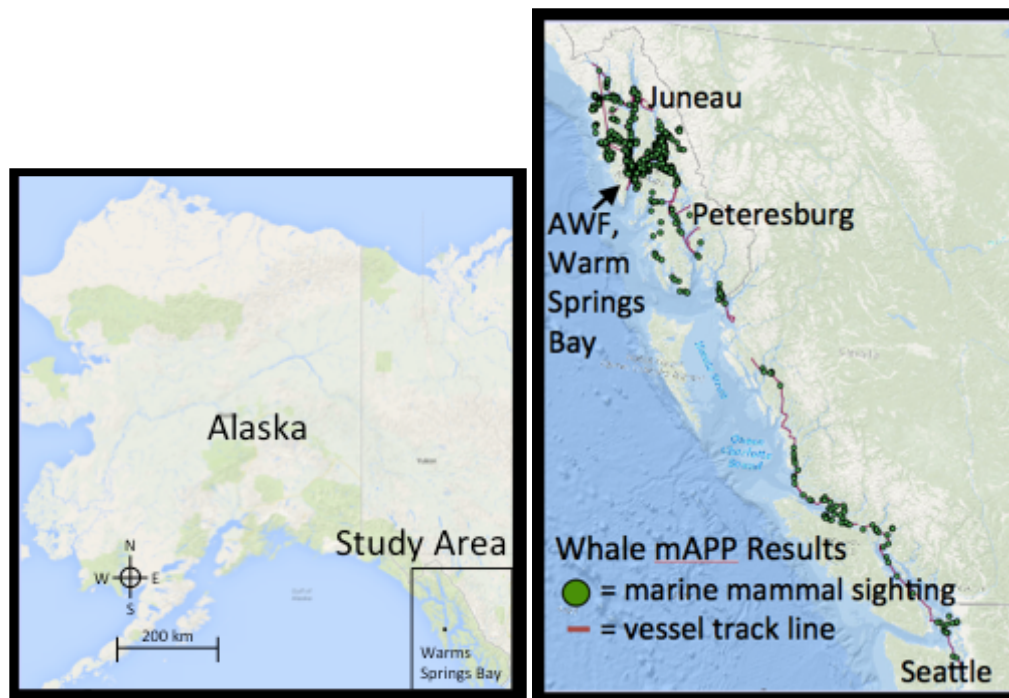


Figure 4.2. Study area

Study area of Southeast Alaska, with green dots denoting the 1256 marine mammal sighting data locations collected from June 20th to September 30th, 2014. Red lines denote vessel track lines, while major cities and the recruitment center in Warm Springs Bay are also noted.

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5 CHAPTER 5: SUGGESTED REVISIONS TO WHALE MAPP

Report to be submitted to the Whale mAPP project, Dr. Lei Lani Stelle

Abstract

As citizen science projects expand and develop, it is important to continue evaluating their progress and need for change in relation to what the users' desire (Herodotou *et al.* 2014). To continue expanding the reach of Whale mAPP, and include more audiences, the project must continuously adapt. Participant surveys represent a common method for evaluating citizen science projects, and highlighting areas of needed improvement (Nov *et al.* 2011; Koss *et al.* 2009; Raddick *et al.* 2009). This chapter highlights key findings from two surveys distributed to Whale mAPP users.

5.1 Online survey results

5.1.1 User interaction with Whale mAPP

An overall positive and supportive response towards Whale mAPP highlights the likely continued success of Whale mAPP as a tool for research and education. Survey results suggest the majority of respondents enjoyed using Whale mAPP (~86%), the *fun facts* (~71%), and the species guide (~71%), and would recommend Whale mAPP to a friend (~90%; Table 5.1). Anecdotally, volunteers emphasized how much they enjoyed the hard copy and detailed species guide for identifying marine mammals. In addition, survey results suggest 81% of participants found Whale mAPP to be easy to use, and 90% would recommend Whale mAPP to a friend (Table 5.1). Users enjoyed identifying the species, and recording their behavior, weather and distance to the animal (Table 5.2).

Yet, respondents suggested specific revisions that could improve the user-Android app interface and user benefit from participating in the project. Survey results suggest half of the users did not purposefully go out on the water to use Whale mAPP, and there was disagreement over if Whale mAPP required too much data to enter (Table 5.1). From these results, the data analysis will likely need to continue accounting for spatial bias, as we cannot expect users to follow an exact transect line. Furthermore, streamlining the mobile app by improving areas of confusion will likely improve the user's experience when recording data. For instance, 41.7% of users found recording the direction to the marine mammal sighting confusing, while another

29.2% were confused when recording the behavior of the animal (Table 5.2). Revising these unclear elements of Whale mAPP will likely reduce the time spent recording information, making the project more compelling and easy to be a part of.

5.1.2 Ranked revisions

Overall, most of the suggested edits in the survey were ranked as important for Android-based volunteers in Southeast Alaska. There is weak evidence that two edits, including more detailed behavior descriptions and dropping a pin to mark animal locations, are significantly more important revisions than including a help section (t-test, p-values = 0.039, 0.045 respectively) (Table 5.3). Anecdotal evidence supports these top two revisions, while the need for an iPhone Whale mAPP was also obvious due to the high percentage of interested volunteers who simply could not participate because they did not own an Android.

In addition, all components of the separate hard copy marine mammal identification guide were ranked high, above 70 on a 1 to 100 scale (Table 5.4). These data suggest that the marine mammal identification guide should continue to be used while recording marine mammals with Whale mAPP. Although not part of the survey, volunteers mentioned how much they enjoyed the separate, hard copy of the marine mammal identification guide. Including a marine mammal guide for other areas, such as Oregon and California, may improve user recruitment and reduce error when identifying species.

5.2 **Revisions made to Whale mAPP**

5.2.1 Changes to the global Whale mAPP version based off of the beta version used in this study

A beta, citizen science Whale mAPP mobile application was revised and used for data collection in Southeast Alaska from June 20th to September 30th, 2014. The success of this version led to several revisions of the original mobile application that will be completed by January 2016. Primarily, the updated Whale mAPP has two versions, one for expert users and another for the public.

In addition *fun facts*, a highly enjoyable educational component of the beta Whale mAPP version will be included in both updated versions (Appendix F). Recording distance and direction to a sighting was required for expert users due to its importance for spatial analysis and scientific use of the citizen science dataset. Visibility, a crucial environmental measurement for Southeast Alaska and other foggy near-shore areas, was also included in the new version. Boat type (motor, sail, self-propelled, other, unknown) and purpose (commercial fishing, recreational fishing, private recreation, research vessel, shipping, transportation e.g. ferry, whale watching boat, other, unknown) was slightly revised to reflect present and anticipated future user groups. Including the boat type, distance/direction recordings, and visibility will enable future Whale mAPP analyses to consider these variables and their potential influence on the results. For instance, why certain boat types, such as a ferry or whale watching boat, may have spatial bias due to only travelling along pre-determined routes. Animal behavior choices were revised and updated to include the iconic bubble net feeding behavior present in Southeast Alaska. These revisions were funded under a pre-existing grant and completed by Smallmelo GIS, LLC.

5.2.2 Changes to Whale mAPP based on user feedback

As funding allowed, high priority Whale mAPP revisions were implemented to improve the user experience and interest in this citizen science project. The top three suggested revisions were to 1) include more detailed behavioral descriptions, 2) drop a pin to mark an animal's location, and 3) edit/revise submitted sightings both during and after a survey trip. Since the accuracy of using a drop pin to record an animal's location, especially in open water settings with few reference points, has not been assessed, this revision was not implemented. Further investigation into the accuracy of using a drop pin method is suggested before implementing this revision.

Therefore, the other two revisions were funded under the Mamie L. Markham Endowment Award, Hatfield Marine Science Center. Behavioral descriptions enable the user to click on a species-specific behavior, and read about how to identify such a behavior. Including descriptions will likely improve the accuracy when recording behavior, as 29.2% of users were confused on how to record behavior information and many volunteers sent questions about how

to identify “milling” or “logging” behavior (Table 5.2). Both in the survey and anecdotally, volunteers were very interested in recording marine mammal behaviors (Table 5.2). This is not surprising as previous studies reported citizen scientists primarily motivated by personal and intrinsic interests as well (Raddick et al. 2010; Nov et al. 2011; Crall et al. 2012).

Furthermore, the most frequent complaint about Whale mAPP was the inability to edit and revise sightings once they were submitted. As one expert user noted:

“I was generally afraid that I would miss a sighting while taking so much time to enter information about the last one. Also, it was tough to not be able to edit sightings when I saw another whale surface with a group I had already recorded.”

Enabling users to revise sightings throughout their survey trip and after completion will improve the users’ experience and accuracy. The user will not become frustrated with having to enter data that keeps changing, or enter behavioral data while watching the animal. Rather, they can record the location and species, while returning to enter behavioral and other details once the marine mammal has left. This revision will also reduce error in the dataset by enabling users to revise their submissions and change information such as how many individuals were present, thereby reducing the number of false submissions.

5.3 Recruitment

In addition to revisions of the mobile app, Whale mAPP should focus on recruitment, including holding in-person tutorials on how to use the mobile app, what the data are being used for, and how they can access their data online. Communication with participants should take place early and often to enhance involvement with the citizen science project. Providing an email for questions or concerns is recommended. Participants frequently expressed interest in receiving summaries of how the data were being used. This was provided to participants involved in this project, and is recommended as a method for maintaining participant interest and engagement with Whale mAPP.

Although a variety of volunteers used Whale mAPP, including fishermen, commercial recreational boat owners, and private boat owners, the majority of participants had a pre-existing

interest in marine mammals and/or the ocean. Targeting audiences already interested in marine mammals, such as tourist organizations, whale watching industries, conservation organizations, etc. would likely recruit more volunteers than a non-target approach.

Future studies should track user groups, length of participation, and avenues for recruitment. Although one-on-one in-person recruitment was effective, this method is not practical for generating an across-state or global user group for Whale mAPP. Other recruitment methods, including media and collaboration with other scientists, should be investigated.

5.4 Summary of results

This study has demonstrated that although many people are interested in this citizen science project, revisions towards the mobile app itself, recruitment, and expansion of the marine mammal identification guide to other regions, are vital for the continual success of this project. In addition, results from this study highlight the type of information that can be attained from distributing surveys, and recommends the use of surveys in the future to evaluate both educational benefits of the project and areas of needed improvement.

5.5 Appendix D

Table 5.1. Volunteer opinions of Whale mAPP

Response counts to statements regarding volunteers' experience using Whale mAPP (n = 24).

Statement	Strongly Agree	Agree	No Opinion	Disagree	Strongly Disagree
Enjoyed using Whale mAPP	10	8	3	0	0
Will continue to use Whale mAPP	6	9	2	3	1
Would recommend Whale mAPP	8	11	2	0	0
Enjoyed the <i>fun facts</i>	8	7	6	0	0
Enjoyed using the species guide	8	7	6	0	0
Enjoyed viewing the vessel track	8	6	7	0	0
Purposefully went out on a trip to use Whale mAPP	2	1	6	6	6
Too much data to enter	3	3	7	3	5
Easy to use	6	11	3	1	0

Table 5.2. Volunteer opinions of data entry for Whale mAPP

Response counts and percentages to the Whale mAPP data entry components presented (n=24).

Perspective	Easy to Record	Enjoyed Recording	Too much information to record	Confused on how to record this information
Whale species	17 (70.8%)	7 (29.2%)	4 (16.7%)	0
Dolphin species	15 (62.5%)	5 (20.8%)	3 (12.5%)	1 (4.2%)
Pinniped species	15 (62.5%)	6 (25%)	6 (25%)	0
Number of species	14 (58.3%)	6 (25%)	6 (25%)	1 (4.2%)
Direction to sighting	9 (37.5%)	2 (8.3%)	3 (12.5%)	10 (41.7%)
Distance to sighting	14 (58.3%)	6 (25%)	3 (12.5%)	3 (12.5%)
Weather information	18 (75%)	6 (25%)	2 (8.3%)	1 (4.2%)
Behavior of animal	10 (41.7%)	6 (25%)	2 (8.3%)	7 (29.2%)
Photo of animal	4 (16.7%)	3 (12.5%)	9 (37.5%)	2 (8.3%)

Total (%)	53.7 %	21.8 %	17.6 %	11.6 %
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Table 5.3. Suggested revisions for Whale mAPP

List of suggested revisions for Whale mAPP mobile application, and their rankings from 1 (the revision is of low importance) to 5 (the revision is very important/essential) based on survey results (n = 24).

Whale mAPP Suggested Revision	Mean Ranking of Importance (1 low to 5 high)
Include more detailed behaviors	3.77
Drop a pin to mark location	3.76
Edit sighting	3.68
Include behavior descriptions	3.68
Add a compass	3.32
Less required data	3.32
Make an iPhone version	3.14
Include species ID into Whale mAPP	3.14
Enter weather at the beginning of the trip	3.05
Include less buttons	3.05
Select specific marine mammals to record	3.05
Include a more detailed map	3.05

Include time spent with marine mammals	3.05
Edit past trip	3.00
Add a help section	2.95

Table 5.4. Ranking of marine mammal identification guide

Survey ranking of all components of the marine mammal identification guide (n=24). Usefulness was ranked by users on a 1 (low) to 5 (high) scale, and rescaled from 0 to a 100.

Component	Example	Usefulness (1 low to 5 high)	Usefulness (0 to 100)
Species List	Humpback whale (<i>Megaptera noveangliae</i>)	4.52	90.4
Full body drawing		4.36	87.2
Fluke drawing	 Humpback whale – fluke present when diving	4.26	85.2
Dorsal drawing		4.23	84.6
Size	Humpback whale – arched back Humpback whale – Medium (< 45')	4.18	83.6
Behavior	Dall's Porpoise – small groups, rooster's tail, often bow ride, no acrobatic tricks	4.18	83.6

Common or not	Humpback whale – Most Common: most likely to be seen in inland waters	4.14	82.8
Blow drawing	 Humpback whale – tall, bushy	4.05	81
Land drawing (pinnipeds)	 Harbor Seal – quiet, on ice or rocks in sheltered shores, round, spotted	4	80

Table 5.4. Ranking of marine mammal identification guide (Continued)

Water drawing (pinnipeds)	 Harbor Seal – short muzzle, will only see the head, near shore	3.82*	76.4*
Threats	Harbor Seal – gear and net entanglements, pollution	3.57*	71.4*

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6 CHAPTER 6: CONCLUSION

This thesis aims to inspire the development and pursuit of the current marine mammal citizen science project, Whale mAPP, by providing an example of the research that can be done with an expansive citizen science dataset (Chapter 2), evaluating current biases associated with the Whale mAPP dataset (Chapter 3), examining educational benefits and areas of needed improvement (Chapter 4), and providing suggested revisions to the mobile app (Chapter 5).

Having a large spatial and temporal scale of sperm whale data enables researchers to answer questions that are otherwise challenging to address. For instance, results from Chapter 2 show a seasonal association of sperm whales with seamounts off the northeastern coast of New Zealand. Previous studies have struggled to prove modeling evidence of sperm whale association with seamounts, even though anecdotal evidence states the contrary. This study suggests using a simplified seamount classification system based on summit depth from surface, and predicts that sperm whales will likely only be seasonally associated with productive seamounts, with summit depths less than 400 meters. These results can be applied to seamount and sperm whale management, an important topic as more seamounts are being investigated for rare Earth mineral mining.

As described in Chapter 3, research on the differences between expert and novice Whale mAPP users in Southeast Alaska revealed that both groups were inclined to have positive survey bias in high-use areas, such as major towns and travel routes, with lower representation in inaccessible areas. This is a common theme found in many citizen science projects, and therefore was not unexpected. What was most surprising was the observed variation in sample size needed for accurate home range predictions that was based on the animals' ecological distribution. Variation in detectability and sample size needed to realistically predict a species' distribution is often overlooked in citizen science studies. Results from Whale mAPP data show the importance of these topics, and the danger of overlooking them - such as predicting inaccurate species distribution patterns or noting differences in novice and expert datasets due to a low sample size or range of spatial sampling. The results will contribute to the broader research in interpreting

citizen science data, and considering the importance of sample size, species' preferred ecological distribution, and survey bias in data analysis.

Chapter 4 highlights commonalities in expert and novice user groups in their motivations, enjoyment of Whale mAPP, and general learning outcomes. The two groups differed in the amount of data they wanted to collect. Novice users would have preferred a more simplified version, while expert users desired additional behavioral descriptions and data entry. These results, along with an analysis of users' suggested revisions presented in Chapter 5, led to the creation of a separate expert and novice/general public version of Whale mAPP to be release in January 2016. Additional funding supported users' top revisions to add behavioral descriptions and allow users to edit past sightings in Whale mAPP. These revisions were funded and supported by the Whale mAPP team due to the success and survey results of data collected with the Southeast Alaskan beta Whale mAPP version.

Overall, this thesis hopes to inspire future marine mammal citizen science data and survey analyses to continue monitoring citizen science projects, so that one day, a dataset as substantial as that of the historical sperm whale data will be available for today's marine mammal populations.

6.1 Areas of further research

Future research should focus on the educational and research theories developed in Chapter 3 and 4. Continued surveys will elicit how and if citizen science perspectives change over time and geographically with regards to the Whale mAPP project. Comparably, evaluating Whale mAPP collected marine mammal data in different geographic areas, for different species, and with different sample sizes will help tease out the details behind the role of species' ecological distributions in needed sample size and differences observed between expert and novice data. Sample bias should also be evaluated with track line data, and incorporated into the home range models by weighing areas of higher or lower than average use appropriately.

With regards to the sperm whale and seamount analysis, techniques presented in Chapter 2 should be applied to other datasets and geographic regions to look for similar patterns. The

results can be applied towards highlighting specific seamounts as important for marine mammal foraging, marine productivity, and conservation.

6.2 Use for document

Results from both the sperm whale and Whale mAPP study will be published in various journals. Chapter 2, “Seasonal sperm whale association with shallow summit seamounts” is in review for publication in the Notes section of *Marine Mammal Science*. Chapter 3, “Interpreting species bias within mammal citizen science data” will be submitted to *Conservation Biology* for publication. Chapter 4, “Connecting back to the users: citizen scientists’ perspective on a marine mammal citizen science app”, will be published as a peer-review journal in *Citizen Science: Theory and Practice*.

Furthermore, this study contributes to the greater work on evaluating citizen science research to improve its applicability towards informal education and applied research. By showing both the potential of a multi-year, regional-collected historical citizen science dataset, we can inspire the growth and development of current citizen science projects, such as Whale mAPP.

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8 APPENDICES

8.1 Appendix E: Whale mAPP consent form

Consent Handout

Please read the following consent handout before choosing to participate in this study.

1. Purpose

You are invited to participate in a research study conducted by Dr. William Hanshumaker and Courtney Hann from Oregon State University. The study will investigate the scientific and educational benefits of volunteers using Whale mAPP to collect marine mammal data. You were selected as a possible participant in this study because you expressed interest in using Whale mAPP, are at least 18 years old, and own an Android device or are willing to loan one from the Alaska Whale Foundation.

2. Activities

If you would like to participate, you will use Whale mAPP to collect marine mammal data in Southeast Alaska. If you have a personal Android, you will be required to download the application Whale mAPP. If you are loaning an Android from the Alaska Whale Foundation, you will use a pre-downloaded version.

In addition, you will fill out a brief survey prior to using Whale mAPP, a secondary survey after using Whale mAPP for two weeks, and a tertiary survey after using Whale mAPP for four weeks. Survey participation is voluntary, but your contribution would be greatly appreciated. The surveys will ask questions about your knowledge on marine mammals and your experience with using Whale mAPP. The data collected will be used for assessing the educational benefits of participating in this project, and potential improvements that will be made to Whale mAPP. You may also be selected to participate in a focus group discussion. If selected, the focus group session will take place at the Alaska Whale Foundation research and outreach center, Warm Springs Bay, Alaska for around one hour. Participation is voluntary, but greatly appreciated. The data collected will be used to further understand user's opinions about Whale mAPP, any educational or learning experiences gained from participating in this study, and changes that should be made for the next generation of Whale mAPP. Light snacks and coffee will be provided during the discussion. If you are taking part in the focus group, please do not share information from the focus group session with anyone outside of the group to help maintain the privacy and confidentiality of other group members. The discussion will also be audio recorded for analysis purposes. It is to be noted that the confidentiality of anything you choose to say during the session cannot be guaranteed. Data collected during the survey, however, will be kept confidential by replacing everyone's name with a number.

Your participation in all activities is voluntary, and you are free to withdraw your consent and discontinue participation at any time without penalty

3. Time

Collecting marine mammal data using Whale mAPP will require spending time out on the water to record the appropriate data. The first survey will last about 5-10 minutes, and the second and third surveys will last about 10-15 minutes. If you participate in the focus group study, the discussion will last about 1 hour.

4. Risks

In this study, a breach of confidentiality would not pose any foreseeable risks to the participants.

5. Costs & Benefits

If you are selected, and choose to participate in the focus group discussion, costs may include travel to Warm Springs Bay and docking fees. Benefits to the individual participants and society include personal benefits of taking part in an important scientific study and society benefits of incorporating volunteer input into improving and refining the mobile application. Educational benefits include developing an interest in science, learning marine mammal facts and identification tools, and engaging in scientific practices. However, I cannot guarantee that you personally will receive any benefits from this research.

6. Confidentiality

Any survey information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. Subject identities will be kept confidential by a coding process, and data secured on a password-protected computer. Confidentiality for the focus group discussion cannot be guaranteed because they will be comprised of 5-7 participants.

If Whale mAPP is downloaded to your mobile device, the App will record your Android's unique identifier number, your location and movement while using Whale mAPP, and any of the information on marine mammals that you record. Information on your Android's unique identifier number will also remain confidential by a coding process and stored separately on a password-protected computer.

With regards to the confidentiality of Internet research and the potential for a breach of confidentiality:

- a. Breach of confidentiality:** There is a chance that we could accidentally disclose information that identifies you.
- b. Internet research:** The security and confidentiality of information collected from you online cannot be guaranteed. Confidentiality will be

kept to the extent permitted by the technology being used. Information collected online can be intercepted, corrupted, lost, destroyed, arrive late or incomplete, or contain viruses.

7. Contact Information

If you have any questions about the study, please contact Courtney Hann at (760) 668-5462 or hannc@onid.oregonstate.edu (or Dr. William Hanshumaker (541) 867-0167, bill.hanshumaker@oregonstate.edu).

If you have questions about your rights or welfare as research participants, you may contact the OSU Institutional Review Board (IRB) Office at 541-737-8008 or by emailing irb@oregonstate.edu.

8. Voluntariness

Your participation is voluntary. You may skip any survey questions or focus group questions that you do not want to answer. Your decision whether or not to participate will not affect your relationship with Whale mAPP or Oregon State University. If you decide to participate, you are free to withdraw your consent and discontinue participation at any time without penalty.

9. Funding

This project is funded by the Alaska Whale Foundation.

By completing the survey and downloading Whale mAPP, you are giving us permission to use the data for research.

Sincerely,

Whale mAPP research team

Principal Investigator: Dr. William Hanshumaker, Oregon State University

Student Researcher: Courtney Hann, Oregon State University

Project: Evaluation of citizen science as a low-cost tool for marine mammal research and education in Southeast Alaska

Approved by OSU IRB

8.2 Appendix F. Marine mammal *fun facts*

COMMON SPECIES

Humpback whale (*Megaptera novaeangliae*)

1. Humpback whales are migratory, baleen whales that feed on euphausiids (krill) and small schooling fish. Every year, around 80% of Alaska's humpbacks travel from cool, productive waters to warm waters in Hawaii for winter breeding!
2. Compared to Alaska, Hawaii is a more beneficial location for humpback whale birthing because there are less predators, the water is warmer, and the water is saltier, and therefore more buoyant for the young calves. Amazingly, this is a 2,800-mile trip from Southeast Alaska to Hawaii!
3. Some humpback whales participate in cooperative feeding called bubble net feeding. One whale swims in spirals below a school of fish to create a bubble net underneath the fish. As this net rises to the surface, additional whales spiral around the school of fish, forcing the prey into a tight ball. A single whale (generally) will begin to sing as the school of fish reaches the surface of the water. As the trumpeting ceases, the whales lunge toward the surface and take in mouthfuls of food. This is a truly remarkable behavior to watch!
4. Similar to many people, humpback whales love eating pollock, capelin herring, and salmon. The difference is that they enjoy munching on the smaller juvenile stage, while we prefer the larger adults.
5. Humpback whales are smart hunters. One excellent example is their relatively recent technique of eating juvenile salmon released from salmon enhancement facilities. This is a buffet for the humpback whales, but an economic loss for the salmon hatcheries. Current research is investigating this topic further.
6. Humpback whales are known as the singing whales of the sea, and have had symphonies recorded from their voices! These songs are generally sung by male whales during the mating season, but also occur here in Alaska during the late fall and winter.
7. Humpback whales aren't physically capable of giving birth to twins, but about 1% has dual fetuses.
8. If you look at a humpback whale skeleton, it has tiny hindquarters near the tail. This is because whales descended from land mammals. The humpback whale's closest land relative is the hippopotamus!
9. When feeding, humpback whales can expand their mouth to hold around 15,000 gallons of water. That is approximately the amount of water in a swimming pool!
10. In May 2014, humpback whales were taken off the endangered species list in Canada!
11. A humpback whale's tongue is around 4,000 pounds and stretches across 1/3 to 1/2 of its body length. That's a long tongue!
12. At birth, humpback whale calves are about 1/3 the size of their mother. That would be like giving birth to a 4-year old sized baby!
13. Humpbacks are old and wise creatures that can live to be 100 years old.
14. Females lose 2/3 of their body weight while nursing their calves. Subsequently, the calf can drink as much as 100 gallons of milk a day, enabling them to gain up to 7 pounds per hour!
15. A humpback whale's throat size is around the size of a basketball. Anything larger, they cannot swallow, and they spit out.
16. Humpback whales can eat 1/2 to 1 ton of food a day! They forage for krill, herring, sand lance, capelin, zooplankton, and eulachon 15-22 hours a day. Imagine eating food consistently for

15 hours a day!

17. Humpback whales are filter feeders. In place of teeth they have 270-400 baleen plates on each side of their mouth. To feed, a humpback opens its mouth taking in up to 15,000 gallons of water, fish, krill, etc. It then closes its mouth and strains the water out, while the food gets swallowed.

18. Have you ever seen a humpback whale lunge out of the water? Perhaps you were witnessing lunge feeding. Lunge feeding is when a humpback whale chases its prey to the surface of the water and lunges through the prey, mouth wide open, and often exploding at the surface with both food and water.

Killer whale (*Orcinus orca*)

19. In Southeast Alaska, killer whales can be split into roughly two groups, Alaskan resident killer whales and transient killer whales. The difference is that resident killer whales feed on fish, while transient killer whales are larger and feed on seals, sea lions, and small cetaceans.

20. Killer whales are both resourceful and intelligent animals. In Alaska, resident populations have been recorded eating long-line catch and feeding on processed fish waste from fishing vessels. What a unique way to eat food!

21. Killer whale pods specialize in what they eat; some hunt salmon, herring, or tuna, while others ambush seal and sea lion haul outs. Their hunting strategies are often collaborative, and they communicate with a “click-like” dialect. Due to the ability of their prey to hear them, transient killer whales do not vocalize while hunting as much as the resident killer whales.

22. From Washington to Alaska, killer whales hunt, feed, and live within matrilineal (female-led) groups, composed of 2-3 generations of related individuals. This would be like living with your parents, grandparents, and children all in one moving house!

23. Pods are multiple groups of killer whales that spend much of their time together. Resident pods greet each other by approaching in two tight lines, followed by more social, and relaxed mingling.

24. Baby killer whales are born orange and black. They slowly turn to white and black after a couple of months.

25. Killer whales are intelligent top predators. Therefore they, like us, need healthy teeth to prevent gum disease and for chewing food. Yet, unlike humans, the most common cause of killer whale death is gingivitis.

26. Unlike humpback whales, killer whales do not have a mating season. Instead, they are likely to mate when food is abundant.

27. 50% of killer whales die within their first year of life. This is due partly to high levels of toxins in the mother’s milk. Toxins accumulate in killer whales because they are apex predators, meaning that they are at the top of the marine food chain.

28. Each killer whale pod has individual dialects! They can recognize other pods for mating based on their unique dialect.

Dall’s porpoise (*Phocoenoides dalli*)

29. Ghost gear is fishing gear that is no longer attached to a boat, and just floats around in the ocean. Ghost nets are dangerous because they can cause gear entanglement for Dall’s porpoises

and other marine mammals.

30. Dall's porpoise are thought to be the fastest of the small cetaceans, a trait that helps them escape from hungry shark and killer whale predators.

31. Dall's porpoise are black and white with thick, stocky bodies. For this, they are often mistaken for baby killer whales. You can tell the difference because there will be no large, adult killer whales with a Dall's porpoises.

32. Dall's porpoise are the only cetacean that rivals the killer whale in speed! These fast porpoises often leave a "rooster tail" splash behind while swimming in small pods (4-8 individuals).

Harbor seal (*Phoca vitulina*)

33. What you put down your sink, toilet, or drain eventually makes it to the ocean. This includes prescription drugs, cleaning supplies, shampoo, etc. Toxic pollutants can impact the health and reproduction of animals, such as harbor seals, that live close to the shore.

34. Harbor seals love to eat fish, squid, crabs, and mollusks. Do you enjoy eating similar seafood? Think about how much your diet overlaps with a harbor seal's diet.

35. Harbor seals are very shy and will abandon favorite haul-out sites and/or pups due to human presence. Make sure to stay quiet when approaching a harbor seal and to keep at least 100 feet away from the seal.

36. Harbor seals (*Phoca vitulina*) are members of the true seal group. They comprise a generally inquisitive, but elusive, species that spend equal time on land and in the sea. These seals are not limited to salt water and have been found in inland waterways and lakes.

37. Harbor seals cannot "walk" on land like sea lions. Instead, they use their hind flippers and body undulations to move on land, hence their family common name of "crawling seals".

38. Harbor seals have a thick layer of blubber that keeps them warm, contributes to their streamlined shape, provides buoyancy, and stores energy.

39. Unlike humpback whales, which migrate between Alaska and Hawaii annually, harbor seals have no definite migrations but will move in search of food.

40. Harbor seals can dive up to 1000 feet and remain underwater up to 23 minutes to hunt for food. How long can you hold your breath for?

41. Harbor seals will sleep on land or just below the water surface. If underwater, the seal will come up to breathe every 5-10 minutes without waking up. What a cool trick!

42. Harbor seals double in size in their first few weeks of life. Harbor seal and humpback whale milk are among the richest in the world!

43. Harbor seals are born mature, with their adult teeth and pelage. Imagine giving birth to a baby with a full head of hair and teeth!

44. Harbor seals are similar to Labradors in that they come in varying colors (white, grey, and black). Have you noticed a variation in their coat colors?

45. Harbor seals and sea lions generally avoid one another. During periods of famine, sea lions will occasionally prey on harbor seals. This demonstrates that harbor seals are lower on the food chain than sea lions.

46. In British Columbia, there is rising concern of harbor seal pups being fed on by bald

eagles and coyotes. Since harbor seals are mostly blubber, they make a good, fatty meal.

47. Male harbor seals “roar” underwater during mating season. Otherwise, harbor seals are very quiet and elusive animals.

Steller sea lion (*Eumetopias jubatus*)

48. While in Southeast Alaska, you will likely see Steller sea lions growling or groaning at you from the shoreline. These noisy animals love to feed on fish and squid in Alaska’s productive ecosystem.

49. Since the 1990s, Steller sea lion populations have declined in Southeast Alaskan waters due to multiple stressors that may include nutritional stress related to competition with commercial fisheries for food (pollock), environmental changes, predation by killer whales, and toxic substances.

50. Steller sea lion stocks have decrease by 40% from 1991 to 2000, with an average decline of 5.4% per year. Your work in collecting Steller sea lion sightings will help scientists estimate their populations and locations in Southeast Alaska.

51. Threats to Steller sea lion recovery include nutritional stress related to competition with commercial fisheries or environmental change, predation by killer whales, net entanglements, parasitism, disturbance from vessel traffic and tourism, and toxic substances from large industries and cities. (Redundant with #25)

52. What is the difference between a sea lion and a seal? Sea Lions are generally larger, have small flaps for outer ears, are louder, and have rotating hind flippers (allowing them to “walk” on land).

53. The hind flippers of Steller sea lions are large and like paddles. They are hairless and webbed, perfect for swimming in the ocean! Sea lions use their fore flippers for swimming propulsion, and hind flippers for steering.

54. Steller sea lions were named after a German naturalist and physician, Georg Steller. He became the first European naturalist to describe many Alaskan plants and animals, including the Steller sea lion, Steller’s sea cow, Steller’s jay, Steller’s Sea Eagle, and Steller’s eider. Many of his studies took place while being shipwrecked on Bering Island.

Sea otter (*Enhydra lutris*)

55. Oil spills can negatively impact sea otters because the oil drastically reduces the insulation in their fur. This would be like taking off your warm, insulating snow jacket in the middle of a blizzard!

56. Sea otters, especially those in the Kachemak Bay area, have recently been affected by a *Streptococcus infantarius* infection, leading to increase deaths. The cause of this infection is still under debate, but current research is looking for an answer.

57. After sea otters were hunted to near-extinction in the 19th and 20th centuries, the Alaska Department of Fish and Game transported 412 sea otters from other areas of Alaska to Southeast Alaska in 1945. This population has growth to the population you see today!

58. Like seals, sea otters spend some time on land and have a relatively well-developed sense of smell. Unlike seals, sea otters lack insulating blubber. Instead, they rely on their thick fur and

digestion of food to keep warm.

59. Sea otters are social and gather in rafts (groups) ranging from a few dozen to over 100 animals. Rafts are sexually segregated (females avoid male feeding areas).

60. Have you seen a sea otter rolling around at the surface? They do this to smooth their fur and wet the tips after combing their fur with their forepaws.

61. There are around 500,000 hairs every square inch on a sea otter's fur. That is the number of hairs on 2 or 3 human heads!

62. Sea otters can dive up to 300 feet and remain underwater for 4-5 minutes to hunt for food. Sea otters eat a large variety of food, including mussels, clams, abalone, snails, octopus, crabs, sea urchins, and sea stars.

63. Have you every seen a sea otter wrapped in seaweed? Sea otters do this while they sleep, so that they don't float away.

64. Sea otters have 1 million hairs per square inch, and almost no blubber for insulation – unlike seals, sea lions and whales.

LESS COMMON SPECIES

Fin whale (*Balaenoptera physalus*)

65. Fin whales are large (up to 24 meters in length and 75 tons), but very sleek and streamlines. Although very rare in Southeast Alaska, the best clue to identification is the asymmetric coloration of the head.

66. Scientists study many whales by listening to their calls underwater! Whales use calls, like humans, to communicate and locate food.

67. Fin whales are the most vocal of all whale species. During the breeding season, males sing almost constantly at frequencies that (when the ocean is quiet) can be heard for 100's to 1000's of kilometers.

Minke whale (*Balaenoptera acutorostrata*)

68. Minke whales are small baleen whales that eat krill and small schooling fishes.

69. A once top secret sound detected by the navy turned out to be the Minke whale "Boing".

Gray whale (*Eschrichtius robustus*)

70. Gray whales often travel alone or in shifting groups, but can occur in large aggregations at both breeding and feeding grounds. This is very different from close-knit killer whale pods.

71. Gray whales feed on amphipods (shrimp-like crustaceans) that they filter from muddy sediment along coastal shorelines.

72. Gray whales swim one of the longest annual migrations, traveling around 5,000 miles from northern feeding grounds (such as Alaska) to warm water summer calving grounds (such as Baja California). How far have you traveled this year?

73. Gray whales were among the first to be protected from whaling, and among the first to be

considered recovered.

Sperm whale (*Physeter macrocephalus*)

74. Prior to whaling efforts, the sperm whale stock was estimated to be 1,260,000. This number reduced to 930,000 in the late 1970s from hunting. The number of sperm whales occurring in Alaska is unknown, which is why you are helping collect that data!

75. Sperm whales are toothed whales, enabling them to eat medium-sized to large-sized squid, large fish, sharks, and skates.

76. Sperm whales are becoming more common in Southeast Alaska. This may be due to climate change and a shift of their prey species (squid and large fish) to higher latitudes. While in Alaska, sperm whales have been recorded feeding off longline gear and becoming entangled in the gear.

77. Sperm whales were originally hunted for their spermaceti and sperm oil, used in making candles, soap, cosmetics, machine oil, lamp oil, pencils, crayons, leather waterproofing, and pharmaceutical compounds. This same whale also inspired the book Moby Dick!

Harbor porpoise (*Phocoena phocoena*)

78. Scientists often estimate whale and porpoise population levels with aerial surveys, where they count the number of animals seen from a plane! Imagine trying to estimate the human population using planes.

79. Causes of recent harbor porpoise population declines are not well understood, but they include habitat degradation, predation, disease, or a combination of these factors.

80. Most harbor porpoise are found in waters less than 100m deep, and concentrate near shore in inland waters, bays, tidal areas, and river mouths. As a result, they are more vulnerable to urban and industrial development, including waste management, nonpoint source runoff, building of docks, filling of shallow areas, and dredging.

Pacific white-sided dolphin (*Lagenorhynchus obliquidens*)

81. Pacific white-sided dolphins travel in groups ranging from 10 to 50 to 100 to 1,000 dolphins! They often work collaboratively to corral fish into tight balls, making them easier to eat.

82. Pacific white-sided dolphins frequently leap completely out of the water while swimming. These acrobats can also be seen jumping and bow riding.

83. Pacific white-sided dolphins often hang out with other animals, including humpback whales, sea lions, other dolphins, and seabirds.

Northern fur seal (*Callorhinus ursinus*)

84. Male Northern fur seals are four to five times larger than the females! They have one of the greatest size differences of any mammal.

85. The Northern fur seal has a lot of fur, around 300,000 hairs per square inch!

86. Northern fur seals can dive up to 637 feet and remain underwater over 7 minutes to hunt for food, such as small fish and squid. How long can you hold your breath for?

87. In July, Northern fur seals go to the Pribilof Islands in Alaska and the Commander

Islands in Russia to have pups and mate. Like many other marine creatures, they usually return to the same site they were born every year.

For all whales & porpoises

88. Dolphins and whales investigate their surroundings by using sound. They use a form of sonar called echolocation, which makes “pictures” of sounds in their brains!

89. Dolphins, whales, and porpoises do not chew their food. They swallow it whole. Imagine swallowing a slice of pizza whole!

90. A female dolphin, whale or porpoise, is called a “cow”. A male dolphin, whale or porpoise, is called a “bull”. A baby is called a “calf”. This may seem funny, but it is because some of their older relatives were cow-like animals.

91. If whales and dolphins live in salt water, where do they get fresh water? Interestingly, they get most of the water they need from the food they eat, such as fish, squid, crabs, octopus, and and shrimp.

92. A changing climate impacts whale by shifting where their prey distribution further north, and reducing sea ice cover. A demand for fossil fuels impacts whales through the noise and pollution from oil and gas activities in the Chukchi and Beaufort seas.

93. Remember to stay more than 100 yards from all marine mammals and to turn off your motor to protect whales, dolphins, seals, and sea lions from unnecessary stress or harm.

For seals and sea lions

94. Seals, sea lions and walruses are all grouped together in the scientific order *Pinnipedia*, which is a Latin word meaning “Fin-Footed”.

95. A “Marine Mammal” is any animal that lives in the ocean, breathes air, gives live birth, nurses their young, and is warm blooded. Seals, sea lions, whales, dolphins, porpoises, manatees, sea otters and even polar bears are considered marine mammals.

96. You, as a citizen scientist, are helping collect important data for marine mammal research and conservation! Thank you!

8.3 Appendix G. Whale mAPP user guide



Whale mAPP User Guide

C. H. Hann, Alaska Whale Foundation

What is Whale mAPP?

Whale mAPP is an Android-based citizen science tool for collecting marine mammal distribution and abundance data. The tool has been developed through a partnership between Alaska Whale Foundation and Smallmelo Geographic Information Services. Our goal is to produce a user-friendly, low-cost application that will allow volunteer boaters to collect baseline data necessary for monitoring marine ecosystems in the face of climate change and other habitat perturbations.

Whale mAPP aboard Your Vessel

This season, we are conducting a study to determine whether Whale mAPP can be an effective data collection tool. We are distributing the application to volunteer boaters and will be examining their results as the field season progresses. Your input and experience are extremely important to us. If interested in participating in the Whale mAPP survey, please contact Courtney Hann (hannc@onid.oregonstate.edu).

Using Whale mAPP

Download Whale mAPP: Download Whale mAPP by going to Whalemapp.org and creating a login account. While still connected to WIFI, also download the background Southeast Alaska map.

***Important: To download Whale mAPP, users must have an Android operating system of at least 4.1. The app will only work if your phone's GPS can connect to satellites and your Android can install files from unknown sources (Settings < Security < check the "Unknown sources" button).

Open Whale mAPP: Start the application by clicking on the whale tail icon.

Setup: Check all boxes. Set the Southeast Alaska/Canada – West Coast map as your background map by selecting it under the *Default offline* map tap.

Record New: This is where you begin each new survey (*i.e.*, whenever the vessel gets underway).

***Important: once open, Whale mAPP will begin recording your route. If no data are recorded during this time, we can only assume there were no animals in the area. Therefore, it is important that you run Whale mAPP only when someone is actively observing for marine mammals and in a position to enter sighting data.

1. **Enter your boat name and vessel type**, then click 'Start trip' to begin the survey. You can login into your account created if still connected to WIFI.
2. **Record marine mammal sightings:** Click on the binocular icon whenever you spot a marine mammal. You will be prompted to enter additional information regarding species, approximate numbers, and estimated bearing and distance to the animal(s). Please fill in all items in bold. As well, please enter a confidence rating that reflects your confidence in any of the information you just entered (*e.g.*, how certain are you it was a humpback?). Click the back button (top left) if you made a mistake, and do not want to record a sighting, or click 'Save' when finished.
3. **End the trip:** Select the anchor icon (top right) when the vessel is no longer underway or you are no longer in a position to record sightings.

My Data: This allows you to upload your data to our server whenever you pass through a WIFI area. You can also delete past survey trips that were incorrect.

Thank you for your help!

8.4 Appendix H. Survey 1

Survey 1: Pre-Whale mAPP Use
C. Hann, Alaska Whale Foundation, IRB Approved

Name: _____ Email: _____ Boat: _____ Date: _____

(1.) How long have you used Whale mAPP?

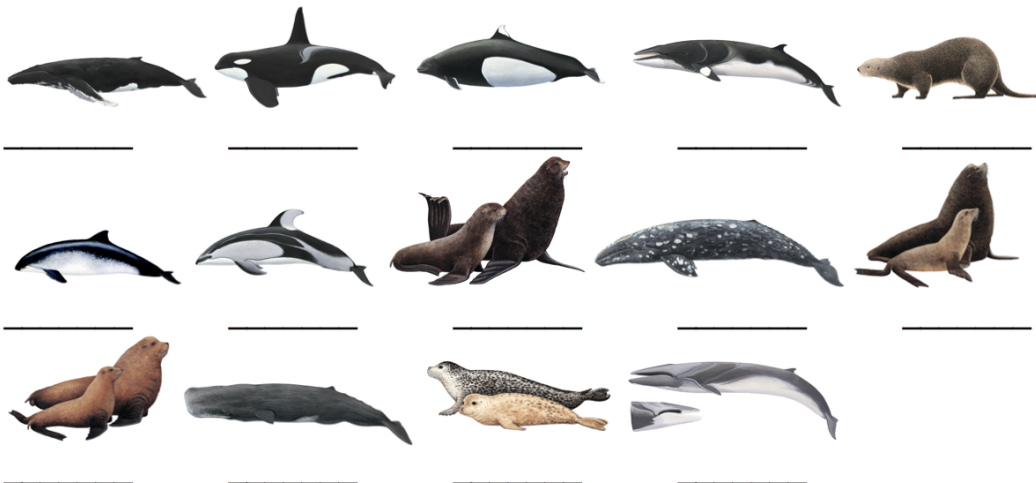
- ☐ Have not used it yet
☐ 2 weeks
☐ 4 + weeks

(2.) Please select which category you most align with

- ☐ Alaskan
☐ Non-Alaskan recreation boater
☐ Whale watching cruise participant
☐ Other

(3.) Matching – match the picture with the species name

- | | | |
|------------------------|--------------------------------|---------------------|
| A. Humpback Whale | B. Fin Whale | C. Minke Whale |
| D. Killer Whale | E. Dall's Porpoise | F. Harbor Porpoise |
| G. Harbor Seal | H. Sea Otter | I. Grey Whale |
| J. California Sea Lion | K. Northern Fur Seal | L. Steller Sea Lion |
| M. Sperm Whale | N. Pacific White-sided Dolphin | O. Unknown |



(4.) Please select which marine mammals are faced with the following threats

	Humpback Whale	Killer Whale	Harbor Porpoise	Harbor Seal	Steller Sea Lion	Sea Otter
Disease						
Net entanglement						
Ship strike						
Habitat loss						
Human hunting						
Reduced prey availability						

(5.) Please mark any global marine mammal conservation topics you know about:

- ☐ Climate change leading to higher sea surface temperatures, ocean acidification, and shifting species distributions
- ☐ Ocean noise, including: ship noise, drilling, seismic operations and military readiness activities
- ☐ Habitat degradation and loss
- ☐ Deliberate killing of some species for food and predator control
- ☐ Depletion of prey resources from commercial fisheries
- ☐ Collision with vessel
- ☐ Entanglement in fishing gear
- ☐ Chemical contamination from land pollution and oil spills
- ☐ Illegal Whaling
- ☐ None of the above

Thank you for completing the survey!

Remember that we need the survey to be completed both BEFORE using Whale mAPP and again, AFTER using Whale mAPPs. The results are essential for determining what people learned from using Whale mAPP.

Principal Investigator: Dr. William Hanshumaker, Oregon State University
(bill.hanshumaker@oregonstate.edu)

Student Researcher: Courtney Hann, Oregon State University (hannc@onid.oregonstate.edu)

Project: Evaluation of citizen science as a low-cost tool for marine mammal research and education in Southeast Alaska

Approved by OSU IRB

8.5 Appendix I. Survey 2

Survey 2: Post-Whale mAPP Use
C. Hann, Alaska Whale Foundation, IRB Approved

Name: _____ Boat: _____ Date: ____

1. How long have you used Whale mAPP?

☐ Have not used it yet

☐ 2 weeks

☐ 4 + weeks

2. Please select which category you most align with.

☐ Alaskan

☐ Non-Alaskan recreation boater

☐ Whale watching cruise participant

☐ Commercial recreation naturalist/crew

☐ Commercial fisherman

☐ Other

3. Matching – match the picture with the species name

A. Humpback Whale

D. Killer Whale

G. Harbor Seal

J. California Sea Lion

M. Sperm Whale

B. Fin Whale

E. Dall's Porpoise

H. Sea Otter

K. Northern Fur Seal

N. Pacific White-sided Dolphin

C. Minke Whale

F. Harbor Porpoise

I. Grey Whale

L. Steller Sea Lion

O. Unknown



4. Please select which marine mammals are faced with the following threats

	Humpback Whale	Killer Whale	Harbor Porpoise	Harbor Seal	Steller Sea Lion	Sea Otter
Disease						
Net entanglement						
Ship strike						
Habitat loss						
Human hunting						
Reduced prey availability						

5. Please mark any global marine mammal conservation topics you know about:

- ☐ Climate change leading to higher sea surface temperatures, ocean acidification, and shifting species distributions
- ☐ Ocean noise, including: ship noise, drilling, seismic operations and military readiness activities
- ☐ Habitat degradation and loss
- ☐ Deliberate killing of some species for food and predator control
- ☐ Depletion of prey resources from commercial fisheries

- ☐ Collision with vessel
- ☐ Entanglement in fishing gear
- ☐ Chemical contamination from land pollution and oil spills
- ☐ Illegal Whaling
- ☐ None of the above

6. Please Rank the Following

	1 (low)	2	3	4	5 (high)
Interest in using Whale mAPP					
Interest in marine mammals					
Motivation to collect marine					
Interest in the ocean					
Android/Technology experience					

8. Why did you decide to start using Whale mAPP?

- | | | |
|--|--|--|
| ☐ Interest in marine mammals | ☐ Interest in using the maps created for personal use | ☐ Interest in enhancing company's association with marine mammal conservation efforts |
| ☐ Interest in technology | ☐ Interest in citizen science projects | ☐ Other: _____ |
| ☐ Interest in science | | |
| ☐ Interest in collecting marine mammal data | | |

9. Why did you decide to stop using Whale mAPP?

- | | |
|---|---|
| ☐ Still using Whale mAPP | ☐ Stopped using Whale mAPP because I left coastal Alaska, but stayed in Alaska |
| ☐ Stopped using Whale mAPP because it was boring | ☐ Stopped using Whale mAPP because of a technical problem |
| ☐ Stopped using Whale mAPP because it took too much time | ☐ Stopped using Whale mAPP for some other reason |
| ☐ Stopped using Whale mAPP because I left Alaska | |

10. Did you use other resources while, or after using, Whale mAPP to learn more about marine mammals? Please check all that apply

- | | | |
|--|---|---|
| ☐ Internet | ☐ Going on a wildlife tour | ☐ Talking with a family member |
| ☐ Book(s) | ☐ Talking with a scientist | |
| ☐ Going to a museum | ☐ Talking with a peer/friend | |

11. Did you notice any patterns in marine mammal sightings

- | | | |
|--|---|--------------------------------------|
| ☐ No | ☐ Yes – weather | ☐ Yes – month |
| ☐ Yes – time of day | ☐ Yes – location | ☐ Yes – other |

12. Did you notice a change in the number of marine mammals you sighted after using Whale mAPP?

- | | | |
|------------------------------------|---|---|
| ☐ No change | ☐ Yes, I noticed less marine mammals | ☐ Yes, I noticed more marine mammals |
|------------------------------------|---|---|

13. Do you think marine mammals change their location seasonally? If so, why? (Select all that apply)

- ☐ No
- ☐ Yes – change their location based on weather
- ☐ Yes – change their location based on food abundance
- ☐ Yes – change their location based on boat traffic
- ☐ Yes – change their location based on the season
- ☐ Yes – change their location based on group behavior
- ☐ Yes – change their location based on predator abundance
- ☐ Yes – randomly change their location

Thank you for answering the previous questions. Please answer the following questions specifically about Whale mAPP. These questions will be used to edit the format and flow of the mobile application.

14. What percent of time did you spend doing the following activities while using Whale mAPP?

	0%	20%	40%	60%	80%	100%
Scanning the water for marine mammals						
Talking						
Fishing						
Reading						
Driving the boat						
Doing another activity inside the cabin or boat						

16. With regards to Whale mAPP, please rank the following descriptions

	1 (needs improvement)	2	3	4	5 (excellent)
Style					
Ease of use					
Engagement					
“Fun Facts” presented					
Marine Mammal Identification Guide					
Interest in entering data					

17. Please rank the following Marine Mammal Guide identification tools

	1 (not useful)	2	3	4	5 (very useful)
Species list					
Drawing – full body					
Drawing – fluke images					
Drawing – dorsal images					
Drawing – blow images					
Drawing – seal/sea lion/sea otter on land					
Drawing – seal/sea lion/sea otter in the water					

Description – common or not					
Description – Size					
Description – Behavior					
Description – Threats					

18. Please check all that apply

	Too much information to enter	Did not know how to enter the data	Interested in entering the data	Easy to enter the data
Whales sighted				
Dolphins & porpoises sighted				
Seals, sea lions, sea otters sighted				
Quantity of species sighted				
Presence of calves				
Direction				
Distance				
Weather & Sea Conditions				
Describe Behavior				
Add a photo				

19. Please rank what components you would like to see implemented into Whale mAPP.

	1 (low)	2	3	4	5 (high)
Edit sightings after recorded					
View past trips					
Edit past trips					
Select specific marine mammals to record data on (e.g. only record information on whales)					
Drop a pin to mark the location of marine mammals on a map (versus recording the distance and direction from the boat)					
Include a compass as part of the app					

Help Section that gives a step-by-step tutorial on how to use Whale mAPP					
Ability to enter more behavioral information (bubble net feeding observations, photo ID, feeding behaviors, etc.)					
Availability on other platforms (iOS/iPhone)					
More Fun Facts and external information about marine mammals					
More detailed background map					
Descriptions of marine mammal behaviors					
Enter the weather in the beginning of the trip instead of associating the weather with a sighting					
Record length of time spent watching/traveling with a marine mammal					
Reduce time spent recording a sighting (i.e. less required information to enter)					
Reduce buttons/sections (i.e. have a sequential windows that prompts the user with what specific data to enter)					
Include species identification tools in Whale mAPP					

20. Please elaborate on sections that you believe need editing:

21. Please rank the following statements

	Strongly Disagree	Disagree	No Opinion	Agree	Strongly Agree
I enjoyed using Whale mAPP					
I will continue to use Whale mAPP					
I would recommend Whale mAPP to a friend					
I enjoyed "Fun Facts" as part of Whale mAPP					
I enjoyed the species identification guide					
I enjoyed viewing my vessel track line and map as part of Whale mAPP					
I purposefully went out on a boat to use Whale mAPP					

There was too much information to enter into Whale mAPP					
Whale mAPP was easy to use					

Thank you for completing the survey!

Remember that we need the survey to be completed both BEFORE using Whale mAPP and again, AFTER using Whale mAPP. The results are essential for determining what people learned from using Whale mAPP.

Principal Investigator: Dr. William Hanshumaker, Oregon State University
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