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# Comparing citizen science reports and systematic surveys of marine mammal distributions and densities

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ABSTRACT

Citizen science observations represent a significant and growing source of species and ecosystem knowledge. These data have potential to support traditional surveys. Databases of citizen observations of wildlife are growing, but how to use this information for scientific purposes is less clear owing to uncertainty in sampling distribution and data quality. In this study, we demonstrate how mapping cetacean patterns using citizen observations and systematic surveys generate consistent and different understandings of cetacean distributions and densities, and evaluate potential risk by assessing cumulative human effects in British Columbia, Canada. We used GIS-based map comparison methods that quantified differences and similarities between geographic datasets to locate where cetacean distributions and densities had spatially unique or spatially analogous representation. Where spatial clusters in both data sources are congruent, we interpret with a higher level of confidence that species occur, and mapped patterns accurately reflect distribution and density. In areas where datasets exhibit dissimilar species densities and distributions, we acknowledge lower confidence and advise further sampling. Regions of agreement were primarily in the central-western portion of the study area (off the southeastern coast of Haida Gwaii); areas of disagreement were heterogeneously distributed across the study area. Spatial clusters from citizen data exhibited significantly higher cumulative human effect scores than from systematic surveys, despite previous data adjustments for human effort. We demonstrate the use of citizen observations as a confirmatory dataset to broaden ecological exploration by augmenting scientific survey datasets and identifying strategic areas for future data collection efforts.

## 1. Introduction

Historically, citizen science has played an important role in ecological studies. Citizen scientists have informally contributed to ecological investigations for centuries, with noted examples of unpaid participation by non-professionals in scientific endeavours, such as Charles Darwin in the 19th century (Silvertown, 2009) and the founding of the Christmas Bird Count (CBC) in 1900 (Butcher, 1990). Today, citizen scientists have a more formally defined role in scientific studies of ecology, in studies such as the North American Breeding Bird Survey (BBS), where volunteers record counts of observed breading bird species along thousands of roadside survey routes (Sauer et al., 1997). Now, as one of the largest sources of comprehensive information on North American birds, it contributes valuable data on species distributions and population trends (Sauer et al., 2013). The successes of projects like the CBC and BBS are due, in part, to their ability to expand the geographic and temporal scope of data collection. Increasing the breadth and quantity of available information is a vital contribution to ecological analyses that are often constrained using traditional frameworks and methods for collecting data. The value of the information gained in these initiatives has led to a better understanding of species distributions and population trends across countries and continents (Cooper et al., 2014).

Citizen science is also supporting the challenging task of acquiring marine species distribution and abundance information. Many marine species, including cetaceans, are difficult to survey given their often elusive and migratory nature, the complex 3D environment they inhabit, and the logistical and financial costs associated with accessing

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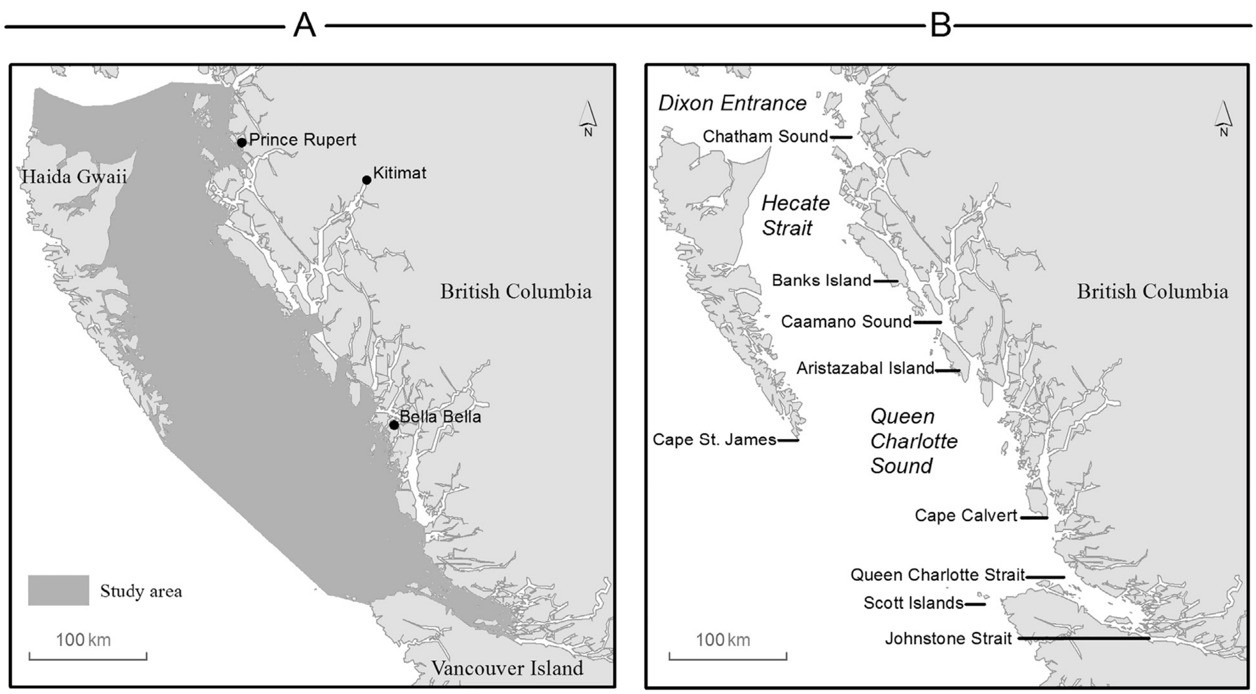


**Fig. 1.** Study area (A) and significant coastal features (B).

these environments. Further, problems can arise from spatial and temporal inconsistencies (e.g., shortened transects or missing survey years, months, and/or days) sometimes resulting in sparse and incomplete datasets. The potential for citizen science to contribute to new scientific knowledge has been demonstrated in marine-based research programs. For example, recreational scuba divers have identified seahorse species distributions and habitat (Goffredo et al., 2004).

Growth in GPS and GIS technology, as well as smart phones, has further contributed to an explosion of citizen science programs for ecological studies, including marine research (Thiel et al., 2014). The proliferation of mobile technology allows citizens to relate species observations to a universal indexing system (i.e., location) and to disseminate information quickly. Also termed crowdsourcing, citizen observation programs leverage observations and knowledge of individuals to collect large quantities of data that can span broad geographic extents. Citizen participants are typically familiar with digital technology, which allows for the inclusion of software tools and mobile applications that facilitate remote data collection. Incorporating public participants in scientific research expedites the collection of geographic information that can be used to confirm data gathered from disparate collection methods, contribute new observations, and provide assessments of data uncertainty. Citizen-contributed data may allow the formulation of new hypotheses given data that are much more extensive and cover more diverse themes compared to traditional data (Miller and Goodchild, 2014) and offer increased opportunities for chance discoveries and new interpretations (Lukyanenko et al., 2016).

Incorporating citizen observations into the field of marine ecology offers many benefits and opportunities for current and future research; however, these datasets may also have fundamental problems. Issues related to effort bias, particularly for data collected haphazardly, can invalidate many assumptions required for statistical analyses. Datasets may exhibit large spatial and temporal gaps or other missing information. Further, participants may have different levels of training or competencies to correctly collect and record data. Although some recommendations and guidelines exist for outlining standards for citizen participation in ecological research (Silvertown, 2009), widely accepted best practices are still under development, continue to evolve, and may depend on the specific application. The sheer volume of information available from citizen observation programs makes overcoming data quality problems a worthwhile pursuit (Hochachka et al., 2012).

Citizen observations and traditional survey data have different information content that can be conflated to potentially offer a more complete representation of species distributions and densities. When combined, citizen science and systematic survey data have the potential to produce a more detailed picture of reality than if separately assessed. Accordingly, citizen observation datasets can often be viewed as complementary, rather than conflicting, to conventional scientific research studies, as each data type has the potential to illuminate different spatial patterns. If collated, the data may aid in forming a greater understanding of species distributions and abundance patterns. To date, however, few studies have focused on how to integrate citizen-collected data with existing scientific investigations and geographic products for cetaceans.

Our research integrates cetacean density maps from systematic surveys and citizen observations that offer an opportunity to investigate potentially complementary information for a relatively data poor region of British Columbia (BC), Canada. Currently, abundance data on cetaceans are limited for much of BC and consequently management and conservation decisions are frequently made using incomplete information. Citizen observer data could supplement traditional survey data, and both data sources could be combined to assess confidence of species distributions. To assess the information content of datasets, we use approaches from spatial analysis and leverage the link between spatial pattern and process to assess where datasets provide a common ecological signal and where there are dissimilarities. If the spatial patterns represented by the two datasets are similar, the same ecological processes are being captured by data collection. Differences indicate areas where we have less confidence in the signal of the data and further data collection may be warranted. Map comparison methods that employ spatial clustering techniques are often applied in remote sensing applications and landscape ecology, and offer pattern-based techniques that can provide ways to characterize similarities and differences between multiple datasets. Using this quantitative methodology, we characterize map uncertainty and spatial patterns of similarity and difference to guide future sampling efforts and marine spatial planning