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# How much effort is enough? The power of citizen science to monitor trends in coastal cetacean species

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ABSTRACT

Citizen scientists provide a cost-effective means of carrying out broad scale, long-term monitoring of the environment while fostering earth stewardship. In this study we investigate how much effort is required by citizen scientists to detect trends in the occurrence of a protected population of bottlenose dolphins (*Tursiops truncatus*). We analyse the WDC citizen science shore-based data collected over nine years (2005–2013) between April to October from within and in the vicinity of a Special Area of Conservation (SAC) for bottlenose dolphins in the Moray Firth, Scotland. Watches comprised a continuous 10 minute scan of the survey area in an hour. During peak season, around 5 watches per day were required to detect annual or between-site trends of 50% in dolphin occurrence in locations where dolphins were sighted reliably (0.1 sightings per hour). Less effort was required at higher sightings rates, and it was not possible to statistically detect trends of $<30\%$. This study highlights the importance of power analysis in designing citizen science programmes and demonstrates their effectiveness in carrying out long term shore-based monitoring of coastal cetacean species, providing a cost-effective early warning system for changes in the marine environment.



## 1. Introduction

Citizen science is the use of volunteers or non-scientific members of the public to carry out scientific research (Silvertown, 2009). In recent years, the use of citizen scientists in ecological and environmental research has exploded, particularly with the advancement in mobile technology (e.g. Sullivan et al., 2009: eBird citizen science online bird surveys). In a world of growing concerns about human impacts on the environment, alongside financial constraints on research, citizen science is of increasing importance not only as a means of collecting data cost-effectively, but for fostering Earth stewardship (Dickenson et al., 2012). Citizen science takes many forms, from large-scale reporting of opportunistic sightings of species (e.g. jellyfish; Pikesley et al., 2014), to more directed broad-scale surveys carried out by volunteers (e.g. Breeding Bird Survey; Sauer et al., 2003), and narrower focus hypothesis-driven volunteer-led monitoring (e.g. investigating leaf-minor attack on horse chestnut trees; Pocock and Evans, 2014). Such data has proven to be invaluable in conservation biology by informing policy and conservation management practices, for example, the UK volunteer Seasearch underwater surveys of the waters

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around the UK informed the selection of the Marine Conservation Zones for conserving biodiversity in England (POST, 2014). In our study, we investigate the use of citizen scientists to monitor a population of bottlenose dolphins, *Tursiops truncatus*, protected within a Special Area of Conservation (SAC), and consider in particular how much effort is needed to allow for the calculation of statistically robust measures of trends in species occurrence within and outside the SAC.

Citizen scientists have been used to monitor cetacean populations for decades, within organisations such as Sea Watch in the UK (www.seawatchfoundation.org.uk; Evans, 1980, 1992 and Evans et al., 2003), and through events such as the 'Great Whale Count' carried out by the Pacific Whale Foundation in Hawaii (www.pacificwhale.org; Tonachella et al., 2012). These primarily shore-based observation programmes have been used to monitor a range of species from bottlenose dolphins (Bristow et al., 2001) and harbour porpoises (*Phocoena phocoena*) (Bailey et al., 2012; Camphuysen, 2011) to humpback whales (*Megaptera novaeangliae*) (Tonachella et al., 2012). The large spatial and temporal scales achievable by using citizen scientists for shore-based cetacean monitoring have shown to be beneficial for conservation management by identifying the spatial extent (Pierce et al., 2010), and temporal trends (Tonachella et al., 2012) of species close to shore. For example, the 'Great Whale Count' carried out by citizen scientists in Hawaii was able to detect a 5% increase in humpback whales which was matched by scientific estimates of their populations (Tonachella et al., 2012).

Shore-based surveys provide a number of benefits as a platform for coastal cetacean research, to supplement more research-intensive methods such as boat-based or aerial surveys (Cheney et al., 2013). Although shore-based surveys are limited spatially to areas close to land, they are a cost-effective means of gathering habitat use and temporal data to assess variation in occurrence of marine mammals at key coastal sites of interest (Evans and Hammond, 2004; Pierpoint et al., 2009). Data collection is also non-invasive and does not cause disturbance or affect the behaviour of the study animals as boat-based surveys have the potential to do. Due to the cost-effectiveness of shore-based surveys it is possible to carry out monitoring over more extended time periods than boat-based surveys, allowing for long-term monitoring to be carried out. For example, 40 years of shore-based surveys off California showed an increase in the diversity of cetacean species sighted in line with warming sea temperatures and an implied regime shift (Shelden et al., 2004; Shelden and Rugh, 2010). Longitudinal studies such as these have been identified as one of the most effective ways of using citizen scientists to measure change and therefore to quantify the impact of conservation policy and measures (Tulloch et al., 2013).

Using citizen scientists in scientific studies has been shown to produce data of similar reliability as using specialists if sufficient training is provided (Newman et al., 2003), and in shore-based studies, if a high enough vantage point is used (Young and Peace, 1999). To ensure that volunteer-collected data can be used to monitor trends in occurrence, it is vital that volunteer programmes understand how much data (volunteer effort) is required to ensure sufficient statistical power to detect these trends (e.g. Jackson et al., 2008). Volunteers are motivated to participate in science for a variety of reasons including environmental stewardship and education (Ryan et al., 2001), but if we are to maintain motivation for participation, monitoring programmes should not overload volunteers and result in burnout (Measham and Barnett, 2008). A target level of effort can help guide the volunteer programme, ensuring sufficient statistical power to detect trends for conservation purposes, while maintaining volunteer motivation. Therefore in this study we explore two main questions:

1. *How much effort is required to detect inter-annual trends in bottlenose dolphin occurrence at a single location*? Using data from a single site for which there is a long-term monitoring programme, we explore the impact of decreasing the number of days monitored on the statistical power to detect an inter-annual trend in bottlenose dolphin occurrence. This is used to evaluate the trade-off between monitoring effort and the magnitude of inter-annual trend that we are able to detect.
2. *What impact does detection rate have on the amount of effort required to detect trends*? Widening the study to include all the sites monitored within the vicinity of the bottlenose dolphin Special Area of Conservation (SAC) we explore the impact of detection rate and rarity on the amount of effort required to reliably assess occurrence at a site. Other studies have shown that species with lower detection rates require more effort to have the power to detect trends (de Solla et al., 2005), so we hypothesise that more effort will be required in those locations with low detection rates.

### 1.1. Moray Firth Shorewatch programme

Our citizen science project is based on the WDC Shorewatch programme which supports volunteers to monitor the presence and absence of coastal cetaceans over time by conducting effort-based watches from shore at specified local sites around Scotland. Volunteers have been carrying out Shorewatches from the Scottish Dolphin Centre in Spey Bay since 2005, and consistently from sites around the wider Moray Firth since 2010. The Inner Moray Firth is an SAC for a small population of bottlenose dolphins estimated at around 195 individuals and is considered to be a stable or increasing population (Cheney et al., 2013, 2014). The SAC boundary was originally based on the animals' core range during the 1980s and 1990s (Wilson et al., 2004). The population range has since expanded to include core sites outside the SAC, including the wider southern Moray Firth coast (Culloch and Robinson, 2008) and Aberdeen Harbour (Weir et al., 2008). Although the population are still encountered within core areas of the SAC throughout the year, with at least 60% of the population having been encountered within the SAC in 16 of the last 21 years (Cheney et al., 2012), dolphins are observed here at higher levels during the summer months (Cheney et al., 2012). Over half of the known individuals from the SAC have also been photo-identified in Aberdeenshire, some of them regularly (Weir et al., 2008). Extensive surveys in recent years have determined that the bottlenose dolphins are rarely encountered offshore in the Moray Firth (Culloch and Robinson, 2008; Eisfeld et al., 2009). SAC protection extends beyond the SAC boundary to include the full range of the population.