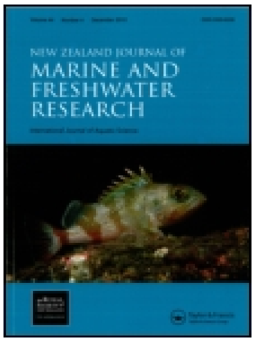

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RESEARCH ARTICLE

Using platforms of opportunity to determine the occurrence and group characteristics of orca (*Orcinus orca*) in the Hauraki Gulf, New Zealand

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We present the first fine-scale data relating to the occurrence and group characteristics for killer whales (*Orcinus orca*) in the Hauraki Gulf, New Zealand, as observed from a platform of opportunity (PoP). Group size and composition were examined in relation to water depth and sea surface temperature (SST). From 2000 to 2010, 119 orca encounters were recorded, involving 1 to 18 animals. The encounter rate varied seasonally, being highest in austral spring and lowest in summer. Water depth in which whales were observed was significantly affected by group composition. Sixty-seven percent of groups contained immature animals. Group size was highly skewed towards smaller groups comprising two animals. While this study illustrates that PoPs can be used to indicate the occurrence and group characteristics of highly mobile social species, biases clearly exist. Through identifying such inaccuracies, we present recommendations on how future data should be collected to minimise error and improve datasets for scientific use.

Keywords: Hauraki Gulf; killer whale; New Zealand; occurrence; *Orcinus orca*; platforms of opportunity

Introduction

In the study of cetaceans, vessels typically used for data collection include independent research vessels and platforms of opportunity (PoPs). The type of research vessel greatly influences the study design, methods of data collection, and the accuracy of how marine mammal behavioural responses can be observed and recorded (Bejder & Samuels 2003). Sightings are sometimes made from more than one observation platform in an effort to reduce bias in estimations (Cheney et al. 2012) and assess the effects of tourism (Bejder & Samuels 2003). However, a common design error occurs when research vessels and observational methods are mismatched, which often results in biased data (e.g. Evans & Hammond 2004; Hauser et al. 2006).

The use of an independent vessel allows research design to be controlled in a number of ways. First, researchers are able to follow individual animals and determine the duration of a focal-follow (e.g. Stockin et al. 2008a; Cheney et al. 2012; Augusto et al. 2013). Second, researchers are able to choose from a selection of several experimental designs, such as the presence or absence of other vessels (e.g. Lusseau 2004; Neumann & Orams 2006; Christiansen et al. 2010; Peters et al. 2012). Third, spatial and temporal coverage are not restricted, which can be highly advantageous for cetacean surveys (Redfern et al. 2006). However, while the use of an independent research vessel is likely to be the best platform to obtain detailed information, it can be an expensive option (Davidson et al. 2014). This is especially true if the

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target species is not resident within the region and thus only intermittently encountered within the study area.

The application of 'citizen science' as an ecological research tool has increased in popularity in recent years, due to its ability to extend the spatial and temporal scope of analyses far beyond the limits of traditional field studies (Dickinson et al. 2010; Wilson et al. 2013). Likewise, the use of opportunistic platforms for data collection has been increasingly recognised as providing an alternative means for scientific data collection on cetaceans (e.g. Williams et al. 2006; Ingram et al. 2007; Macleod et al. 2009; Stockin et al. 2009; de Boer 2010; Wiseman et al. 2011; Eyre & Frizell 2012; Isojunno et al. 2012; Palacios et al. 2012; Davidson et al. 2014). Such platforms can include large shipping vessels (Williams et al. 2006), ferries (Kiszka et al. 2007; Macleod et al. 2009; Arcangeli et al. 2013), cruise ships (Compton et al. 2007; Palacios et al. 2012) and commercial tour vessels (Hauser et al. 2006; Perez-Vallazza et al. 2008; Azzellino et al. 2008; Stockin et al. 2009; Visser et al. 2010; Wiseman et al. 2011; Davidson et al. 2014). Commercial vessels are often used as platforms for studying various aspects of cetacean biology and ecology (reviewed in Robbins 2000; Robbins & Mattila 2000). For example, tour vessels have been used to good effect as a research platform in studying cetaceans, including, but not limited to, studies of mother–calf interactions (Sardi et al. 2005), distribution (Hauser et al. 2006; Wiseman et al. 2011), sightings per unit effort (Koslovsky 2008), habitat preferences (Moura et al. 2012), occurrence (Dahood et al. 2008; Stockin et al. 2008b; Davidson et al. 2014) and predation events (Visser et al. 2010). However, using such PoPs places a number of limitations on the type of data which can be collected and interpreted without the introduction of biases (Hauser et al. 2006; Wall et al. 2006; Kiszka et al. 2007; Wiseman et al. 2011; Moura et al. 2012).

Observations collected using PoPs include many limitations. First, PoPs may be restricted both spatially and temporally, and types of data may not be collected, due to logistical considerations of the 'parent project' (Redfern et al. 2006). For example, Kiszka et al. (2007) indicated that spatial coverage and survey effort for several toothed cetacean species throughout the English Channel and Bay of Biscay was strictly limited by the pre-determined course of the vessel. Consequently, interpretation of species' habitat preferences could not be inferred beyond the extent of the relatively fixed route used by the PoP. In addition, because research may not be the primary focus for the 'parent project', effort or vessel tracks are often unavailable, limiting the type of analyses that can be conducted. Second, a researcher is limited by the length of time spent with a focal group and how the vessel is manoeuvred around focal individuals/groups (e.g. Wall et al. 2006). Third, only animals occurring in close proximity to the vessel can be observed, which may limit species identification and group size estimation (Palacios et al. 2012). Considering the commercial nature of many PoPs, staff can lack specific expertise with regards to marine mammal sightings (Redfern et al. 2006; Moura et al. 2012), which may affect the quality and reliability of the data (Martinez & Stockin 2011).

Despite such limitations, there are several benefits to using PoPs. One of the important factors is that PoPs are a comparatively inexpensive way to conduct surveys on cetaceans (e.g. Evans & Hammond 2004; Kiszka et al. 2007; Moura et al. 2012). In addition, PoPs have the ability to extensively cover regions where little information is known, on a regular basis. The collection of sighting information from a PoP may be the first step in developing a species list, providing a rough measure of status and variation in seasonal abundance (Evans & Hammond 2004), and reporting an area of interest. From such information, cetacean hotspots can be identified, which could be further targeted by research vessels using a more refined survey methodology (Evans & Hammond 2004).

While some aspects of data collection and boat movements on PoPs cannot be controlled, it is possible to prescribe how the data are collected and how some of the constraints are accounted for in analysis. For instance, Redfern et al. (2006) state that when modelling cetacean habitat, data collected from PoPs can be considered equivalent to information collected from research vessels, as long as data are collected by trained observers following strict survey and design protocols and coverage is sufficiently broad both spatially and temporarily to illustrate habitat variability (e.g. Cañadas et al. 2005).

Collecting data on highly mobile species such as cetaceans can be challenging from any type of platform, and observing and monitoring the social interactions of cetaceans can be difficult (Sakai et al. 2011). The structure of cetacean societies varies considerably, with most dispersing from their natal group, while a smaller number remain within the same group for life (Clutton-Brock & Lukas 2012). As an example, male sperm whales (*Physeter macrocephalus*) leave their natal group around 6 years of age and become increasingly solitary (Connor et al. 1998). A striking contrast can be made with the populations of killer whales or orca (*Orcinus orca*, herein referred to as orca) found off the northeastern Pacific, termed 'residents' (Barrett-Lennard 2000), and the populations of long-finned pilot whales (*Globicephala melas*) found off the Faeroe Islands (Amos et al. 1993; Heimlich-Boran 1993), which have never been recorded dispersing from their natal group.

When examining marine mammal social structures, the practical complexities involved in observing these animals are significant, especially given that individuals tend to be fast moving and wide ranging. Of all the cetaceans, orca are the fastest of the odontocetes, capable of average speeds of 3.6 m^{-1} during casual swimming (Williams 2008). This is considerably faster than mysticetes, which have an average swim speed of approximately 2.1–2.6 m sec^{-1} (Williams 2008). Another difficulty results from acoustic connectivity, where some groups which may visually appear to an observer to be isolated may actually be in acoustic contact with dispersed individuals, making the relevant social unit harder to observe (Simmonds 2006). Janik (2000) determined that bottlenose dolphin (*Tursiops truncatus*) whistles in the Moray Firth, Scotland, could be heard from up to 25 km away. Baird et al. (2010) used satellite tags to monitor the movement patterns of false killer whales (*Pseudorca crassidens*) in the Hawaiian Islands and found that individuals sometimes dispersed over 100 km before re-associating. Similarly, Filatova et al. (2006) found that orca form 'acoustic groups', which in some cases can be separated by a distance of 10 km. As such, investigating group dynamics of highly social species such as orca can pose a challenge.

Despite the difficulties of conducting research on highly mobile predators, orca have been studied in New Zealand waters during the past two decades (see Visser 1999a,b,c, 2000, 2005; Visser & Fertl 2000; Visser et al. 2010; Dwyer & Visser 2011). Whilst the local population is small (fewer than 200 individuals; Visser 2000), three possible subpopulations have been described (i.e. North Island only, North and South Islands, and South Island only; Visser 2000). While their use of the Hauraki Gulf (HG) in the North Island of New Zealand has been previously noted (Visser 2000, 2007), this study presents the first fine-scale examination that focuses on the occurrence and group characteristics for orca in this region, as observed from a PoP.

The PoP used in this study, *Dolphin Explorer* (hereafter referred to as *DE*), is a commercial tour boat offering dolphin and whale watch tours within the HG. Previous data on the New Zealand fur seal (*Arctocephalus forsteri*; Clemens et al. 2011), Bryde's whale (*Balaenoptera edeni*; Wiseman et al. 2011), bottlenose dolphins (Berghan et al. 2008) and the common dolphin (*Delphinus* sp.; Stockin et al. 2008b; Petrella et al. 2011) have been successfully collected from this vessel.

Herein, sightings and environmental data collected in the HG from *DE* between 2000 and 2010 were used to assess the potential use and biases of PoPs for acquiring data on orca. By identifying the biases associated with current data acquisition methods from PoPs, we discuss recommendations on how future data collection can be improved to minimise bias associated with highly dispersed and mobile species, such as orca.

Materials and methods

Study area

The HG study area (36°10′–37°10′S, 174°40′– 175° 30′E) is a large, shallow (< 60 m depth; Manighetti & Carter 1999), semi-enclosed coastal body of

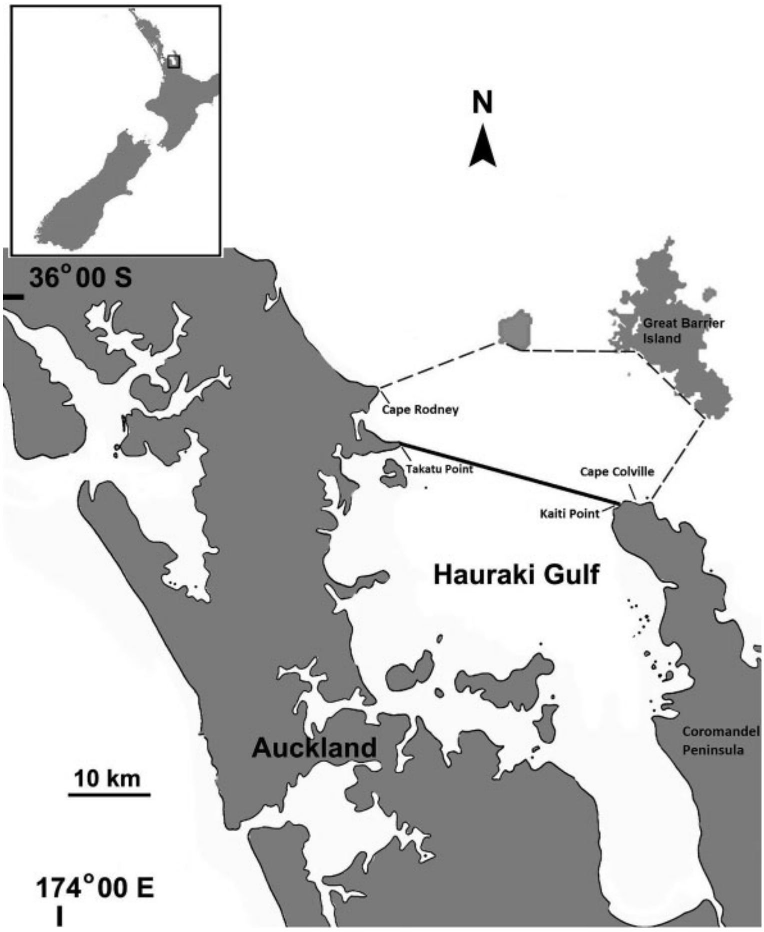

Figure 1 Location of the Hauraki Gulf, New Zealand, showing the inner and outer areas of the Hauraki Gulf (solid line) and the outer boundary of operation for the platform of opportunity used in this study, *Dolphin Explorer* (DE, dashed line).

temperate water, located on the northeastern coastline of the North Island, New Zealand (Fig. 1). This body of water is open to the north, landlocked to the west and south and partly protected in the east by the Coromandel Peninsula and Great Barrier Island. The boundary for this study between the Inner and Outer HG extends from Takatu Point on the east coast of the mainland to Kaiti Point on Coromandel Peninsula (Fig. 1). Sea surface temperatures (SSTs) within this region vary from approximately 14.8 °C in austral winter to approximately 21.2 °C during the austral summer (Stockin et al. 2008b).

Ocean circulation within the study area is influenced by the subtropical East Auckland Current (EAUC), which delivers subtropical waters to the outer HG and its continental shelf (Stanton & Sutton 2003; Sikes et al. 2009). Strong coastal upwellings make the study area an extremely productive (Booth & Søndergaard 1989) and biologically diverse region (Stockin et al. 2008b). Seasonal upwelling occurs in the later austral winter to early spring, when prevailing westerly winds introduce nutrients into surface waters, which elevates spring chlorophyll-*a* levels in the outer Gulf and along the outer shelf (Chang et al. 2003; Zeldis et al. 2004). Stratification of the study area occurs in the austral summer (Proctor & Greig 1989) and the strongest winds mainly occur from the northwest/southeast directions.

Data collection

Orca were observed from a PoP, *DE*, a 20 m tour catamaran powered by twin 350 hp inboard diesel engines, with a 5 m observer eye height. Given that observers' eye height is known to affect the detectability of cetaceans at sea, survey conditions were assessed in relation to the observational eye height used (Hammond et al. 2002). Onboard *DE*, data were collected whilst the vessel was conducting commercial cetacean viewing tours, which typically last approximately 5 h. Data were included when visibility was good (≥1 km) and in Beaufort sea state (BSS) 4 or less. The vessel speeds ranged from 5 to 15 kts. *DE* is restricted by the commercial permits it holds to perform surveys within specified boundary limits. These include waters south of a line from Cape Rodney to Great Barrier Island and to the southwest, to Cape Colville on the Coromandel Peninsula. *DE*'s permit further specifies that the vessel must not enter waters less than 10 m deep. If orca were observed in water shallower than 10 m, depth was approximated from nautical charts or obtained from research vessels alongside the group.

Observations were conducted by experienced observers using a continuous scanning methodology (Mann 1999) by naked eye and with binoculars (Bushnell 8 × 42 magnification). Sighting cues used to detect orca included splashing and/or silhouettes of travelling animals, water disturbance due to surface activity of animals, sighting of dorsal fins and presence of birds.

Once within 400 m of a group of orca, the vessel would slow to an approach speed (≤5 kts) and, where feasible, environmental parameters (i.e. water depth, SST, tidal and sea state, visibility and weather) were recorded. The vessel subsequently travelled a slow parallel course to the moving group, approaching slightly to the rear in a slow and continuous manoeuvre at the onset of an encounter (following Marine Mammal Protection Regulations [MMPR 1992] and *DE*'s commercial permit conditions). Once the vessel was within c. 200 m of the group, the start time and location of the encounter was recorded using a global positioning system (GPS). In addition, data relating to group size and composition were noted and photo-identification (hereafter referred to as photo-id) was opportunistically collected following standardised methodologies outlined by Bigg (1982).

For this study, all sightings recorded within a similar locality (≤22 km radius), on the same day, were considered to be the same group of orca. These parameters were set based on Filatova et al. (2006) who indicated, via use of hydrophones, that orca can be found by their calls at a distance of 10 km, and Ford et al. (2005), who described orca travelling distances of up to 11 km within a 30 min period.

Following Bigg (1982), group composition was categorised on a broad scale as adults-only versus groups containing immature animals. Immatures were defined as calves and juveniles that did not appear fully grown, and were up to 0.75 of the size of a female adult (Bigg 1982). Adults were defined as all animals not included in the prior category.

Data analysis

Prior to analyses, data were cross checked to remove any duplicates. Where duplicates were detected, the group with the largest size was retained within a 24 h period, as it is likely the most accurate representation of an 'acoustic group'.

Monthly and seasonal patterns in occurrence were investigated in relation to environmental parameters. Water depth and SST at which orca occurred, in relation to group size and group composition, were analysed. Encounter rate (ER) was calculated as the total number of sightings of orca per total surveys conducted. For the purposes of analyses, group size was classified as: one to five (small); six to 10 (medium); and > 10 animals (large). These categories were based on the mean group size (mean = 5.6, SEM = 0.4, n = 116). Where necessary, medium and large groups were pooled due to small sample sizes (i.e. > five). ER was also analysed in relation to group size using binomial z-tests for two proportions (Fleiss 1981), with 95% confidence intervals (CI) calculated. Observations were restricted to daylight hours (spring, 0630–1800; summer, 0600–2030 NZST; autumn, 0700–2000; winter, 0730–1715 NZST). Seasonal analyses were based on the austral seasons as follows: spring (September to November), summer (December to February), autumn (March to May) and winter (June to August).

The distribution of continuous response variables (SST, water depth) were initially tested for normality and homogeneity using Kolmogorov-Smirnov and Levene's tests, respectively (Zar 1996). In most cases, data were not normally distributed. When data transformation failed to improve normality, nonparametric Mann-Whitney U and Kruskal-Wallis tests were applied. A Dunn's Multiple Comparison post hoc test was subsequently conducted, when applicable. Categorical datasets (group size and composition) were analysed using Pearson χ^2 tests. A Fisher's Exact test was performed when categorical data did not meet the conditions for χ^2 analyses. Parametric analyses and a Bonferroni Multiple Comparisons post hoc test were undertaken after a log-transformation had been performed on water depth and SST data for the purpose of assessing differences in the number of group size categories among groups containing immature animals in relation to water depth and SST. All statistical analyses were conducted using SPSS (version 18, IBM, SPSS Inc. 2009) at $\alpha = 0.05$.

Finally, a retrospective analysis of opportunistic photo-id data was conducted to examine, where possible, any potential bias with the group-size estimates reported. Photo-id data was used to determine if group-size estimates were correct by: (1) comparing the minimum number of individuals captured; and (2) examining for the presence/absence of expected associates for known individuals photo-identified (following Visser 2000). Here, expected associations were based on long-term photo-id of this population (since 1994), and defined as well recognised individuals that previously have had associates with them during five or more occasions (Visser 2000, I. Visser, Orca Research Trust, unpubl. data). While overestimation of group size could not be assessed (as some individuals may not have been photographed despite being present), photo-id was used to identify underestimation by examining the number of individuals represented in the photo-id data versus the reported group size estimates.

Results

Survey effort

Data were collected monthly between September 2000 and April 2010 during 4582 trips onboard *DE*. A total of 119 independent orca encounters were recorded, with effort greatest during summer and lowest in spring and winter. ER also varied seasonally, being highest in spring and lowest in summer (Fig. 2).

Presence in relation to abiotic parameters

Orca were sighted in water depths ranging from 4.8 to 47.9 m (mean = 24.7, SEM = 1.39, n = 105). Although this species was often observed in deeper waters during autumn (median = 29.8, interquartiles = 19.6–37.7, n = 16) and winter (median = 27.8, interquartiles = 11.7–38.8, n = 40) than in spring (median = 16.8, interquartiles = 7.7–37.5, n = 38) and summer (median = 19.9, interquartiles = 12.0–24.6, n = 11), no seasonal difference in water depth was evident (H = 4.78, d.f. = 3, P = 0.188).

Orca were located in waters with SST ranging from 12.8 to 23.6 °C (mean = 17.0, SEM = 0.26, n = 104). Occurrence in relation to mean log-transformed SSTs varied significantly between seasons (ANOVA: F = 49.566, d.f. = 3, $P < 0.0001$; Fig. 3), ranging from 14.4 °C (SEM = 0.22, n = 33) in winter to 19.8 °C (SEM = 0.49, n = 14) in autumn. Bonferroni post hoc tests also indicated that both winter and spring differed significantly from all other seasons ($P < 0.05$).

Group size in relation to abiotic parameters

Group size ranged from a single orca to 18 individuals (mean = 5.6, SEM = 0.4, n = 116;

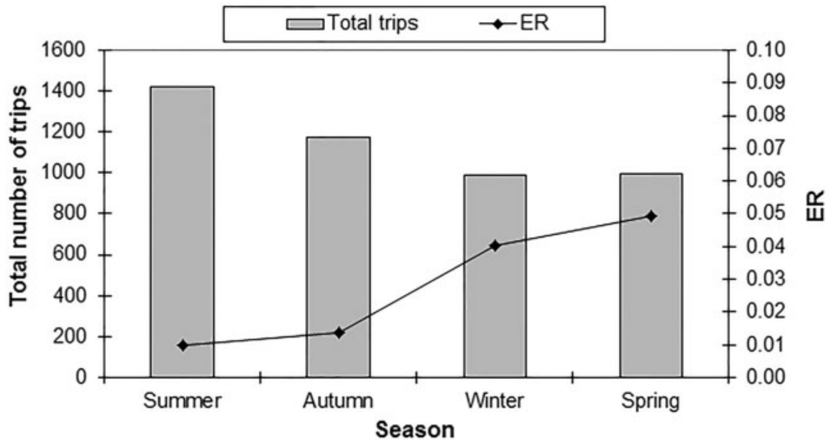

Figure 2 Seasonal encounter rate (ER) for orca (*Orcinus orca*) sightings between September 2000 and April 2010 in the Hauraki Gulf, New Zealand.

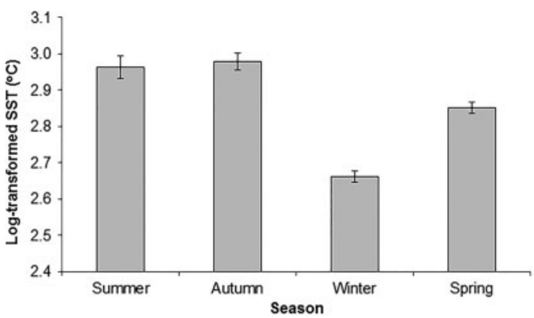

Figure 3 Season in relation to sea surface temperature (SST) for orca (*Orcinus orca*) sightings between September 2000 and April 2010 in the Hauraki Gulf, New Zealand. Bars represent the standard error of the mean.

Fig. 4), although they were predominantly observed in smaller groups (one to five animals, 58.6%, n = 68), where group sizes of two animals accounted for 25% (n = 29) of these smaller groups. While smaller groups of orca were most frequent in winter (39.7%, n = 27), and medium/large groups (> five animals) were most common in spring (47.9%, n = 23), group size did not vary significantly seasonally (χ^2 = 5.320, d.f. = 3, P = 0.150).

When accounting for ER in relation to group size, ER was highest for medium groups in spring and highest for both small and large groups in winter (Fig. 5). Given that there were no significant differences between ER in autumn and summer (z = 0.82, 95% CI = −0.006 to 0.014, P = 0.411), or between winter and spring (z = −0.75, 95% CI = −0.021 to 0.010, P = 0.451), autumn/summer and spring/winter were pooled, respectively. Significant differences in ER were detected for both small (z = −4.34, 95% CI = −0.022 to −0.008, P < 0.0001) and medium groups (z = −2.20, 95% CI = −0.011 to 0.001, P = 0.028).

Group size varied with water depth (H = 17.38, d.f. = 2, P < 0.001), with groups containing one to five animals typically recorded in deeper waters (median = 31.7, interquartiles = 16.4–40.2, n = 60), whilst groups containing > 10 animals were frequently observed in shallower waters (median = 9.7, interquartiles = 7.2–10.7, n = 10; Fig. 6).

The mean SST at which different group-size categories were observed was significant (F = 4.365, d.f. = 2, P < 0.015; Fig. 7). Large groups (> 10 animals) were recorded in cooler waters (mean = 15.5, SEM = 1.1, n = 7), while medium groups (six to 10 animals) were observed in warmer waters (mean = 18.0, SEM = 0.5, n = 33).

Opportunistic photo-id was only available for 14 of the 119 encounters. When analysing group-size estimates, taking into account those individuals who could be expected to be present (expected associations), five of the 14 records (37.1%) had group-size estimates, which were too small to incorporate expected associates. In addition, there

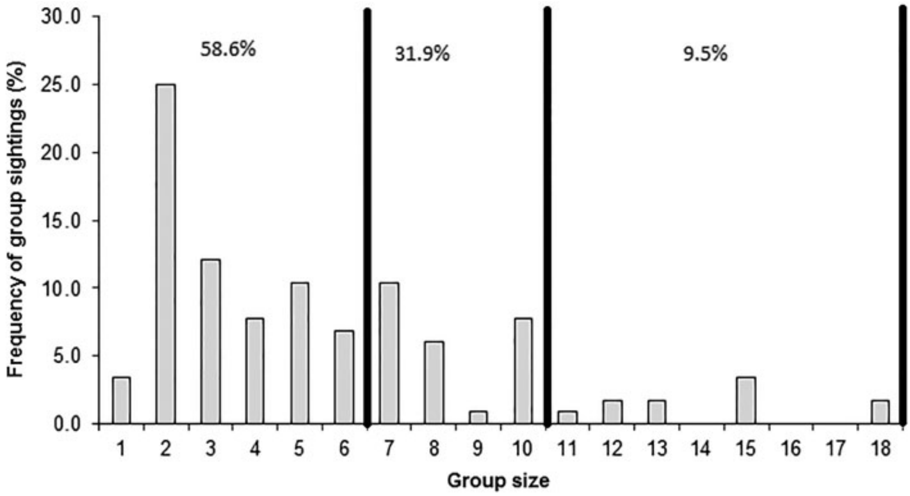

Figure 4 Frequency of orca (*Orcinus orca*) group sightings between September 2000 and April 2010 in the Hauraki Gulf, New Zealand. Vertical lines separate the group-size categories: small, medium and large.

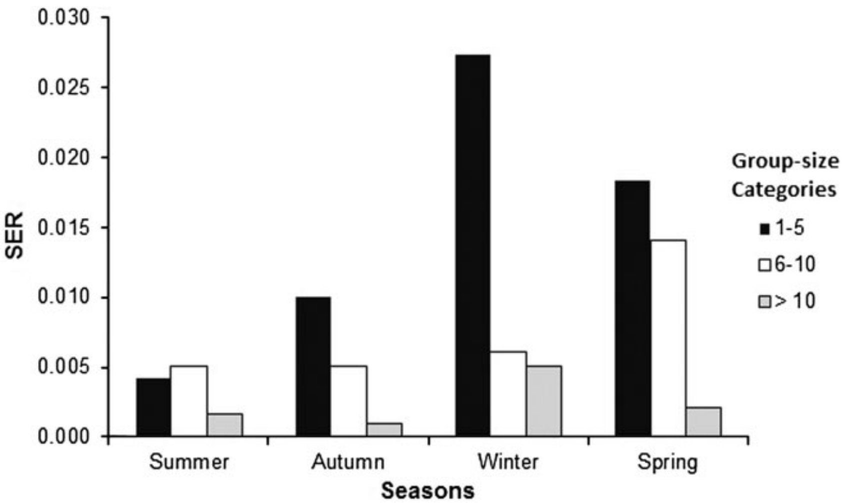

Figure 5 Seasonal encounter rate (ER) for orca (*Orcinus orca*) sightings in relation to group size between September 2000 and April 2010 in the Hauraki Gulf, New Zealand.

were two further encounters (14.3%), where the group size was estimated to be less than the number of individuals photo-identified.

Group composition in relation to abiotic factors

Analyses were performed only on data from groups in which immatures were confirmed as present or absent. Sixty-seven percent of groups (n = 63) included immature animals and were observed across all seasons. The relative frequency of groups containing immature animals (in relation to all groups) could not be assessed statistically for months and years due to a small sample size.

Sightings of immature animals were highest in spring (42.9% of groups, n = 27) and lowest in

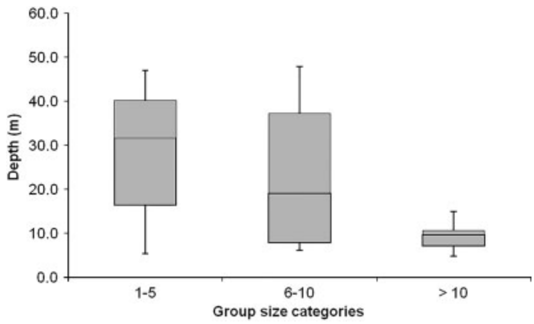

Figure 6 Group-size categories in relation to water depth for orca (*Orcinus orca*) sightings between September 2000 and April 2010 in the Hauraki Gulf, New Zealand. Lines represent the median, boxes the 25th and 75th interquartiles, and bars the range.

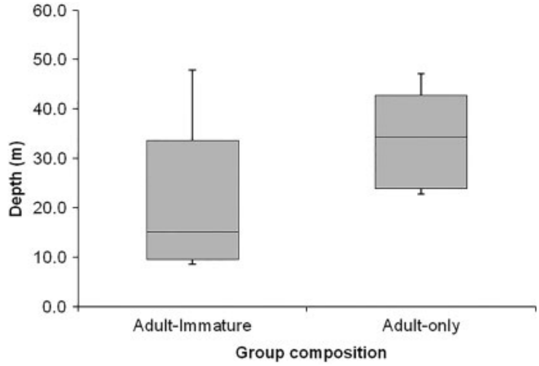

Figure 8 Group composition (immature versus adult-only groups) in relation to water depth for orca (*Orcinus orca*) sightings between September 2000 and April 2010 in the Hauraki Gulf, New Zealand. Lines represent the median, boxes the 25th and 75th interquartiles.

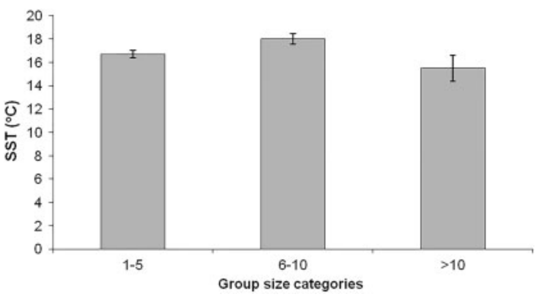

Figure 7 Group-size categories in relation to sea surface temperature (SST) for orca (*Orcinus orca*) sightings between September 2000 and April 2010 in the Hauraki Gulf, New Zealand. Bars represent the standard error of the mean.

summer (15.9% of groups, n = 10). However, the relative frequency of groups containing immature compared to adult-only animals did not vary significantly across seasons (χ^2 = 1.481, d.f. = 3, P = 0.723).

Water depths in which orca were located varied significantly (W = 2081, P = 0.0022; Fig. 8), with a higher presence of immature animals in shallower waters (median = 15.0, interquartiles = 9.5–33.6, n = 57) compared to groups containing adults only (median = 34.4, interquartiles = 23.8–42.8, n = 26). No significant difference in SST was observed between groups containing either immatures or adult-only animals (t = 0.893, P = 0.375).

Discussion

Presence in relation to abiotic parameters

Orca were encountered in the HG in water depths ranging from 4.8 to 47.9 m, with a mean water depth of 24.5 m. O'Callaghan & Baker (2002) recorded orca in a mean water depth of 35.3 m. These depths very likely relate to the foraging methods primarily used by New Zealand coastal orca which have developed a specialised benthic foraging technique for capturing rays (*Dasyatis brevicaudatus, D. thetidis* and/or *Myliobatis tenuicaudatus*; Visser 1999c, 2000). According to Visser (1999c), in all areas where orca were observed to feed on stringray, the average water depth was 12 m, with foraging for rays not observed in depths > 30 m. While water depths may be associated with the prey species being consumed, it likely is also influenced by the type of data which were gathered from *DE*. For example, in the HG, *DE* may have spent more time in deeper waters considering the main species of interest for their commercial tours is the Bryde's whale, which is found at a mean water depth of 42.3 m (Wiseman et al. 2011).

The SST for orca sightings in the HG ranged between 12.8 °C and 23.6 °C, with a mean temperature of 17.0 °C. This finding is comparable with orca sightings from warmer waters, such as those in Papua New Guinea (Visser & Bonoccorso 2003), where SST temperatures are typically 26–30 °C (Davies et al. 1997), and in northern Peru where orca sightings were associated with SST over 20 °C (García-Godos 2004). The SST at which HG orca were observed varied significantly by season, with warmest waters recorded in autumn and coldest waters in winter.

Sighting encounter rates

Relative to effort, orca numbers were highest from June to November, indicating that the species uses the HG primarily during the winter and spring months. Nonetheless, opportunistic observations in the HG indicate that orca likely frequent HG waters all year round, although sightings were less frequent in summer and autumn. This concurs with Visser (2000, 2007), who reported a peak in sightings on the east coast of the northern North Island (including the HG) between August and October, with numbers still relatively high in November, and a secondary peak in May and June.

Sighting rates for orca in the HG may change due to seasonal variation in prey availability, as indicated for populations worldwide (e.g. Baird 2001; Iñíguez 2001; Pistorius et al. 2002; Ballard & Ainley 2005; McCluskey 2006). While the distribution and local abundance of prey could account for sighting rates indicated herein, the changes in sighting rates may also reflect platform bias caused by the non-random search patterns employed. For example, there may be differences between surveys conducted by the PoP and some research vessels, as the PoP may have received reports of orca sightings (i.e. from members of the public and/or coastguard) that research vessels may not be aware of. Additionally, the PoP used was not using methods designed for the specific purpose of monitoring occurrence and group characteristics of orca. Consequently, it is possible that the results presented herein represent an artefact of such a non-random search effort.

Previous studies of orca in New Zealand waters identified the east coast, northern North Island (including the HG) to have the highest sighting rate (Visser 2000). Although this is a reflection of high effort in this region, it is also possible that this area is used more frequently by orca, or that a larger subpopulation exists in this region (Visser 2000). Indeed, whilst New Zealand orca have been found to range over large distances (Visser 1999a, 2000, 2007), it has also been suggested that some individuals exhibit a smaller home range (Visser 2000, 2007). Another possible reason for the prevalence of orca records within the HG relates to platform bias, as the PoP may actively search for this species. Skippers acknowledge that when orca are known to be within the HG, an effort will be made to search in the location reported. This is not an uncommon practice, as orca have a high profile in the whale-watching industry worldwide (e.g. Duffus & Dearden 1993; Duffus & Baird 1995; Hoyt & Iñíguez 2008) and are the species of choice for many whale watchers (Hoyt 2006). Considering the PoP actively searches for orca who are known to be within the HG, a bias may result as animals become habituated to the vessel. Orca within this region may therefore behave differently in the presence of the PoP.

Group size in relation to abiotic parameters

Orca in the HG were observed as lone animals, and in groups of up to 18 individuals. Visser (2000, 2007) recorded group sizes for orca in all of New Zealand waters ranging from two to 22 individuals, with 12 individuals being most common (24% of encounters, n = 13). Worldwide, orca group size can vary considerably between and within populations. For example, Pacific northwest populations were predominantly recorded in group sizes of two to six individuals (97% of encounters) and of ≤ 12 individuals (52% of encounters) for 'transients' (Ford & Ellis 1999) and 'residents' (Ford et al. 1994), respectively. Off the west coast of Africa (off Angola, Gabon, São Tomé and Cameroon), the mean best estimate of orca group size was six individuals (18% of encounters, n = 32; Weir et al. 2010). Similarly, Palacios et al. (2012) reported the mean group size for orca of five individuals. In Papua New Guinea, groups of three individuals were the most sighted (n = 15; Visser & Bonoccorso 2003). Ivkovich et al. (2010) indicated that the mean group size for orca in Avacha Gulf, Russia, northwest Pacific, was six individuals.

Group sizes of ≤ five individuals were most frequently observed (58.6% of encounters, n = 68), with the most prevalent group size being two (25% of encounters, n = 29). Considering that this study examines the same population detailed by Visser (2000, 2007), it could be anticipated that the most prevalent group size would be similar in both studies. However, the PoP data presented indicated that the group size most reported was two, compared to 12 reported in Visser (2000, 2007). Photo-id data suggest that this trend may represent a bias from the PoP, as not all individuals within a group may have been photographed, leading to an underestimate of the mean group size. To examine this further, known associates for individual orca documented within the New Zealand population (Visser 2000, 2007) were examined with respect to their expected associates. Previous association indices have been performed on this population where, although there were some low association indices, the highest association index was 0.93 for four dyads (Visser 2000) where 1 would indicate that the animals were always seen together. This indicates that, for at least some individuals observed from the PoP, the likely associated conspecific may have been overlooked. For instance, one individual first documented in 1994 and catalogued as NZ29 (Visser 2000) was encountered by the PoP twice, in groups recorded as consisting of two individuals. However, the long-term photo-id records of this individual indicates that this male has never been observed (n > 20) without NZ28 and NZ30, his presumed older brother and mother, respectively (Visser 2000, I. Visser, Orca Research Trust, unpubl. data). All three animals have also been photographed with several other individual orca in the New Zealand population (I. Visser, Orca Research Trust, unpubl. data). Such known associations were not fully represented in either group of two individuals recorded by the PoP. Bigg (1982), when discussing orca populations off British Columbia, Canada, stated that pods generally do not split for more than a few hours or days. Bigg et al. (1990) also confirm similar strong social groupings. As such, the recognition of a single individual will generally indicate that the remaining members of its pod are nearby. Visser (2000) recognises that the New Zealand orca population has a more fission–fusion society than the population referred to by Bigg (1982). Consequently, there may be occasions where some individuals are separated for prolonged periods from other members of their pod. Overall, some individuals may not have been recorded due to: (1) biological factors (e.g. the possible wide distribution of individuals within a group, all of which may have not been observed); (2) PoP constraints (e.g. limited time with a focal group); and (3) observer variability (e.g. accuracy and consistency of the amount of data collected).

Alternatively, the group sizes reported herein may be representative of true group size, despite the previous associations that have been observed in the New Zealand orca population. It is plausible that individuals may have been seen from the PoP without their known associates being present, even if this has not previously been recorded for this population. The only way to assess for potential bias in capturing all individuals from a PoP would be to conduct a double platform survey (Buckland et al. 2001) between a PoP and a research vessel. This is akin to distance sampling methods that require estimation of detection probability, since true absence is often difficult to discern from false absence (Buckland et al. 2001). Here, the same group of orca would have to be observed concurrently and photo-id would need to be collected simultaneously from both platforms. This study reported six encounters with a single orca in the HG. Similar findings of lone orca have been reported in Alaska, USA (Maniscalco et al. 2007), Argentina (Lopez & Lopez 1985; Iñíguez et al. 2005), southeastern Brazil (Santos & Netto 2005; Santos & da Silva 2009; Lodi & Farias-Junior 2011), Kamchatka, Russia (Ivkovich et al. 2010), Marion Island (Condy et al. 1978), Pacific northwest (Ford & Ellis 1999), Papua New Guinea (Visser & Bonoccorso 2003), Peru (García-Godos 2004), Vancouver Island, Canada (Bigg 1982) and West Africa (Weir et al. 2010). However, solitary orca have not previously been encountered in

New Zealand waters (Visser 2000, 2007). Of course, it is possible that those individuals sighted within the HG were indeed travelling or foraging alone and that this is just a relatively new occurrence within the New Zealand population. Alternatively, considering that solitary animals are extremely unusual for this species in New Zealand waters (Visser 2000), it is possible that this result is due to the wide distribution of individuals within a group and limited time spent with the animals, as previously discussed. Moreover, as the PoP is restricted by its operational boundaries, it may be difficult to follow a focal group outside the HG to confirm the actual group size.

Another concern when recording group size from a PoP is the variability of observers, affecting the accuracy and consistency of data collection. Campbell & Francis (2011) described variation among observers to be one of the major challenges when using count data. In this study, the limited photo-id data indicated that observers may have underestimated orca group size in the HG. Conversely, a recent study by Martinez & Stockin (2011) revealed that experienced tour operators typically overestimate group size and such group estimates were only accurate half of the time (51.1%). Lusseau & Slooten (2002) also reported that members of the sighting network in Fiordland, New Zealand, overestimated group size when in the presence of large groups ($n \geq 25$ individuals). Furthermore, variation between PoP and independent research platform data may be due to differences in methodologies employed for data collection (Palacios et al. 2012). Martinez (2010), whilst researching Hector's dolphins (*Cephalorhynchus hectori hectori*), observed researchers systematically recording group size at the onset of an encounter. Crew members conversely did so whenever possible (e.g. during an encounter or at the end of an encounter; Martinez & Stockin 2011).

Bias associated with PoP data collection could be reduced by exercising caution when estimating group size. In terms of observer variability, all personnel should be appropriately trained to systematically collect and store sighting data for all encounters (including location, time of encounter, species, water depth, SST, group size, group composition and photo-id), providing invaluable long-term datasets to researchers and managers. Such datasets could be valuable for researchers who are examining various aspects of species ecology including abundance, social structure, range and site fidelity. Training need not be time consuming or expensive, but should comprise at a minimum some field experience with a trained observer. The precision of data collected from PoPs, such as the overestimation of group size, could be further reduced by implementing a standardised sampling protocol (e.g. by recording it systematically at the start of an encounter; Martinez & Stockin 2011).

Group composition in relation to abiotic factors

Groups containing immature animals represented over 67.0% of groups encountered during the present study. This is consistent with findings reported in Alaska, USA, where 68.1% of observed groups of orca contained immature animals (Leatherwood et al. 1990). However, the number of groups containing immatures in this population is relatively high when compared to other populations worldwide. In Papua New Guinea waters, Visser & Bonoccorso (2003) reported 43.2% of orca sightings containing immatures. Likewise, 53.8% of orca sightings in waters off Peru contained immature animals (García-Godos 2004).

In the HG, groups containing immature animals were sighted year round. This concurs with Visser (2000), who found that nearly all groups of orca encountered in various locations around the New Zealand coastline had immature animals present throughout the year. This may indicate that a distinct breeding season is unlikely for this species in New Zealand waters. However, caution must be taken when recording the presence of immature orca. The presence of immatures all year round may, therefore, be a reflection of the time needed for this species to reach maturity, rather than the addition of new recruits into the population. Additionally, discrepancies may be attributable to observer variability, as crew members on board may have varied levels of experience and training in identifying immature animals. This was highlighted by Martinez & Stockin (2011), who state that crew experience plays a key role in recording immature animals accurately.

Martinez & Stockin (2011) suggested tour operator data could not viably be used to estimate calving seasonality given the lack of consistency in data reporting from PoPs. Similar inconsistencies in data collection were also observed in Fiordland (Lusseau & Slooten 2002). Consequently, the precision of data collected from PoPs on the presence (or absence) of immature animals could again be improved via training of crew members (e.g. Campbell & Francis 2011) or the inclusion of experienced researchers onboard (e.g. Stockin et al. 2008b; Clemens et al. 2011; Petrella et al. 2011; Wiseman et al. 2011).

Summary

The findings presented here indicate that PoP data can be an efficient way to gather baseline data, albeit with possible biases. These biases relate to: (1) biological factors (e.g. the possible wide distribution of individuals within a group, all of which may have not been observed); (2) PoP constraints (e.g. limited time spent with a focal group, area covered within a given time); (3) observer variability (e.g. accuracy and consistency of the amount of data collected, levels of experience and training); and (4) platform bias (e.g. animal habituation to the vessel, prior knowledge of species location, non-random search patterns, opportunistic sightings and targeting of emblematic species, lack of GPS tracks).

Despite such biases, studies on the accuracy and consistency of data collection from PoPs have suggested that quantitative data were in general agreement with data collected from independent research platforms by experienced researchers using standardised sampling methods (e.g. Lusseau & Slooten 2002; Dahood et al. 2008; Martinez & Stockin 2011), with some exceptions. As such, PoPs can be a valuable means of collecting information on cetaceans for both research and management purposes (e.g. Evans & Hammond 2004; Kiszka et al. 2007; Moura et al. 2012; Davidson et al. 2014).

Whilst there are limitations of using PoPs for long-term research, some of these are likely to apply to long-term dedicated research vessels as well, particularly variation in ability of observers (who may have various levels of experience regardless of the level of training they receive), and also the ability to detect widely distributed groups. An advantage of conducting long-term research from a PoPs is that scientific research can be communicated to a wider community which will enhance public awareness of research projects.

Invaluable information collected from PoPs can be further improved by implementing specific sampling protocols, including systematic attempts to conduct photo-id and collect quantitative data (SST, water depth, group size and group composition). Data should also be collected systematically across various PoPs, in addition to ensuring data are correctly stored so they are accessible for interested parties. As a minimum requirement, crew members should be trained by an experienced observer on how to collect and store data in a field environment. Researchers should also (where feasible) be involved in training of crew members and conducting PoP surveys. To ensure the most accurate record of group-size estimates, a focal group should be observed as long as possible to examine potential fusion with other individuals. Duplicate detections from PoP and research vessels would also be advantageous to confirm true group size.

In order to maximise the value of data for conservation purposes, data collected from PoPs should be made available to researchers, conservation management agencies and other interested stakeholders. To improve the collection and reporting of vessel movements and cetacean sightings from multiple PoPs, a web application such as 'Whale and Dolphin Tracker' could be beneficial (as used by the Pacific Whale Foundation; Kaufman et al. 2011; Davidson et al. 2014). Such a system could be adapted by tour operators worldwide, improving the accuracy and efficiency of data recording and making consistent sighting data available for future research. Furthermore, where PoPs already report information, such a system would greatly enhance the overall quality of data collected. Finally, automating tracking of vessel routes (often lacking) would increase the type of analyses that can be conducted (e.g. Davidson et al. 2014).

If PoPs follow the recommendations outlined here, and are given appropriate guidance in the implementation of such practices, their value as contributors to the ongoing long-term conservation of species such as orca could be far reaching.

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