

## Observations of killer whales (*Orcinus orca*) in the fjords of Chilean Patagonia

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**Abstract** Killer whales occur in Chilean waters, but their seasonality, diets, and overall distribution are poorly known. Here, we present data on group composition, site fidelity, and prey species of individual killer whales recorded in 63 sightings between 2004 and 2012 in the Chilean Patagonian fjords. Group sizes were small (mean = 5, SD = 2.5 for calf groups; mean = 3, SD = 1.5 for non-calf groups), and occurrence was significantly lower in summer months. Photographs enabled identification of 55 individuals from natural markings, and all resembled Southern Ocean type A killer whales. The species was transient in the area; the average presence was 1.7 days with 60 % of individuals seen only once. Occupancy was 3–44 days, and low levels of site fidelity were recorded (64 % of individuals were seen in only 1 year). Group composition at short time scales (3 months)

remained stable, but we detected changes at longer time scales. Prey included fish, otariids, and seabirds. Twelve individual killer whales showed a broad dietary spectrum: 3 ate otariids and fish, 2 ate birds and otariids, and 7 ate otariids, birds, and possibly fish. Further research is needed to increase basic biological knowledge of these killer whales and to determine the relationship with type A killer whales from the Southern Ocean.

**Keywords** Group stability · Patagonian fjords · Prey · Seasonal occurrence · Southern Ocean type A killer whale

### Introduction

Killer whales (*Orcinus orca*) are found in all the world's oceans (Forney and Wade 2006), and this wide distribution results in a variety of morphological and behavioural patterns among populations (De Bruyn et al. 2013). In the Southern Ocean, 5 types of killer whales have been proposed (types A, B (2 forms), C, and D) based on differences in their diets, behaviour, morphology, habitat preferences, and genetic characteristics (Pitman and Ensor 2003; Morin et al. 2010; Pitman et al. 2010; Pitman 2011; Foote et al. 2013). In southern South America, the species has been studied in detail in northern Patagonia (Argentina) (López and López 1985; Hoelzel 1991) and sightings have been compiled for southern Chile (Capella et al. 1999; Häussermann et al. 2013).

Here, we present the results of dedicated observations of killer whales obtained during a 9-year study in the southern Chilean Patagonian fjords. Our findings provide new data and insights into this poorly understood population and complement the still limited information available on killer whales in southern South America.

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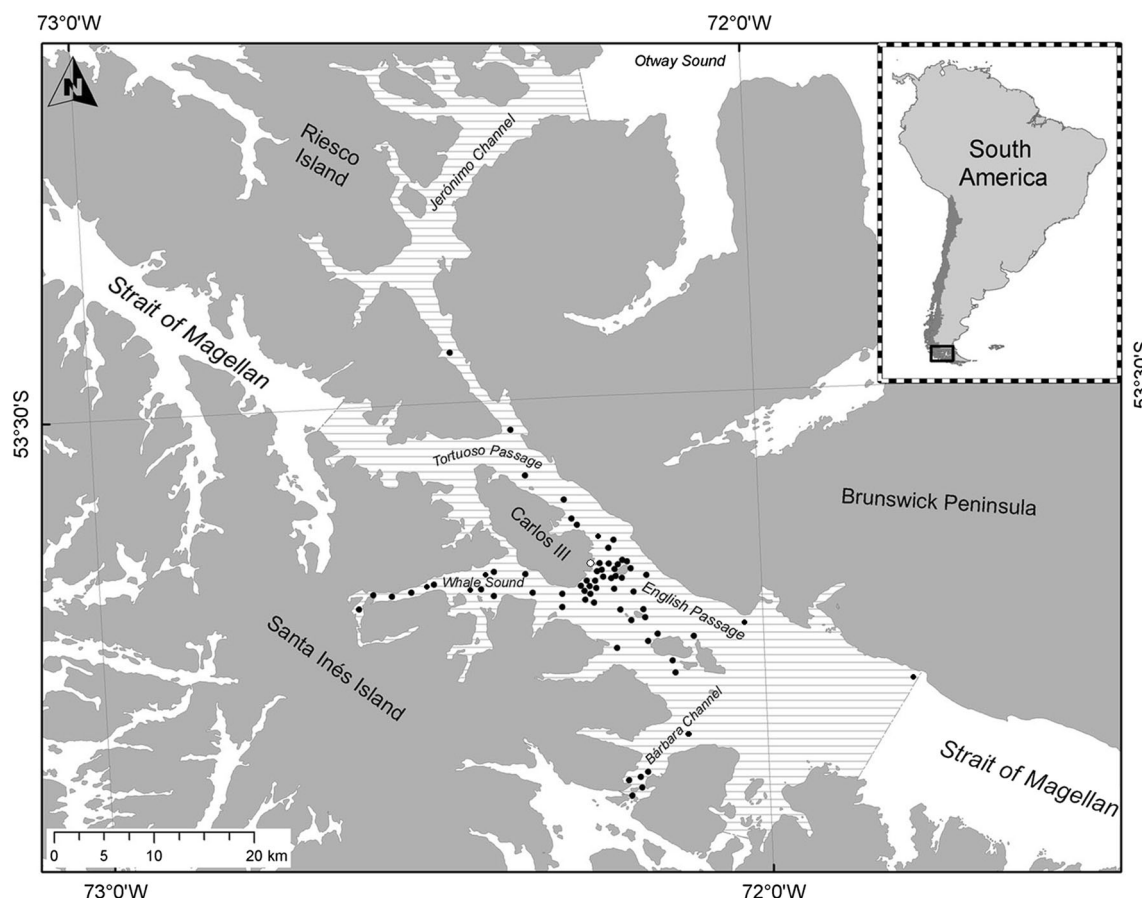
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**Fig. 1** Map of the study area covering approximately 950 km<sup>2</sup> (shaded) of the Chilean Patagonian fjords, southern South America; the box indicates where observations were made between 2004 and

2012. Black dots show the positions of killer whale sightings, and the white dot indicates the land-based observation site in the southeast of Carlos III Island

## Materials and methods

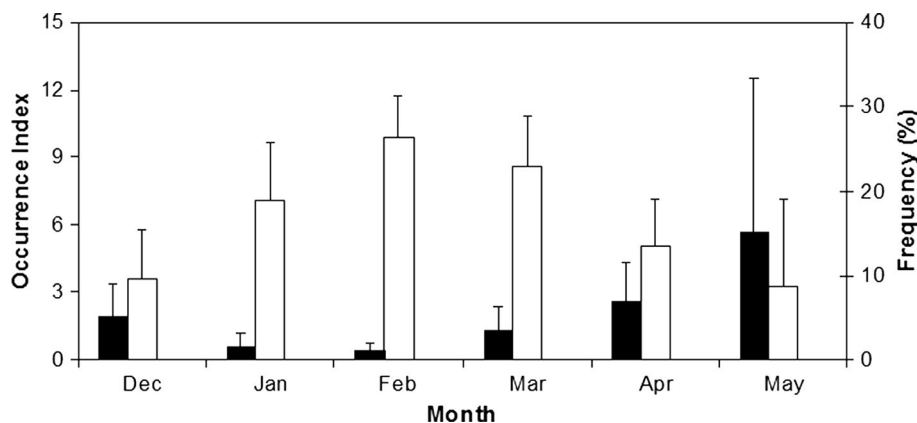
The study area covered approximately 950 km<sup>2</sup> of the inner waters of the Strait of Magellan (53°40'S, 72°20'W) and the contiguous fjords of southern Patagonia, Chile. The area is characterized by the presence of 2,000 otariids [South American fur seals (*Arctophoca australis*) and South American sea lions (*Otaria byronia*)] (Venegas et al. 2002), 90–100 humpback whales (*Megaptera novaeangliae*), more than 8,000 Magellanic penguins (*Spheniscus magellanicus*) (Miranda et al. 2009), and other seabirds. The study area was regularly surveyed during 2004–2012 as part of the long-term monitoring of feeding humpback whales. Boat-based surveys were performed on a random schedule and covered 18,100 km over a total of 520 days. Independent land-based observations were conducted on 780 days using 10 × 40 binoculars and a Nikon NE-205 theodolite and were usually made less than 1 km from the observation point located at 50 m above sea level on eastern Carlos III Island (Fig. 1). The total survey effort was 1,059 days (5,054 h), 97 % taking place during the

summer–fall (December–May) with an average of 114 days per season (SD = 13.6, range 97–131) and 4.7 h per day (SD = 0.4, range 4.1–5.4).

Information for each sighting included date, location, behaviour, group size, foraging events or harassment, numbers, and estimated distance of potential prey (otariids, humpback whales, and floating seabirds) up to 500 m from killer whales. When possible, we took photographs from the boat to enable identification of individual killer whales from natural markings (e.g. saddle patch pigmentation, dorsal fin shape, and nicks) (Ford et al. 2000).

We determined the composition of groups of killer whales according to 5 age–sex classes based on comparison of the estimated relative size of the animal and the dorsal fin, following the criteria of Bigg et al. (1990). An individual of a size in the range of a mature female, but without the constant close proximity of a calf, was considered to be undetermined. We used good quality photographs to compare the eye patch size and orientation, and the presence or absence of a dorsal cape, with patterns for the 5 killer whales types recognized in Southern Ocean waters.

**Fig. 2** Mean OI for killer whales (number of sightings per 100 h effort) and frequency (%) of average effort (*h*) by month between December (spring) and May (fall) 2004–2012 in the Chilean Patagonian fjords. Vertical lines indicate SD



For individual killer whales, we determined occupancy (the period in days between the first and last sighting within a season) and site fidelity (the number of years an individual was sighted during the study period). The stability of groups was evaluated based on the individual composition of groups re-identified at short time scales (within a 3-month period or a season) and at long time scales (more than 10 months apart or in 2 contiguous summer–fall seasons).

## Results and discussion

A total of 63 sightings (37 boat-based and 26 independent land-based sightings) were recorded (Fig. 1), representing 67 males, 63 females, 72 sex undetermined, 23 juveniles, and 52 calves. Group sizes showed no significant difference between boat- and land-based observations (Mann–Whitney *U* test,  $U = 41.5$ ,  $P = 0.62$ ). Groups with calves and/or juveniles included 2–16 individuals (mean = 5.0, SD = 2.5,  $n = 43$ ) and were significantly larger than non-calf groups (mean = 3, SD = 1.5,  $n = 20$ ; Mann–Whitney *U* test,  $U = 186.5$ ,  $P = 0.0002$ ).

Killer whales were seen throughout the year, and although our survey effort was sporadic between winter and late spring (3 % of total effort), we made 20 % of opportunistic sightings ( $n = 12$ ) in June, September, October, and November. There was no statistical difference in survey effort between years for the summer–fall season (Student's *t* test,  $t = -0.08$ ,  $P = 0.93$ ,  $n = 9$ ), but there was a significant difference between months (Kruskal–Wallis test,  $H = 24.8$ ,  $P = 0.00016$ ,  $df = 5$ ,  $n = 41$ ), with less effort in December and May. Fewer sightings occurred in the summer months compared with the fall months when effort was taken into account (Fig. 2). A standardized observation index, the occurrence index (OI) by month (number of sightings per 100 h effort), tended to be higher in late spring (December) and fall (April and May) (Fig. 2),

with significantly lower values in both January ( $P = 0.014$ ) and February ( $P = 0.0074$ ) than in April (Kruskal–Wallis test,  $H = 8.78$ ,  $df = 5$ ,  $n = 50$ ). This lower occurrence in summer months is in contrast to an equal seasonal distribution of sightings of killer whales in southern Chile, reported by Häussermann et al. (2013). However, the data in that study were not standardized by effort.

From 655 photographs of 31 groups, we made 82 positive identifications (12.5 % success). Fifty-five unique individuals were identified, including 15 females (27.3 %), 13 sex undetermined (23.6 %), 12 males (21.8 %), 8 calves (14.5 %), and 7 juveniles (12.7 %). We obtained 30 good quality photographs showing the head and back of 27 individuals from 13 separate groups of killer whales. All of them resembled Southern Ocean type A killer whales (Pitman and Ensor 2003), characterized by a medium-sized eye patch oriented parallel to the body axis, and no dorsal cape (Fig. 3). However, resemblance to type A killer whales must be viewed with caution because there is a lack of genetic verification and individual comparison with Southern Ocean type A killer whale catalogues.

Killer whales seemed to be transient in the study area; the average presence was 1.7 days (SD = 1,  $n = 82$ ) with 60 % of individuals seen only once, 24 % seen on 2 days, and 16 % seen on 3 or 4 days during the summer–fall season. Time of occupancy was short between December and May, with a range of 3–44 days (mean = 10.4, SD = 11.6,  $n = 33$ ). We found low levels of site fidelity over 9 years with 63.6 % of individuals ( $n = 35$ ) sighted in just 1 year, 27.3 % ( $n = 15$ ) in 2 years, and 9.1 % ( $n = 5$ ) in 3 different years. Fourteen adults were re-sighted in consecutive years, and the maximum interval between sightings was 7 years for 1 adult female (seen in 2004 and 2011) and 1 adult male (seen in 2005 and 2012). The transient condition and low fidelity in the study area is not surprising because killer whales are highly mobile, with studies elsewhere reporting daily movements of 60–240 km and home ranges



**Fig. 3** Photographs of eight different killer whales in the Patagonian fjords of Chile; all show eye patch shape and body colour patterning similar to type A killer whales in Antarctica

covering thousands of km<sup>2</sup> (Andrews et al. 2008; Foote et al. 2010; Matkin et al. 2012). The infrequency of re-sightings in several years in this study suggests a level of residency for most individuals in the fjords region of no longer than 1 year or 1 consecutive summer–fall season.

Group stability depended on the time scale. At short time scales, composition remained unchanged in 100 % of re-sightings of groups with all members photo-identified ( $n = 9$ ). At long time scales group composition was less stable. Seven from 12 groups (58 %) with all members photo-identified had at least 1 adult individual (8 females, 4 males, 2 undetermined) belonging to a different group in previous sightings (separated by 1–7 years). Two groups remained unchanged, and 2 others were part of a larger group in previous sightings. The apparent lack of stability of social groups between years in this study, particularly among females, differs from findings for fish-hunting killer whales in the eastern North Pacific (Bigg et al. 1990; Ford et al. 2000), but is typical of mammal-hunting killer whales in the same area (e.g. Baird and Whitehead 2000). Therefore, the findings described do not indicate a different social structure to this last type of killer whale. Our results

may have been affected by the small number of observations and/or may indicate that the groups sighted belonged to more stable larger aggregations not detected by our survey.

No interactions between killer whales and humpback whales were recorded, although between 1 and 11 humpbacks (including 7 cow–calf pairs) were observed within an estimated 500 m radius along the travel route of killer whales in 52 % of the sightings ( $n = 33$ ). The absence of harassment of humpback whales is consistent with the extremely low number of attacks reported (Jefferson et al. 1991; Dahlheim and White 2010).

We recorded chasing and feeding events in 5 and 9 sightings, respectively (Online Resource 1), and 12 of the 14 events involved groups of killer whales with calves. We observed 7 pursuits and feeding events targeting South American fur seals and South American sea lions (which also included a Magellanic penguin and a young kelp gull (*Larus dominicanus*) being killed and eaten and 2 Magellanic diving petrels (*Pelecanoides magellanicus*) being killed but not eaten). We also observed 2 events targeting fish (killer whales were observed with unidentified large

fish in their mouths) although we could not be certain that the fish were actually consumed. Killer whales killed otariids by ramming or knocking the seals with the head or the side of the body, pushing the prey out of the water with the head or throwing it from the mouth, or pulling it underwater while held in the mouth or pushing it down with the body. Finally, the whale chewed and ingested the prey on the surface ( $n = 2$ ) or underwater ( $n = 5$ ). We did not see killer whales swatting pinnipeds with their tails as has been described for other areas (Ford et al. 1998; Dahlheim and White 2010; Pitman and Durban 2012). Chasing and eating otariids lasted between 1 and 10 min, based on the time from the start of the attack until the prey was eaten. Females (with calves) carried out the killing on 5 occasions and males on 2 occasions, and prey was shared in at least 6 cases. Juvenile killer whales were involved in all cases of seabird hunting. In 73 % of sightings, we observed 8–625 otariids and 8–300 seabirds floating within an estimated 500 m radius along the travel route of the killer whales. Most of time, the otariids and seabirds exhibited no obvious evasive behaviour.

Chasing without obvious feeding was noted in 5 sightings: 1 with fur seals close to a resting rockery, 3 with fish (although predation may have taken place because killer whales were observed swimming fast and in circle formations on the surface, with extended diving in areas where sardine schools were being preyed on by birds, fur seals, and larger fish), and another with killer whales seen pursuing southern hakes, *Gadus australis*, which were chasing sardines close to the shore. Although the capture and consumption of fish were not observed in the chasing events involving fish, the prey was likely to have been southern hake, the most common large fish caught by fishermen in the study area, or pink cusk-eel (*Genypterus blacodes*) (pers. obs.). This suggestion is consistent with Häussermann et al. (2013) who recently reported that fishermen working in the southern hake fishery in the Strait of Magellan have observed killer whales removing fish from their lines.

Therefore, we observed feeding on different prey in 12 individual killer whales (Online Resource 1): 3 killer whales (a female, a male, and a juvenile) feeding on fur seals and fish (on 2 occasions with fish observed in the mouth but with no definite evidence of fish consumption), 2 individuals (a female and a juvenile) feeding on both penguins and sea lions during 1 sighting, 3 individuals (a female, a male, and a calf) feeding on fur seals (on 2 occasions) and a kelp gull, and 4 whales (2 females, a male, and an undetermined) feeding on fur seals and sea lions. Fish predation may have also occurred on two occasions for the last 7 killer whales mentioned above, as suggested by the observation of indirect behaviours (swimming in circle formations) (e.g. Dahlheim and White 2010).

Prey species previously reported for killer whales in southern Chile include Patagonian toothfish (*Dissostichus eleginoides*), South American sea lions, South American fur seals, and Imperial shags (*Phalacrocorax atriceps*) (Capella et al. 1999; Hucke-Gaete et al. 2004; Häussermann et al. 2013), but our observations are the first to document a non-specialist diet for identified individual killer whales. In addition, we documented predation on a Magellanic penguin and a kelp gull, and the killing of Magellanic diving petrels. Recently, Häussermann et al. (2013) did report predation on Magellanic penguins and gulls at 42° S, based on anecdotal evidence from fishermen, and the killing and subsequent abandonment of Magellanic diving petrels is consistent with killer whale behaviour with birds observed elsewhere (Williams et al. 1990).

Killer whales have been reported to attack or harass more than 100 different species, including seabirds (Jefferson et al. 1991; Visser et al. 2010). The broad dietary spectrum of 10 individual killer whales in this study is consistent with some sub-populations observed in New Zealand waters (Visser 2000) and transient populations in the North Atlantic and the eastern North Pacific (Ford et al. 1998; Saulitis et al. 2000; Foote et al. 2009). Many prey species have been reported for Southern Ocean killer whales (Guinet et al. 2007; Visser et al. 2008; Pitman and Durban 2010, 2012), but it is not known whether, at an individual level, a generalist diet is a common or a special case, as has been described for killer whales off the Patagonian coast in Argentina, and in South African and Australian waters (De Bruyn et al. 2013). Killer whales that resemble the type A form have been observed taking minke whales, southern elephant seals (*Mirounga leonina*), penguins, and fish near sub-Antarctic islands (Guinet et al. 2000, 2007) and have also been involved in the depredation of demersal long-lines targeting Patagonian toothfish near the Crozet and Kerguelen Islands (Roche et al. 2007).

The feeding habits of Chilean fjord killer whales differ from the habits of killer whales observed in other parts of Patagonia. At Peninsula Valdés, Argentina, killer whales strand themselves while attempting to capture South American sea lions in shallow waters (López and López 1985; Hoelzel 1991). On the Argentinean coast of the Beagle Channel, 200 km south of our study area, killer whales prey on dwarf minke whales (*Balaenoptera acutorostrata* subsp.) and sei whales (*B. borealis*). These species try to shelter near the shore and occasionally beach themselves while attempting to avoid predation (Goodall et al. 2007), behaviour observed centuries ago according to ethnographic studies of the native Fuegian people (Massone and Prieto 2005).

The lower occurrence of killer whales and apparently limited feeding activity in the study area during the summer months were unexpected because there is a high prey

density of seabirds, otariids, and humpback whales in these waters during the summer. This finding is unlikely to be a sampling artefact, because there was a high survey effort during the summer months. Our findings could reflect a reduced presence of these killer whales as a result of a summer migration to other Southern Ocean waters, similar to the seasonal movements from Antarctica to lower latitudes described for type B killer whales (Durban and Pitman 2012).

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