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Killer whale (*Orcinus orca*) occurrence and predation in the Bahamas

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*Killer whales (*Orcinus orca*) have a cosmopolitan distribution, yet little is known about populations that inhabit tropical waters. We compiled 34 sightings of killer whales in the Bahamas, recorded from 1913 to 2011. Group sizes were generally small (mean = 4.2, range = 1–12, SD = 2.6). Thirteen sightings were documented with photographs and/or video of sufficient quality to allow individual photo-identification analysis. Of the 45 whales photographed, 14 unique individual killer whales were identified, eight of which were re-sighted between two and nine times. An adult female (O06) and a now-adult male (O04), were first seen together in 1995, and have been re-sighted together eight times over a 16-yr period. To date, killer whales in the Bahamas have only been observed preying on marine mammals, including Atlantic spotted dolphin (*Stenella frontalis*), Fraser's dolphin (*Lagenodelphis hosei*), pygmy sperm whale (*Kogia breviceps*) and dwarf sperm whale (*Kogia sima*), all of which are previously unrecorded prey species for* Orcinus orca.

Keywords: killer whales, Bahamas, predation, Atlantic, *Orcinus orca*

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INTRODUCTION

Killer whales are predominantly temperate or cold water species and much is known about their distribution, behavioural ecology and localized abundance in colder climes (Forney & Wade, 2007). Although known to occur in the tropics (Leatherwood & Dalheim, 1978; Olson & Gerrodette, 2008), their occurrence in lower latitudes is not considered to be common in the north-west Atlantic (Katona *et al.*, 1988; Reeves & Mitchell, 1988), as evidenced by the scarcity of published accounts. Existing records of occasional sightings and strandings of killer whales in the waters of the wider Caribbean comprise reports covering much of the region including Florida (Moore, 1953), the Dominican Republic (Mattila *et al.*, 1994), Puerto Rico (Winn *et al.*, 1979), the Virgin Islands (Erdman, 1970) and Dominica (Evans, 1997). There were also a small number of killer whales taken in the St Vincent fisheries between 1967 and 1974 (Caldwell & Caldwell, 1975).

In the Bahamas, although killer whale sightings have been documented from as early as 1913 (Murphy, 1947), only one published record exists since that initial published account (Backus, 1961). Here we summarize all reported sightings in the Bahamas, including re-sightings of individuals, and document four new species of cetacean prey.

MATERIALS AND METHODS

Killer whale sightings from throughout the Bahamas were collated from a variety of sources. Primary data sources included sightings reported via a public sighting network and encounters with killer whales documented during dedicated marine mammal surveys. Since 1991, marine mammal sighting reports have been obtained through a public sighting network established and maintained by the Bahamas Marine Mammal Research Organization (BMMRO). This forum has increased public awareness of marine mammals locally and created a platform for citizen science to contribute to a database of cetacean sightings in the Bahamas, currently consisting of 22 species. In addition, dedicated opportunistic and line transect vessel surveys have been conducted in the northern Bahamas since 1991, mostly concentrated around Abaco Island (Figure 1), for the purpose of documenting the behavioural ecology, distribution and abundance of cetaceans in local waters. Survey effort covered approximately 5000 km of track line annually in both pelagic and coastal habitats and has occurred year-round since 2001.

During encounters, data were collected on species, group size and composition, and behaviour state of the animals, and each animal was photographed as described by Bigg (1982), for the purposes of species confirmation and individual identification. Additionally, both photographic and video recordings were used to document observations of killer whale feeding behaviour and prey species when feasible. Predation events were determined by directly observing killer whales killing an animal, including surfacing with prey parts in their mouths. Acoustic recordings were taken whenever possible during encounters, using a hydrophone at a depth of 10 m recording to an M-Audio Microtrack II digital recorder with a frequency response of 0.5 dB from 20 Hz to 20 kHz and a sampling rate of 96 kHz.

A catalogue of photographically identified killer whales was created from all documented killer whale encounters in the Bahamas. High quality photographs of individual whales were examined for key identifying characteristics including the dorsal fin, saddle and eye patch. All photographs and captured video stills of individual killer whales were compared to

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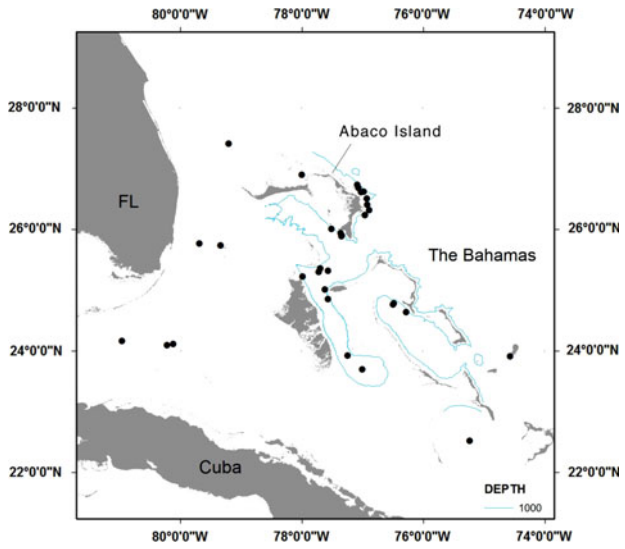

Fig. 1. Killer whale sightings (black circles) in the Bahamas and adjacent waters from 1913 to 2012. The 1000 m isobath is indicated in blue. See online publication for colour figure: doi: 10.1017/S0025315413000908

the catalogue, allowing individual animals to be repeatedly identified both within and across survey years and regions, and new individuals to be added to the catalogue chronologically upon discovery.

In addition to reviewing the published literature for killer whale sightings in the Bahamas, we also conducted an extensive search of local fishing websites and blogs, and requested photographs and videos of opportunistic encounters from individuals when their contact information was available.

RESULTS

The first reported sighting of a killer whale in Bahamian waters was from the whaling ship 'Grace' in 1913 (Murphy, 1947), and the first photographic evidence was of a stranded killer whale at Man O'War Cay in the northern Bahamas in 1960 (Backus, 1961). Contemporary records include an additional 32 sightings throughout the Bahamas and adjacent waters (Figure 1). Thirteen of these records include photographs and/or video of sufficient quality to allow identification of individual animals (Table 1). Despite the lack of documented evidence from the remaining 19 encounters, species

Table 1. Killer whale sightings in the Bahamas from 1913 to 2011. Seasonality is indicated by month–year order. For each encounter group size, prey taken, whale ID numbers, whether photographs or video were collected, and the information sources are indicated. Species abbreviations are: Sf, Atlantic spotted dolphin (*Stenella frontalis*); Lh, Fraser's dolphin (*Lagenodelphis hosei*); Ks, dwarf sperm whale (*Kogia sima*); Kb, pygmy sperm whale (*K. breviceps*); Ksp, unknown *Kogia* species. 'BMMRO' indicates data collected during dedicated cetacean surveys.

Month	Year	Group size	Prey	Whale ID	Photos or video?	Source
	1939	1			N	Mowbray, 1939
Apr	1968	6			N	CETAP, 1982
Apr	1981	3			N	Reeves & Mitchell, 1988
Apr	2008	2			Y	Public report
May	1994	3			Y	Public report
May	1995	6			N	Public report
May	1998	1			N	Public report
May	2003	2			N	Public report
Jun	1960	1			Y	Backus, 1961
Jun	1996	6		4	Y	Public report
Jun	1996	3			N	Public report
Jun	1997	2			N	Public report
Jun	2001	7	Lh & Ks	1, 2, 4, 6, 7, 8, 9	Y	BMMRO
Jun	2006	3		4, 6	Y	Public report
Jun	2008	3			N	Public report
Jul	1987	6	Ksp.	2, 10	Y	Public report
Jul	1993	6			Y	Public report
Jul	1995	6	Sf	1, 2, 3, 4, 5, 6	Y	BMMRO
Jul	2001	3	Kb		Y	Public report
Jul	2003	3			N	Public report
Jul	2005	4	Ks	1, 7, 9, 13	Y	BMMRO
Jul	2007	3			Y	Public report
Jul	2009	4		2, 4, 6, 14	Y	BMMRO
Jul	2010	4		2, 4, 6, 14	Y	BMMRO
Aug	1913	7			N	Murphy, 1947
Aug	2002	12		11	Y	Public report
Aug	2007	6			N	Public report
Aug	2008	2			N	Public report
Aug	2011	4		2, 4, 6, 14	Y	Public report
Aug	2011	4		2, 4, 6, 14	Y	Public report
Sep	2011	4		2, 4, 6, 14	Y	Public report
Oct	1991	12		11, 12	Y	Public report
Nov	2007	3			Y	Public report
Nov	2010	2			Y	Public report

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identification is considered to be sufficiently reliable due to the gross morphologically diagnostic characteristics unique to killer whales. Killer whale sightings were reported during every month from April through to November, although the majority of sightings were recorded in May through to August; none were reported during December through to March. Group sizes were generally small with a mean of 4.2 whales (range = 1–12, SD = 2.6).

Forty-five whales were photo-identified from the 13 encounters. After photographic comparisons among all encounters, 14 unique individual killer whales were identified, eight of which were re-sighted an average of five times (range = 2–9), representing at least one matriline. The most frequently sighted whale was an adult male (O04), first encountered in 1995 off the Atlantic side of Abaco Island, in the northern Bahamas, and subsequently re-sighted eight more times over a 10-yr period (2001 to 2011). Of particular note were sightings of this whale off south-west Abaco Island in June 2001, and only 5 km away from this location eight years later, in July 2009. During eight of the nine encounters that included O04 between 1995 and 2011, he was observed in a group of whales that included the adult female O06 who was seen with two different calves during this period (Table 1). Based on the high rate of co-occurrence of these two whales, and longitudinal data including genealogical studies of killer whales in the eastern North Pacific documenting natal fidelity to social groups (Baird & Whitehead, 2000), it is likely that this pair consists of a female and her male offspring.

Killer whales were observed preying on four species of marine mammals during five encounters, and three of these encounters were documented by BMMRO's field team (Table 1). Prey species identified included Atlantic spotted dolphin (*Stenella frontalis*), Fraser's dolphin (*Lagenodelphis hosei*), dwarf sperm whale *(Kogia sima*) and pygmy sperm whale (*K. breviceps*). In four out of these five encounters, the killer whales preyed on *Kogia* species (Table 1). Two of the killer whales present during the June 2001 encounter were also present in the 2005 encounter, and the encounter locations for these two events were less than 2 km apart. During both of these encounters, the killer whales predated upon dwarf sperm whales (Figure 2).

In 2009, a group of four killer whales approached a group of seven sperm whales (*Physeter macrocephalus*) containing a small calf. When the killer whales were approximately 0.5 km away, the sperm whales formed a rosette with their heads oriented inwards, and appeared to be protecting the calf, at the centre of this formation. Once the formation was complete, a young male sperm whale with an erect penis breached three times in succession, during which time the killer whales turned approximately 45° away from the sperm whale group, increased their speed and swam away. The sperm whale behaviour during this encounter was remarkably similar to that described by Pitman *et al.* (2001) during a fatal attack on sperm whales by killer whales off the coast of central California, although here the killer whales did not attack.

Moreover, no predation was observed during an encounter with a group of four killer whales in the waters off south-west Abaco Island in 2010, only approximately 8 km away from locations in south-west Abaco where killer whales have been observed preying on marine mammals. In 2010, behavioural and photographic data were collected over a period of 7 h during which the killer whale group was followed off the south-west coast of Abaco Island and visual contact was maintained. During the course of the encounter, the killer whales were silent, with real-time listening to the hydrophone documenting no sounds, and post-analysis of recordings made whilst in the presence of the killer whales having recorded no sounds either. The whales remained in a tight formation, and travelled slowly in a primarily directional course throughout the encounter, passing within 1 km of three different groups of Blainville's beaked whales, and four groups of *Kogia* sp. without any obvious alteration of their course of travel or behavioural state. There was an occasional zig-zag pattern to their track but this was believed to be avoidance of the research vessel during close approaches to obtain photographs.

During three encounters (2001, 2009 and 2010), we deployed a hydrophone to listen for killer whale sounds immediately before, during and after prey captures, as well as during periods when the whales were travelling slowly. Killer whale sounds were recorded in 2001 following predation on a dwarf sperm whale by seven killer whales, but no killer whale sounds were recorded during all other events, both before, during and after obvious predation events, as well as during slow travel as exhibited in 2010.

Fig. 2. A young killer whale with a dwarf sperm whale (*Kogia sima*) in its mouth off Abaco, the Bahamas (sighting 21, 27 July 2005).

DISCUSSION

It is assumed that due to the public interest in this species, most sightings have been reported either to the media, or to interest groups in the Bahamas, and therefore we believe the density of killer whales in the Bahamas to indeed be very low, as per our sighting record data. It is unknown whether killer whales historically occurred in this area in low density. Although there is no record of killer whales preying on the Caribbean monk seal (*Monachus tropicalis*), the commercial over-exploitation during the 1800s (Kenyon, 1977) of this potential prey species may have contributed to a decline in killer whale abundance in the Bahamas. Overall the low density of marine mammal prey in the tropics probably means that the area can no longer support an abundance of marine-mammal eating killer whales, if in fact it ever did.

The mean group size reported here is similar to that reported for groups of killer whales off Scotland foraging on seals (Beck *et al.*, 2011) as well as other studies of

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marine-mammal eating killer whales from warm water environments, e.g. Hawaii (Baird *et al.*, 2003). Small group size is suggested to be optimal for foraging success on marine mammals (Baird & Whitehead, 2000), and our observations support this suggestion for tropical killer whales in the Atlantic. Indeed, marine mammals appear to form significant prey for killer whales in the Bahamas, and particularly *Kogia* sp.

The lack of vocalizations produced by killer whales recorded during this study provides further support that that they may be targeting marine mammals as prey. By deliberately displaying stealth behaviour and remaining silent before an attack, they will avoid alerting marine mammal prey species with auditory ranges overlapping killer whale vocalization frequency range (Morton, 1990; Barrett-Lennard *et al.*, 1996; Deecke *et al.*, 2005).

Although *Kogia* sp., the principal killer whale prey identified in this study, occur in the Bahamas year-round (Claridge, 2006), killer whale occurrence here appears to be transitory. Movement patterns of killer whales are typically associated with the availability of prey species (Dahlheim, 1981). Recent studies, however, have shown that large scale movements of killer whales between Antarctic and subtropical waters may be needed for skin maintenance (Durban & Pitman, 2011), although these movements were aseasonal. Furthermore, the warm waters of the Gulf Stream would likely deem such a long migration (i.e. from the Arctic to the Bahamas) unnecessary. Nonetheless, Matthews *et al.* (2011) showed seasonal movement of killer whales from the Arctic to the mid-Atlantic in response to the onset of ice formation and suggested that killer whales in the North Atlantic have a large overall range.

It is notable though that the peak in killer whale sightings in the Bahamas occurred during late spring and early summer months which coincides with the seasonal migration of pelagic fish into the region (e.g. Theisen, 2007). However this apparent seasonal occurrence may simply be an artefact of increased opportunities for sighting whales as recreational fishing peaks during these months in response to the increase in pelagics. It is also possible that killer whales actually follow migrating pelagic fish into the Bahamas, and that the pelagics are their primary targeted prey (e.g. Guinet *et al.*, 2007) and marine mammals are taken opportunistically. However, (Dunphy-Daly *et al.*, 2008) suggested that a temporal shift in group size and habitat preference in *Kogia sima* in the area where our observations of predation on this species occurred may be the result of a predator avoidance response. If this is the case, it seems unlikely that this level of learned response to predation would result from opportunistic predation pressure. Certainly based on what we have reported here, *Kogia* appears to be a targeted, and perhaps important prey species for killer whales in the Bahamas.

Future work should include comparing photographic catalogues with other mid-Atlantic killer whale scientists, genetic sampling, the use of high frequency recording equipment for acoustic sampling, and satellite tracking (e.g. Andrews *et al.*, 2008) to help further our understanding of the population structure, movements and dynamics of these Bahamian killer whales.

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REFERENCES

Andrews R.D., Pitman R.L. and Ballance L.T. (2008) Satellite tracking reveals distinct movement patterns for Type B and Type C killer whales in the southern Ross Sea, Antartica. *Polar Biology* 31, 1461–1468.

Backus R.H. (1961). Stranded killer whale in the Bahamas. *Journal of Mammalogy* 42, 418–419.

Baird R.W., Mcsweeney D.J., Bane C., Barlow J., Salden D.R., Antoine L.R.K., Leduc R.G. and Webster D.L. (2003) Killer whales in Hawaiian waters: information on population identity. *Pacific Science* 60, 523–530.

Baird R.W. and Whitehead H. (2000) Social organization of mammal-eating killer whales: group stability and dispersal patterns. *Canadian Journal of Zoology* 78, 2096–2105.

Barrett-Lennard L.G., Heise K., Saulitis E., Ellis G. and Matkin C. (1995) *The impact of killer whale predation on Steller sea lion populations in British Columbia and Alaska.* Report to the North Pacific Universities Marine Mammal Research Consortium, Vancouver, BC, Canada.

Barrett-Lennard L.G., Ford J.K.B. and Heise K.A. (1996) The mixed blessing of echolocation: differences in sonar use by fish-eating and mammal-eating killer whales. *Animal Behaviour* 51, 553–565.

Beck S., Kuningas S., Esteban R. and Foote A.D. (2011) The influence of ecology on sociality in the killer whale (*Orcinus orca*). *Behavioral Ecology* 23, 246–253.

Bigg M. (1982) An assessment of killer whale (*Orcinus orca*) stocks off Vancouver Island, British Columbia. *Report of the International Whaling Commission* 32, 655–666.

Caldwell D.K. and Caldwell M.C. (1975) Dolphin and small whale fisheries of the Caribbean and West Indies: occurrence, history and catch-statistics with special reference to the Lesser Antillian Island of St Vincent. *Journal of the Fisheries Research Board of Canada* 32, 1105–1110.

CETAP (Cetacean and Turtle Assessment Program) (1982) *A characterisation of marine mammals and turtles in the mid- and North Atlantic areas of the U.S. Outer Continental Shelf, Final Report (Contract AA551-CT8-48, U.S. NTIS PB83-215855).* Washington, DC: Bureau of Land Management.

Claridge D.E. (2006) *Distribution and habitat selection of beaked whales.* MSc dissertation. University of Aberdeen, Aberdeen, UK.

Deecke V.B., Ford J.K.B. and Slater P.J.B. (2005) The vocal behaviour of mammal-eating killer whales: communicating with costly calls. *Animal Behaviour* 69, 395–405.

Dunphy-Daly M.M., Heithaus M.R. and Claridge D.E. (2008) Temporal variation in dwarf sperm whale (*Kogia sima*) habitat use and group size off Great Abaco Island, Bahamas. *Marine Mammal Science* 24, 171–182.

Durban J.W. and Pitman R.L. (2012) Antarctic killer whales make rapid, round-trip movements to subtropical waters: evidence for physiological maintenance migrations? *Biology Letters* 8, 274–277.

Erdman D.S. (1970) Marine mammals from Puerto Rico to Antigua. *Journal of Mammalogy* 51, 636–639.

https://doi.org/10.1017/S0025315413000908 Published online by Cambridge University Press

Evans P. (1997) *Dominica, nature island of the Caribbean: a guide to dive sites and marine life*. (Ministry of Tourism, Government Headquarters, Roseau, Dominica). Sussex: Faygate Printing, pp. 28.

Forney K.A. and Wade P.R. (2007) World-wide abundance and density of killer whales. In Estes J.A., DeMaster D.P., Doak D.F., Williams T.M. and Brownell Jr R.L. (eds) *Whales, whaling and ocean ecosystems*. Berkeley, CA: University of California Press, pp. 145–162.

Guinet C., Domenici P., De Stephanis R., Barrett-Lennard L., Ford J. and Verborgh P. (2007) Killer whale predation on bluefin tuna: exploring the hypothesis of the endurance–exhaustion technique. *Marine Ecology Progress Series* 347, 111–119.

Katona S.K., Beard J.A., Girton P.E. and Wenzel F. (1988) Killer whales (*Orcinus orca*) from the Bay of Fundy to the equator, including the Gulf of Mexico. *Rit Fiskideildat* 11, 205–224.

Kenyon K.W. (1977) Caribbean monk seal extinct. *Journal of Mammalogy* 58, 97–98.

Leatherwood J.S. and Dalheim M.E. (1978) Worldwide Distribution of Pilot Whales and Killer Whales. Available at: http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA061809 (accessed 28 June 2013).

Matthews C.J.D., Luque S.P., Petersen S.D., Andrews R.D. and Ferguson S.H. (2011) Satellite tracking of a killer whale (*Orcinus orca*) in the eastern Canadian Arctic documents ice avoidance and rapid, long-distance movement into the North Atlantic. *Polar Biology* 34, 1091–1096.

Mattila D.K., Clapham P.J., Vasquez O., Bowman R.S., Mattila D.K., Clapham P.J., Vásquez O. and Bowman R.S. (1994) Occurrence, population composition, and habitat use of humpback whales in Samana Bay, Dominican Republic. *Canadian Journal of Zoology* 72, 1898–1907.

Moore J.C. (1953) Distribution of marine mammals in Florida waters. *American Midland Naturalist* 49, 17–158.

Morton A.B. (1990) A quantitative comparison of the behaviour of resident and transient forms of the killer whale off the central British Columbia coast. *Report of the International Whaling Commission* 12, 245–248.

Mowbray L.L. (1939) Certain citizens of the warm seas. In *The Book of Fishes*. Washington, DC: National Geographic Society.

Murphy R.C. (1947) *Logbook for Grace: whaling brig Daisy 1912–1913*. New York: Time Inc., pp. 46–63.

Olson P.A. and Gerrodette T. (2008) *Killer whales of the eastern tropical Pacific: a catalog of photo-identified individuals*. US Department of Commerce, NOAA Technical Memorandum NMFS NOAA-TM-NMFS-SWFSC-428, 126pp.

Pitman R.L., Ballance L.T., Mesnick S.L. and Chivers S.J. (2001) Killer whale predation on sperm whales: observations and implications. *Marine Mammal Science* 17, 494–507.

Reeves R.R. and Mitchell E. (1988) Killer whale sightings and takes by American pelagic whalers in the North Atlantic. *Rit Fiskideildat* 11, 7–23.

Theisen T.C. (2007) *Population genetic structure, movement patterns, and environmental preferences of the pelagic wahoo*, Acanthocybium solandri. Dissertation, Florida Atlantic University, USA.

and

Winn L.K., Winn H.E., Caldwell D.K., Caldwell M.C. and Dunn J.L. (1979). Marine Mammals. In *A summary and analysis of environmental information on the continental shelf and Blake Plateau from Cape Hatteras to Cape Canaveral, by Center for Natural Areas*. (Vol. I, Book 2, Ch. 12). Alexandria, VA: National Technical Information Service.

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