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Distribution and abundance of killer whales (*Orcinus orca*) in Nunavut, Canada—an Inuit knowledge survey

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*Traditional ecological knowledge is being increasingly used in wildlife management in northern regions, and Inuit harvesters in Nunavut, Canada, have extensive knowledge about local wildlife species. We collected Inuit knowledge on killer whales (*Orcinus orca*) through 105 semi-directed interviews in 11 Nunavut communities from 2007 to 2010. Interviewees provided extensive information on killer whale movements, seasonal presence, distribution and abundance in the eastern Canadian Arctic. Observations from different communities were often complementary, and there was consistency in interview comments both within and among regions. Nearly all participants had seen killer whales at least once, and the whales were present every summer (July–September) in all regions, although movements depended on ice conditions. Relative abundance of killer whales varied by region, and they were reported more often in North Baffin communities than in other regions. Killer whales migrated through Hudson Strait and Lancaster Sound following their marine mammal prey. Estimates of local population sizes were variable, with suggested numbers that varied from tens to the low hundreds. Most interviewees in the Foxe Basin, Hudson Bay and north Baffin regions thought that killer whale presence was increasing. In contrast, half the South Baffin interviewees noted declines in past abundance due to the 1977 harvest of 14 whales that became trapped in a saltwater lake. Interviews provided information at a long temporal and wide spatial record. Inuit are reliable observers and continued killer whale research will be most effective if it integrates modern science approaches with the traditional skills, knowledge and experience of Inuit harvesters.*

Keywords: killer whale, Arctic, experience, harvesters, semi-directed interviews, traditional ecological knowledge, observation, wildlife management

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INTRODUCTION

Anecdotal evidence and reported observations suggest that the presence and occurrence of killer whales (*Orcinus orca*) is increasing in the eastern Canadian Arctic (Higdon, 2007; Higdon *et al.*, 2012). Inuit hunters have expressed concern regarding effects on marine mammal prey populations, including a number of marine mammal species of socio-economic and cultural importance (Higdon, 2007; Ferguson *et al.*, 2012a, b; Westdal *et al.*, 2013). There has been little directed scientific study on killer whales in the Canadian Arctic (Matthews *et al.*, 2011; Young *et al.*, 2011) and the ecology of this population is poorly known. Killer whales may be capable of significant impacts on prey populations and ecosystem structure (Springer *et al.*, 2003, 2008), and increased knowledge of Arctic killer whale distribution and ecology is needed for effective conservation and management. The Arctic region is undergoing considerable environmental and ecological changes (e.g. Serreze *et al.*, 2007; Higdon & Ferguson, 2010), and information on changing distribution and/or abundance of killer whales may help improve understanding of ecosystem dynamics and changes.

Increased sighting frequency may be related to a growing population, range expansion with decreasing ice extent, increased effort and reporting, or some combination thereof (Higdon, 2007; Higdon & Ferguson, 2009; Higdon *et al.*, 2012). Whatever the reason(s), increased presence of marine mammal-eating killer whales is likely to influence the abundance, distribution and behaviour of Arctic cetaceans and pinnipeds (Ferguson *et al.*, 2012a, b). In Nunavut, killer whales prey on a variety of species, including bowhead (*Balaena mysticetus*), narwhal (*Monodon monoceros*) and beluga (*Delphinapterus leucas*) whales, and ringed (*Pusa hispida*) and bearded (*Erignathus barbatus*) seals (Reeves & Mitchell, 1988; Higdon, 2007; Ferguson *et al.*, 2012a, b; Higdon *et al.*, 2012; Matthews & Ferguson, 2013 (this volume)). All these species are important to Inuit subsistence and culture, and negative opinions towards killer whales often relate to perceived competition for resources (Westdal *et al.*, 2013).

Reported sightings peak during the ice-free season, and killer whales appear to be relatively common in some areas of the eastern Canadian Arctic (Reeves & Mitchell, 1988; Forney & Wade, 2006; Higdon *et al.*, 2012). There are no

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data on population size and growth or stock structure, however. In comparison to other Arctic cetaceans, killer whale population size is small and densities are low, making standard survey techniques (aerial and vessel-based) less effective methods for estimating population size and trends (Forney & Wade, 2006; Higdon, 2007). One valuable source of information is the traditional ecological knowledge (TEK) and observations of Inuit harvesters, which represents the cumulative body of knowledge a person gains, through observation, experience and cultural transmission, about their local environment and the ecological relationships of the species residing there (Berkes, 1999; Usher, 2000).

There has been growing interest in the collection and use of TEK for co-management of Arctic resources and it is being increasingly used for wildlife management purposes (Wenzel, 2004; Tester & Irniq, 2008). A combination of information derived from TEK and modern science techniques is useful as they can provide different but complementary types of information (Huntington *et al.*, 2004; Gagnon & Berteaux, 2009; Lewis *et al.*, 2009; Westdal, 2009; Westdal *et al.*, 2010). Information from TEK surveys can also provide resource managers with a long temporal and wide spatial record (Ferguson *et al.*, 1998), and can be especially valuable in remote locations where scientific data are logistically difficult to collect. A number of studies have shown the value of Inuit observations in informing wildlife management and conservation (e.g. NWMB, 2000; Mallory *et al.*, 2006; Lewis *et al.*, 2009). Inuit harvesters are dedicated and reliable observers, and their observations can be particularly valuable for little known, rare and distinct species that are hard to survey using traditional scientific methods (Mallory *et al.*, 2003, 2008). Inuit harvesters have considerable knowledge on killer whales (e.g. Ferguson *et al.*, 2012a), despite this species generally being a non-harvested species in Canada. Here, we summarize information on the spatiotemporal distribution and abundance of killer whales collected using semi-directed interviews with Inuit hunters and elders throughout Nunavut.

MATERIALS AND METHODS

We used semi-directed interviews to document information on killer whale distribution and ecology provided by Inuit hunters and elders throughout Nunavut (11 communities in the *Qikiqtaaluk* (Baffin Island, including Foxe Basin) and *Kivalliq* (western Hudson Bay area) regions between July 2007 and March 2010: Figure 1; Table 1). Semi-directed interviews allow for the collection of TEK in an open and flexible way that avoids the rigidity of questionnaires (Huntington, 1998, 2000). We developed a list of questions in advance but the interview remained open-ended, giving each interviewee the option to elaborate on matters that they considered important. Using this process, the interviewee does not always address every topic that was included in the original list of questions, but in many cases allowed the interviewee to provide information not anticipated by the researcher.

Most interviewees were identified from lists of knowledgeable hunters provided by the local Hunters and Trappers

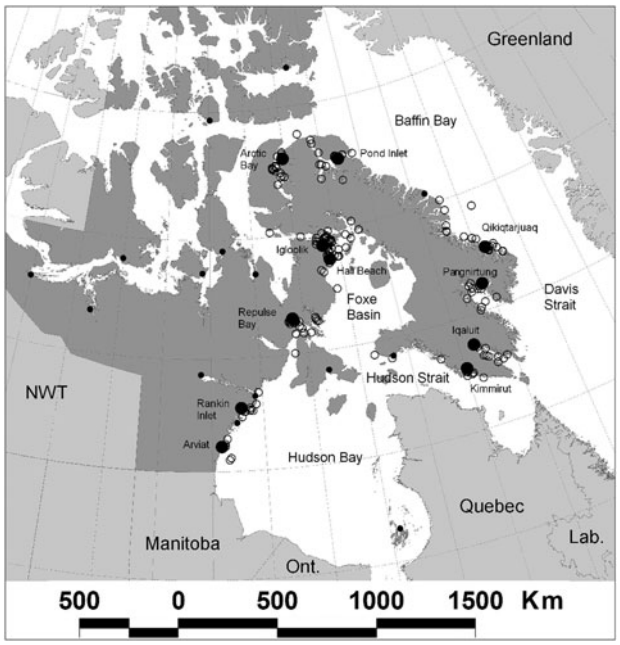

Fig. 1. Map showing Nunavut (darker grey) and surrounding area, major marine water bodies, locations of Nunavut communities (black circles: large circles with labels indicate communities interviewed, smaller circles are communities that were not included in the interview study), and killer whale sightings reported and mapped by interviewees (open circles, $N = 189$).

Table 1. Summary information for 105 semi-directed interviews conducted in 11 Nunavut communities, including region and demographic characteristics (sex and age (birth decade)) of interviewees.

Region	Community	Date visited	No. of interviews (no. male)	Interviewee age (birth decade)								
				1910	1920	1930	1940	1950	1960	1970	1980	No data
Foxe Basin	Hall Beach	February–March 2008	7 (5)		1	3		2	1			
	Igloolik	February–March 2008	16 (16)		1	4	3	1	4	2	1	
Repulse Bay	Arviat	March 2008	5 (4)			1		2	1			1
	Rankin Inlet	March 2008	10 (9)		1	2	3	2				2
	Repulse Bay	July–August 2007	17 (17)			2	3	3	5			4
South Baffin	Iqaluit	April–May 2009	7 (7)		1	1	1	1		1		2
	Kimmirut	February 2009	5 (5)			1	2	1				1
	Pangnirtung	January 2009	11 (9)	1		1	2	4	1			2
North Baffin	Arctic Bay	April 2009	11 (10)				3	5				3
	Pond Inlet	March 2010	8 (6)			3		3	1			1
	Qikiqtarjuaq	March 2010	8 (8)			1	1	6				
Total		July 2007–March 2010	105 (96)	1	4	19	18	30	13	3	1	16

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Organization (HTO) (reputational sampling), augmented using snowball sampling (suggestions of potential interviewees from other interviewees or interpreters). The most knowledgeable subjects identified by the HTOs tended be the active and former male hunters of middle age and older (see Results). Interviews were conducted using paper copies of maps from the Nunavut Land Use and Occupancy Study (Freeman, 1976), at varying spatial scales. Multiple maps were used in each community to capture sightings from different locations where interviewees have lived or travelled (e.g. Foxe Basin interviewees who formerly lived in Pond Inlet or Arctic Bay, and *vice versa*). In each interview, the maps were used to document spatial information, including specific observations of killer whales, general locations where killer whales are seen, migration routes, the interviewee's hunting locations and travel routes, and the locations of outpost camps.

Interviews were conducted in each community with the aid of a local interpreter, and most were conducted in Inuktitut (some using a mix of English and Inuktitut or English only). As such, for many interviews, our analyses are based on the statements provided by the translator and not the actual interviewee. We sought clarification on statements whenever warranted, and made efforts to ensure that the translator understood both our questions and the interviewee responses, to the extent possible. Interviews often consisted of extensive back-and-forth dialogue between the interviewer, translator and interviewee. Additionally, we sought to hire interpreters with experience of doing this kind of work and known to have an extensive knowledge of Inuktitut terminology. There were times however when interpreters had difficulty understanding some of the terminology used by elder interviewees. We trust in the honesty and accuracy of the interpreters when it comes to their descriptions of interviewee responses regarding general patterns (e.g. seasonal occurrence, relative abundance), but acknowledge that some important nuances were likely lost in translation (see Freeman, 1976: p. 53). We informed all interviewees that the interviewer would be available at the local hotel on the last day of the community visit, to allow interviewees to review their transcripts if they desired. Additional details on the interview process and questions, research permitting and approvals, and reasons for choosing particular communities are described in Ferguson *et al.* (2012a) and Westdal *et al.* (2013).

Data summary and analyses

The type of information provided varied among interviewees given the open-ended format, and a mix of qualitative and quantitative survey data on killer whales was analysed. Qualitative data were analysed using an interpretive approach to categorize results, where interviewee statements were manually grouped into related categories (e.g. distribution, abundance, seasonality) and patterns then summarized (Kitchin & Tate, 2000). Results were summarized within and between communities and four different regions (Table 1), and across eastern Nunavut as a whole. All individual sighting reports were added to a larger killer whale sightings database (Higdon, 2007), and observations from nine communities (pre-2010 interviews) were included in a recent analysis (Higdon *et al.*, 2012). In this study we report on information related to killer whale abundance and distribution in Nunavut waters. Inuit interviewees also provided extensive information on killer whale prey items and predation behaviour (Ferguson *et al.*, 2012a), and on human dimensions in killer whale management and conservation in Nunavut (Westdal *et al.*, 2013).

The information provided by each interviewee varied due to the semi-directed nature of the interview process, but all provided some indication of the number of killer whale sightings they had over the course of their lifetimes (also see Westdal *et al.*, 2013). This included a mix of quantitative (e.g. seen only once or twice, seen 5–10 times, $N = 29$) and qualitative (e.g. seen a few times, many times, regularly, annually, $N = 75$) descriptions. The number of lifetime sightings was given a categorical ranking, with interviewee responses ranked on a four-point scale: (1) None; (2) Little (one or two sightings in their lifetime); (3) Few (3–5 sightings, plus qualitative descriptions of 'a few' and 'some'); and (4) Many (one interviewee with 5–10 sightings, plus all those noting 'many' sightings). For statistical analyses, the None ($N = 3$) and Few ($N = 23$) categories were combined. The categorical ranking was tested against region, age (birth decade) and harvester status (full-time or part-time harvester) using χ^2 analyses of contingency tables. Community and regional results were summarized as an index of relative killer whale abundance. Interviewee age was divided into two categories for statistical analyses: those born in the 1910s–1940s and those born in the 1950s–1980s (i.e. evenly split into four decades per category, also see Westdal *et al.* (2013)).

The distribution of interviewee responses regarding various facets of killer whale abundance (sighting frequency, annual presence, population trends) by region was tested using χ^2 goodness of fit tests, and χ^2 tests of independence were employed to compare responses among different variables (e.g. dependence of population trend statements on past experience seeing killer whales). Fisher's exact tests were used in cases where χ^2 was inappropriate due to expected values less than five (McDonald, 2009). The index of qualitative variation (IQV) (Gibbs & Poston, 1973; Wilcox, 1973) was used to measure variability among responses, both within response categories and by region. The index is based on the ratio of the total number of differences in the distribution to the maximum number of possible differences within the same distribution. The IQV can vary from 0.00, when all cases are in the same category and there is no variation, to 1.00, when the cases are distributed evenly across the categories and there is maximum variation.

RESULTS

Interviewees

Of the 105 semi-directed interviews conducted in 11 communities (5–17 interviews per community, mean = 9.5), the majority of interviewees were male (91%, Table 1). We made an effort to interview older hunters to collect the longest temporal record possible. Information on age (year or birth decade) was provided by 89 interviewees, and the majority of these (72, 81%) were born in the 1950s or earlier (42 born in the 1940s or earlier, and the oldest interviewee was born in the 1910s) (Table 1). Younger hunters were interviewed on occasion, but only four interviewees were born in the 1970s or 1980s, and only one was less than 30 years old. The two age groups defined for analyses were evenly divided (42 born in the 1910s–1940s, 47 born in the 1950s–1980s).

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Harvester status was provided by 92 interviewees, with varying levels of detail. Some interviewees identified themselves as active full-time ($N = 18$) or active part-time ($N = 10$) harvesters, and another 13 stated that they were active part-time harvesters but were formerly full-time harvesters with reduced effort due to age, health or work. Nineteen elders were no longer active, due to age and health, but were full-time harvesters for most of their lives (or in the case of female interviewees were married to full-time harvesters). The remaining 32 interviewees simply noted that they were active hunters, without stating if they were full-time or part-time. The data were divided into two categories for statistical analysis – full-time and part-time. Full-time included those who identified themselves as active full-time, active part-time but formerly full-time, and no longer active but formerly full-time ($N = 50$) and part-time included the ten who identified themselves as part-time hunters plus the 32 who simply identified themselves as 'active' and were assumed to be part-time based on our experience in Nunavut communities. The majority of these interviewees were middle-aged or younger (in their 30s to 50s), and there are few full-time harvesters in this age bracket as many people have wage employment for at least part of the year (there are some younger full-time hunters, and some interviewees identified themselves as such) (also see Westdal *et al.*, 2013).

Killer whale presence in Nunavut

Nearly all participants (97%) had seen killer whales at least once, although not necessarily near their current community. Killer whales are widely distributed in Nunavut and have been observed in the general vicinity of all 11 communities, often in the same general areas and typically close to the community where the majority of harvesting activity is now focused (e.g. Priest & Usher, 2004) (189 individual observations were compiled from the interviews, mapped in Figure 1 to indicate the areas where whales are generally observed). However, the magnitude of their presence varies, and interviewees in some communities report seeing killer whales more regularly than others. Most interviewees ($N = 78$, 74%) provided an opinion on whether or not killer whales were present annually in their local area. In all four regions, the majority of interviewees reported that killer whales were present on an annual basis (Figure 2A). Patterns for yes/no responses did not vary by region (Fisher's exact test, df = 3, $N = 78$, $P = 0.313$), although analyses are confounded by non-responses, particularly in the Hudson Bay region. A small number of interviewees in all regions thought killer whales were not present every year, particularly in Foxe Basin and South Baffin.

Seasonal distribution

Killer whales are generally observed during the ice-free summer season, and interviewees in all communities noted that occurrence in a particular summer depends on ice conditions. Most interviewees provided information on the month(s) or season(s) when killer whales are usually seen. Over half the interviewees in each region reported that killer whales were usually seen in August (Figure 3), with July and September reported about equally often. Reports of killer whale presence in May occurred only in the South Baffin region, and this region also had the highest percentage of reports indicating June. Interviewees in Kimmirut noted that killer whales are usually observed migrating past in both spring and autumn.

Twenty-one interviewees discussed killer whale arrival in the spring and/or summer, and most noted that arrival depends on ice conditions. Half ($N = 11$) reported that killer whales arrive once the ice has cleared, while eight indicated that they are present after break-up starts, when there is still some loose ice present. One Repulse Bay interviewee noted that they usually arrive after the ice is gone, but in some years arrive when some ice is still present. One from Igloolik indicated that killer whales do not come to northern Foxe Basin in heavy ice years. Springtime killer whale occurrence, or lack thereof, at the floe edge (edge of the landfast ice) was mentioned by 28 interviewees. Most ($N = 20$) indicated that killer whales are not seen at the floe edge, as far as they were aware. Interviewees had never seen them there, despite considerable time spent hunting at the ice edge. Eight interviewees did note floe edge sightings, although only two were direct observations (once seen during springtime by an Igloolik hunter, and one from Pond Inlet noted that they were sometimes seen in June and July at the floe edge). The others were second-hand reports: two Pangnirtung interviewees noted that other hunters had seen three at the floe edge in April 2009 (also reported independently to DFO; S. Sowdlooapik, Government of Nunavut, personal communication, April 2009), and eight were reportedly observed at the Igloolik floe edge in June 1999 (a year when killer whales were reportedly more numerous than usual, Cosens & Blouw, 2003). One Igloolik interviewee stated that killer whales were present in July at the floe edge, and another noted that they had been seen going by the floe edge in Repulse Bay in June. A Repulse Bay interviewee had also heard of floe edge sightings in the spring. Overall, however, there were was very little evidence of killer whales being observed early in the season, before most of the ice is gone.

Six interviewees (North Baffin, Hudson Bay and South Baffin regions) noted that killer whale depart again before freeze-up, soon after the ice starts to form. Eleven interviewees stated that killer whales are never seen during the winter, and another 11 suggested that they went south to the open ocean where there is no ice. Five interviewees indicated that they did not know where killer whales went during winter. One from Arviat suggested that they might overwinter in the area between Greenland and Baffin Island (Davis Strait, Baffin Bay). An interviewee in Qikiqtarjuaq reported regular winter sightings while working on fishing trawlers off the coast of Labrador. Some groups would be small, and others would be larger groups of up to ~20 whales.

Relative abundance of killer whales throughout Nunavut

SIGHTING FREQUENCY OF INTERVIEWEES

The categorical index of killer whale sighting frequency was available for all 105 interviewees. Only one-quarter of interviewees had none or few lifetime killer whales sightings ($N = 26$), and a third had many sightings ($N = 31$). Sighting frequency patterns varied across region ($\chi^2 = 24.412$, df = 6, $N = 105$, $P = 0.0004$) (Figure 2B). This was most pronounced for interviewees with many killer whale sightings, as they were predominantly in the North Baffin region (63% of the total, IQV for

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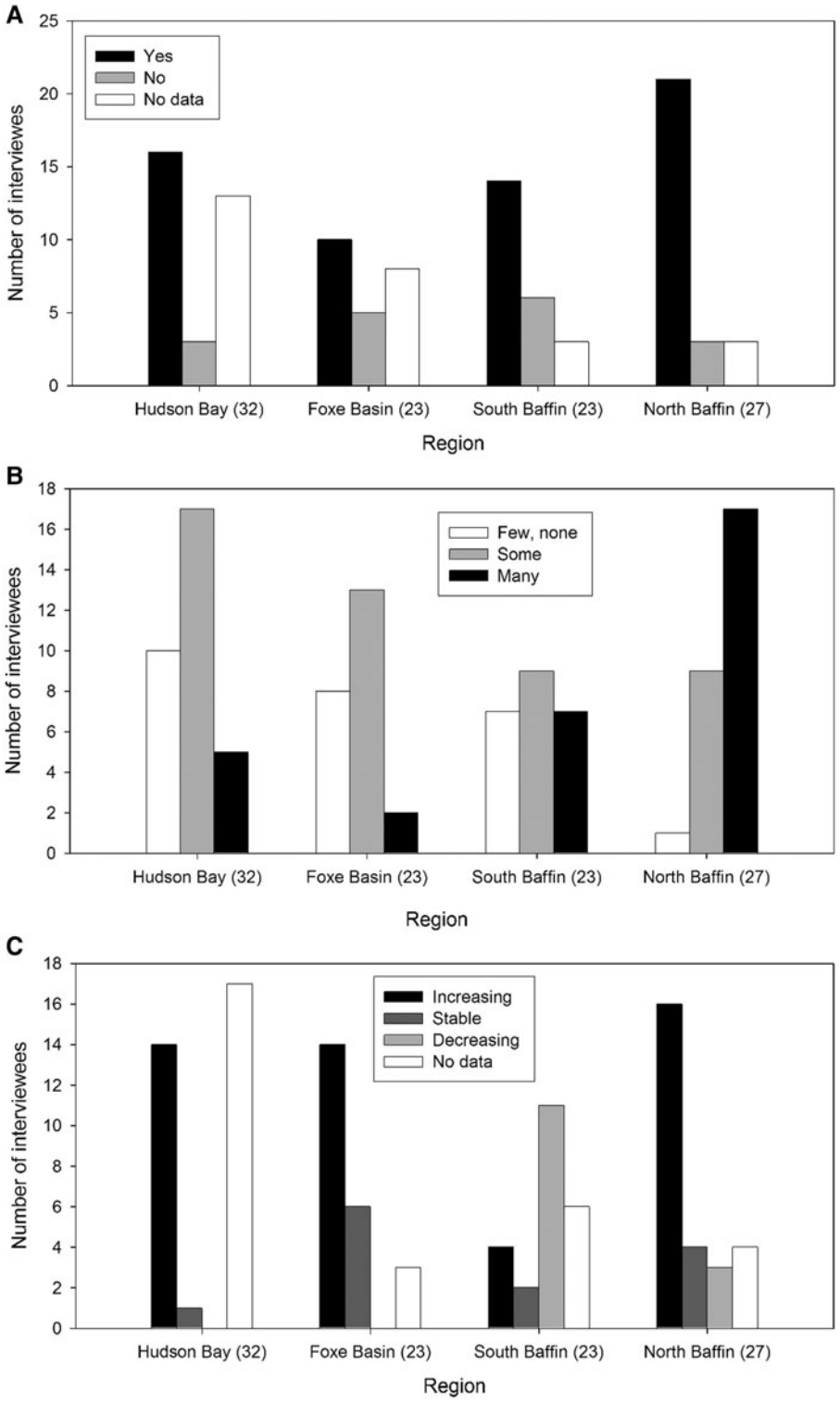

Fig. 2. Summary of interviewee responses by region (Table 1) to questions on killer whale occurrence: (A) whether killer whales are observed annually; (B) sighting frequency of individual interviewees; (C) observed trends in sighting frequency or population size.

region = 0.737). Sighting frequency categories were more variably distributed in the other regions (IQV range 0.828–0.992). The distribution of interviewees with some killer whale sightings was evenly distributed across all four regions, and the distribution of those with few or no sightings was somewhat uneven, with few in the North Baffin region. The proportion of interviewees with many, and many or some (i.e. both categories combined) killer whale sightings is mapped in Figure 4 as a measure of relative killer whale abundance in eastern Nunavut waters.

Sighting frequency also varied by community, with nearly all Arctic Bay residents (9 out of 11, 88%) having many killer whale sightings, and the other two North Baffin communities having half their interviewees with many sightings.

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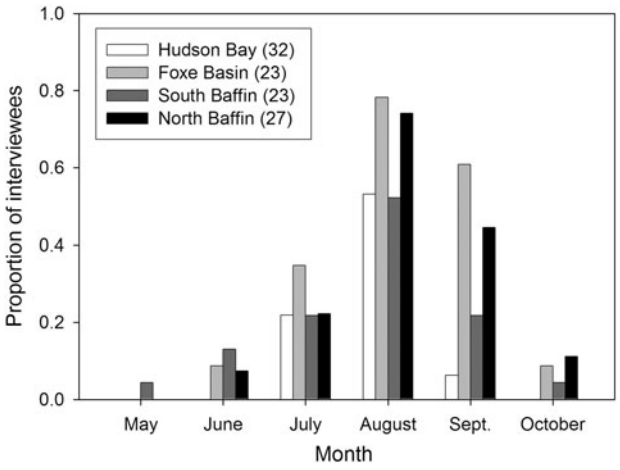

Fig. 3. Summary of interviewee responses by region (Table 1) on the months when killer whales are observed.

Eight of the Arctic Bay interviewees reported that they see killer whales every year, and four from Pond Inlet reported seeing killer whales frequently or regularly (e.g. almost every year). Three interviewees also reported that they do not see them often, or only once in a while, however. In Qikiqtarjuaq, two interviewees reported seeing whales every year, two more reported seeing them regularly, whereas others ($N = 2$) reported either rarely seeing them or having only one lifetime sighting. Further south, over half (6 out of 11) the Pangnirtung interviewees also had many sightings, including five who reported that they see killer whales every year, or did historically (prior to 1977, when 14 were killed after becoming trapped in a saltwater lake, Reeves & Mitchell, 1988), and another reported that he sees them 'frequently'.

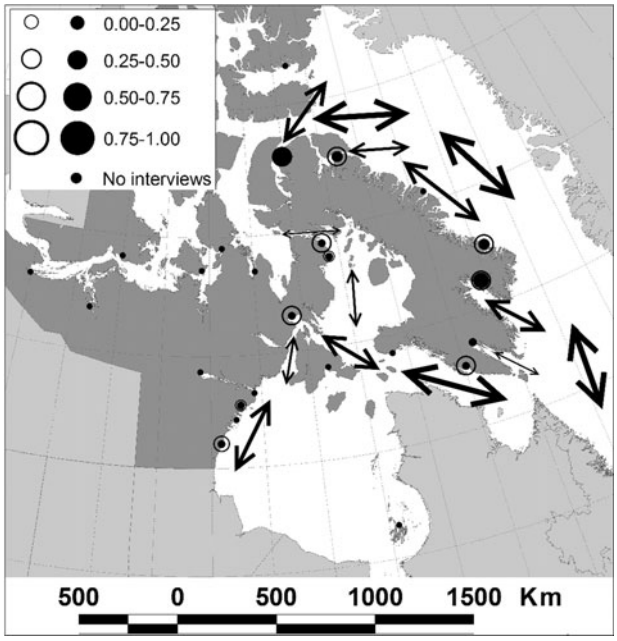

Fig. 4. Map showing frequency of killer whale sightings among interviewees in the 11 Nunavut communities visited and Inuit observations and knowledge of killer whale movements and suspected migration routes. Size of community symbols indicates the proportion of interviewees that had 'many' killer whale sightings (black inner circles) and the proportion with 'many' or 'some' combined (open outer circles). Arrows summarize killer whale movement patterns, with thickness approximately proportional to the number of interviewees identifying each area as a movement or migration corridor.

In contrast, Arviat and Kimmirut had no interviewees with many killer whale sightings, and Rankin Inlet, Hall Beach, Igloolik and Iqaluit had very few (≤14%). Kimmirut interviewees had never seen killer whales in the local area ($N = 2$), or had seen them once ($N = 1$) or rarely ($N = 1$), although the fifth interviewee reported occasional observations from the 1960s to the 2000s. Four Arviat interviewees reported only a single sighting in the local area, despite a lifetime of travelling and boating there (interviewees born between the 1930s and 1950s), and the fifth (born in the 1960s) had never seen killer whales. One Rankin Inlet interviewee reported seeing killer whales on 'many occasions', but the other interviewees had seen killer whales in the local area only once ($N = 3$), twice ($N = 2$) or never ($N = 3$) (with most reporting additional sightings in other areas). In Igloolik, most interviewees reported seeing killer whales in Foxe Basin rarely or occasionally ($N = 11$ noting less than five sightings in their lifetime) or having never seen them there ($N = 2$), although one reported seeing 'lots'. Three Igloolik elders declined an interview, and two indicated they had never seen killer whales before. Four Hall Beach interviewees had only seen killer whales once, another had never seen them in Foxe Basin, and another had seen them four times. Another 17 people who were contacted declined an interview, including nine who stated that they had never seen killer whales before and four who said they had only seen them once, at a distance. Four Iqaluit interviewees reported only seeing killer whales once, despite living there for 40-plus years. The youngest Iqaluit interviewee (born in the 1970s) reported sightings every summer in recent years, but always outside of Frobisher Bay. Three Iqaluit elders declined an interview, stating that they do not see killer whales in the bay. Results for Repulse Bay were variable, with one interviewee reporting that he saw killer whales every year, others with occasional sightings ($N = 8$) and others having never seen killer whales or only seen them in other areas.

RELATIVE ABUNDANCE AS REPORTED BY INTERVIEWEES

Many interviewees formerly lived in other areas of Nunavut, travelled extensively when younger, or often visit relatives in other communities, and thus have knowledge of killer whales in multiple areas. In total, 22 interviewees provided information on the relative abundance of killer whales in different areas of Nunavut (range 2–9 interviewees per region). Killer whales are reported to be less abundant in Foxe Basin than they are in Pond Inlet ($N = 8$), Arctic Bay ($N = 6$) and Repulse Bay ($N = 2$). Repulse Bay Inuit also see more killer whales than those in Rankin Inlet ($N = 3$), Iqaluit and Kimmirut ($N = 1$ each). Both the Pond Inlet and Pangnirtung areas were reported to have more killer whales than near Arviat ($N = 1$ each). One interviewee also indicated that there are more killer whales in Admiralty Inlet (near Arctic Bay) than Pond Inlet, and another suggested that there were more near Pangnirtung than Pond Inlet (historically at least). These observations further reinforce the pattern of relative abundance measured by interviewee sighting frequency. One Qikiqtarjuaq interviewee, a commercial fisherman, also reported that killer whales are more abundant

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offshore in Baffin Bay and Davis Strait, an area where there has been no directed study, than along coastal Baffin Island.

Movements and Migration

Interviewees provided extensive information on killer whale movements and suspected migration routes, summarized in Figure 4. Interviewees in all regions noted that killer whales are usually seen migrating past, although the whales sometimes stay around for a few days to several weeks to hunt ($N = 18$; Foxe Basin = 6, Hudson Bay = 3, North Baffin = 5, South Baffin = 4). Killer whales can be fast swimmers that are always moving around, or staying in different areas for only a short period of time ($N = 24$; Foxe Basin = 6, Hudson Bay = 2, North Baffin = 9, South Baffin = 7). Twelve interviewees reported that killer whales generally avoided shallow water, migrating through the deeper areas. This included seven people from Foxe Basin, who all noted that killer whales are not seen in the eastern side of the basin because it is too shallow. Five interviewees (Foxe Basin and North Baffin regions) reported that more killer whales migrate offshore than in shallow coastal waters. Reported major travel routes for killer whales are through Hudson Strait and Lancaster Sound (Figure 4). These whales follow similar routes as other marine mammals, as they may be migrating to follow their food. Nine Foxe Basin interviewees noted a relationship between bowhead population growth and increased killer whale presence, suggesting that killer whales were following bowheads to their summering areas.

Killer whales moved into Admiralty Inlet from Lancaster Sound as the ice breaks up, and were seen most frequently on the west side of the inlet where narwhal congregate ($N = 6$). They have also been observed near the community, which was reported to be a recent occurrence ($N = 6$). Five Pond Inlet interviewees discussed killer whale migration (both east and west) through Eclipse Sound. Killer whales move throughout Cumberland Sound, and sometimes even enter Pangnirtung Fjord, close to the community ($N = 6$). Three Iqaluit interviewees noted that killer whales are rarely seen inside Frobisher Bay, and are usually seen outside the bay. After migrating through Hudson Strait, killer whales enter Repulse Bay through Frozen Strait ($N = 3$), and they will also follow narwhal into Lyon Inlet ($N = 3$). One interviewee noted that killer whales will also move south through Roes Welcome Sound, and reported a sighting there, whereas another noted that he had never heard of killer whales there. Five interviewees noted that killer whales move north and south along the western Hudson Bay and Foxe Basin coastlines. One Repulse Bay interviewee noted that killer whales are often seen in that area around five days after being reported in Igloolik or Rankin Inlet. Foxe Basin interviewees suggested that killer whales came north from Hudson Bay and Hudson Strait, moving through either western ($N = 4$) or central ($N = 3$) Foxe Basin. Four interviewees suggested that killer whales do not migrate through Fury and Hecla Strait, but three others indicated that they do, following bowhead whales into the Gulf of Boothia in summer, and following narwhal in the opposite direction in autumn.

Absolute abundance

Interviewees in all four regions provided estimates of the number of killer whales thought to be present in the local area, although these numbers were highly variable (Table 2). Most interviewees ($N = 84$) provided at least some information, although 22 of these simply noted that they did not know or it was a topic to which they had given no thought. Two interviewees noted that abundance varied year to year, depending on food supply and/or ice conditions. Seventeen interviewees provided a numerical estimate of local abundance, with seven suggesting a local abundance of less than 20 whales (Table 2). Thirteen suggested a local population of less than 100 whales, although four indicated larger

Table 2. Summary of information provided by interviewees on abundance of killer whales in their local areas.

Summary of interviewee information on abundance on killer whales, number of whales present in area	Region			
	Foxe Basin	Hudson Bay	North Baffin	South Baffin
No information ($N = 21$)	3	9	5	4
No idea, not sure, doesn't know, doesn't give it any thought ($N = 22$)	6	4	9	3
Estimated total population size ($N = 17$)				
Less than 20	1	1	4	1
20 to 50		2	1	1
More than 50	1	1		
Hundreds		1	3	
Reports of maximum seen at a time ($N = 16$)				
Less than 20		3		1
20 to 30		4	2	1
50 or more		1	2	
100 or more		1	1	
Qualitative estimates of abundance ($N = 24$)				
Few, hardly any, not many	5	3	1	6
Less than many people think, because prey species are not declining	1			
Large group, lots, quite a few, too many	3	2	2	1
Number varies each year	1		1	
More in offshore regions			3	

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numbers: an estimate of 400–500 from Repulse Bay, a report from Pond Inlet that hundreds would be seen in offshore Baffin Bay in summer during the 1960s, an Arctic Bay interviewee who estimated over 200 killer whales were in Admiralty Inlet in late August 2004, and another Arctic Bay interviewee who felt that there might be hundreds in the area every year. Sixteen interviewees did not explicitly estimate local abundance but did note the largest aggregations that they had seen or heard of. Reports were again highly variable, with most reporting maximums of less than 30 whales, although several reported large aggregations of 100-plus animals. Qualitative estimates of abundance were provided by 24 interviewees, with the majority (15) stating that killer whales are rare (or few in number, hardly any, not many). Conversely, eight interviewees stated that there were lots, quite a few, or too many (Table 2). Three North Baffin interviewees indicated that killer whales are more abundant in offshore regions than they are near the coast.

Population trends

Most interviewees (75, 71.1%) provided an opinion on changes in killer whale abundance, local occurrence, and/or sightings over time (four others (one per region) noted that they were unsure if the population size was changing, and were removed from statistical analyses of regional patterns given the small sample size). Interviewees often distinguished between changes to sighting frequency and changes in population size (Table 3). Of 53 interviewees who reported 'increases', 27 specifically stated that the population was increasing, and 13 noted that sighting rates were increasing but did not mention anything about population size. Another eight reported increases in both sighting frequency and population size, and five suggested that sighting rates were increasing but the population was stable (i.e. killer whales spending more time in the local area, but no growth in numbers). Eight interviewees suggested that the killer whale population in their area was stable. For statistical analyses, reports of increasing numbers or increasing sightings were combined into one category, except for the reports of increasing sighting rates of a stable population, which were combined with reports that the population size was stable.

There was a significant difference in responses among regions (Fisher's exact test, $I = 75$, $df = 6$, $I < 0.0001$). Most interviewees thought that killer whale presence was increasing in the Foxe Basin, Hudson Bay and North Baffin regions (Figure 2B). No interviewees in the Hudson Bay or Foxe Basin regions felt that killer whale numbers (or sightings) were decreasing (but note the high degree of non-response for Hudson Bay: 17 of 30 with no data), and only three North Baffin interviewees provided the opinion that killer whale numbers were decreasing. In comparison, 11 of the 17 South Baffin interviewees that provided a response to this question suggested that the killer whale population was declining (every Pangnirtung interviewee). All 11 interviewees reported that killer whales are seen less frequently and in smaller groups than in the past, although one said that they have started to see more of them again in the last decade. Ten interviewees discussed an incident in 1977 as a possible link to this decline: 14 killer whales became trapped in a saltwater lake and were killed by local hunters (Reeves & Mitchell, 1988). Some participants felt that these killer whales were possibly part of the same group that returned to this area each year, and there have not been as many frequenting the area since this hunting event. Two said that killer whales did not return to the area for a long time after the incident, and one thought that in the future more killer whales will return again.

DISCUSSION

Interviews with Inuit hunters and elders provided extensive information on the distribution, abundance, and movements of killer whales, and these data represent a significant contribution to the body of knowledge on this species in the Canadian Arctic. Semi-directed interviews allowed an open and flexible format that avoids the rigidity of questionnaire surveys, but also resulted in variation in the types of information collected. Inuit harvesters are reliable observers with good recall abilities, and the semi-directed interviews provided information at a long temporal and wide spatial record. Interviewing elders allowed us to extract a long temporal record and a wider spatial record (from a period when Inuit were more mobile, prior to social changes such as movement into permanent communities). Information reliability is always a concern with historic recollections provided by older interviewees, as reliability can decline with time since an event was observed (e.g. Lien *et al.*, 1994). Inuit informants, however, may be 'more reliable' than many survey or

Table 3. Summary of interviewee opinions and observations of changes in killer population size and/or sighting frequency.

Region	Community	Increasing sightings	Increasing population	Increasing population and sightings	Increased sightings, population stable	Population declining	Population stable
Foxe Basin	Hall Beach		3		2		
	Igloolik		9	2			4
Hudson Bay	Arviat	3		1			
	Rankin		3	1			1
	Repulse Bay	1	3	2			
North Baffin	Arctic Bay	3	3		1	1	2
	Pond Inlet		4			2	
	Qikiqtarjuaq	2	2	2			1
South Baffin	Iqaluit	4			2		
	Kimmirut						
	Pangnirtung					11	
Total		13	27	8	5	14	8

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interview participants (e.g. commercial fishermen). Freeman (1976: vol. II) noted that people in non-literate cultures are trained from early childhood to have accurate memories, and for young men in hunting societies the greatest emphasis is on accurate recall of environmental information. Smith (1991: p. 153) considered the memories of his Inuit informants to be 'very keen', with an accuracy of recall that was 'extremely high'. Arima (1976: 35) concluded that Inuit recall was highly reliable within living memory from at least young adulthood, i.e. for approximately half a century.

Nonetheless, some degree of memory attrition was inevitable among older interviewees. Freeman (1976: vol. II, p. 53) noted that for land use interviews conducted in the early 1970s, it was apparent that incomplete data was being provided for the early years of the study (the years prior to the local arrival of traders, generally pre-1910s–pre-1930s throughout Nunavut). The information provided for this period was typically in the form of general statements rather than specific, personal information. Reliable information was thus provided for a period of ~50 years, in agreement with the conclusions of Arima (1976) noted above. Some elder interviewees also were no longer active harvesters due to age/health concerns, and thus were not as knowledgeable about recent trends in killer whale occurrence (many of whom acknowledged this as well). Any recent bias from elder interviewees would have a negligible effect on the overall patterns and trends however, given that approximately half (43 of 89 with age information) of the interviewees were middle-aged (born in the 1950s or 1960s) active harvesters who, while living in a much different socio-economic environment than their parents, were able to provide a current perspective on killer whale occurrence near their communities. These results would suggest that, given the age distribution (Table 1) of our interviewees, we have reliable (as perceived by interviewees and interpreters) information on killer whale occurrence in Nunavut from the present and extending back at least to the mid-1900s.

Killer whales were observed during summer (July–September) in all areas of Nunavut where interviews were conducted, most often in North Baffin communities, particularly Arctic Bay. Killer whales were described as fast swimmers (see Matthews *et al.*, 2011) that are always moving around, staying in different areas for short periods of time. They are often seen passing through or migrating past sighting locations, but they sometimes remained in one area for short periods (days to weeks) hunting other marine mammals. Killer whales were reported to migrate through Hudson Strait and Lancaster Sound and follow the routes used by their marine mammal prey (Ferguson *et al.*, 2010a, 2012a). Belugas, narwhals, and bowhead whales follow regular migration routes and show fidelity to summer ranges (Higdon *et al.*, 2012), providing predictable foraging locations for killer whales. Most interviewees thought that killer whale presence was increasing in their area, with South Baffin (Pangnirtung) a notable exception.

Interviewees in Foxe Basin felt that the increase in killer whale occurrence there was related to the increasing bowhead population (Ferguson *et al.*, 2012a). Northern Foxe Basin is a nursery ground occupied by cow–calf pairs and juvenile bowhead whales in spring and early summer (NWMB, 2000; Cosens & Blouw, 2003), when ice cover provides a possible refuge from killer whale predation (Ferguson *et al.*, 2010b, 2012b; Higdon & Ferguson, 2010). When sea ice habitat is reduced in late summer and early autumn, bowhead calves and juveniles are likely more vulnerable to predation, and reports of predation attempts on bowhead whales peak during this time (Ferguson *et al.*, 2010a, 2012a; Higdon *et al.*, 2012). Satellite-tagging studies confirm bowhead selection for heavy ice conditions in summer, and killer whale avoidance of the same (Ferguson *et al.*, 2010b; Matthews *et al.*, 2011). Some groups of killer whales may preferentially hunt bowhead whales (Ferguson *et al.*, 2012b; Matthews & Ferguson, 2013 (this volume)), and the importance of Foxe Basin as a summertime foraging area may increase in the future.

Killer whales were considered to be less abundant than other marine mammal species found throughout the eastern Arctic, although estimates of local population sizes were variable. In general, interviewees suggested that the local population of killer whales around their communities varied from tens to the low hundreds, and they were usually observed in small groups (<10) (the database analyses in Higdon *et al.*, 2012 show similar patterns). Young *et al.* (2011) identified 53 individual killer whales from photographs of nine different sightings in Hudson Bay and along Baffin Island. Only one whale was re-sighted (within a year), and no matches were discovered when photographs were compared to 63 individuals photo-identified in the north-west Atlantic (Lawson *et al.*, 2007; updated to 67 individuals in Lawson & Stevens, 2013 (this volume)). Both photo-identification catalogues are known to be incomplete, as not all individuals were identified in each photographed encounter and numerous photographs were of insufficient quality for use (Young *et al.*, 2011; Lawson & Stevens, 2013 (this volume)). The total number of killer whales found in the western North Atlantic and eastern Canadian Arctic is higher than the combined estimate of the two catalogues, but population size is not known with any certainty. Population structure is similarly uncertain, although analyses of stable isotopes in killer whale teeth indicates some dietary separation at both the individual and population levels (Matthews & Ferguson, 2013 (this volume)), suggesting that multiple ecotypes may exist in this region.

Forney & Wade (2006) synthesized information on global killer whale abundance using a variety of sources and assigned abundance classes for different regions. They considered killer whales to be 'common' (0.20–0.40 whales per 100 km^2) in parts of the Canadian Arctic, 'uncommon' (0.10–0.20 whales per 100 km^2) in Newfoundland and Labrador waters, and 'rare' (0–0.10 whales per 100 km^2) in more southerly areas such as the Bay of Fundy and the eastern United States. In contrast, killer whales were 'abundant; (>0.40 whales per 100 km^2) in parts of the north-east Atlantic such as northern Norway and the Norwegian Sea. COSEWIC (2008) assigned the killer whales found in the Canadian eastern Arctic and north-west Atlantic to a single population due to uncertainty in stock relationships (but see Matthews & Ferguson, 2013 (this volume)), with an area of occupancy of over 3.3 million km^2. If we consider killer whales to be 'uncommon' (Forney & Wade, 2006) across the entire eastern Canadian range, resulting population size estimates would range from 3300 to 6600. COSEWIC (2008) estimated that the population size was likely <1000 mature animals (and possibly <250 mature animals), based on sighting effort and knowledge of Pacific killer whale population abundance. Population size is underestimated in the photo-identification catalogues and may also be underestimated by

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Inuit interviewees, particularly if killer whales are abundant in offshore regions, as was suggested by several interviewees with experience in that area. Of note, most interviewees who did provide an opinion on population size also indicated a high level of uncertainty in their estimate.

Marine mammal research in remote Arctic regions is expensive and logistically challenging, particularly for species like killer whales that exist at relatively low densities, range over large areas, and have variable movement patterns contingent on local sea ice conditions. Directed field research on Arctic killer whales has been successful (Matthews *et al.*, 2011), but most published studies have been based on chance observations (e.g. Steltner *et al.*, 1984; Campbell *et al.*, 1988; Laidre *et al.*, 2006) or compilations of sighting reports (e.g. Reeves & Mitchell, 1988; Higdon, 2007; Higdon & Ferguson, 2009; Higdon *et al.*, 2012). Observations by local harvesters compiled through semi-directed interviews have contributed much information on killer whale movements, relative abundance and distribution over a wide spatial range and a long temporal record, in addition to data on predation ecology (Ferguson *et al.*, 2012a) and human dimensions of Arctic killer whale management and conservation (Westdal *et al.*, 2013). Local observations, including those collected here, also contribute most of the available records in the Arctic killer whale sighting database (Higdon *et al.*, 2012). Information from different communities was often complementary, and there was consistency in interview comments related to the relative abundance of killer whales in different areas of Nunavut, seasonal distribution patterns, and trends.

Information derived from TEK can complement that obtained via modern science techniques, and long-term community observations can provide greater confidence in scientific results (Johannes *et al.*, 2000). The incorporation of TEK to address scientific research questions is relevant and valuable, and continued research on Arctic killer whales will be most effective if it integrates modern science approaches with the traditional skills, knowledge and experience of Inuit harvesters. Efforts are underway to develop a citizen science programme, where local residents can collect and contribute data (e.g. identifiable photographs), and a community-based monitoring programme. Many of the photographs in the photo-identification database (Young *et al.*, 2011) have been contributed on an opportunistic basis by both southern and Inuit scientists and photographers working on a variety of projects. Continued submissions from local photographers will be critical to developing an expanded database with photographs from around the region. Similarly, two recent killer whale strandings in Hudson Bay (Ferguson, unpublished data) were both discovered and reported by local Inuit, and residents of the local communities conducted the sampling.

Inuit are concerned about environmental change and killer whale effects on marine mammal species are a descriptive indicator of socio-economic and cultural changes happening in the Arctic. The importance of top-down predation results in negative opinions towards killer whales due to the perceived competition for similar resources (Westdal *et al.*, 2013). Killer whale numbers are likely increasing (there have been no harvests in the Canadian Arctic in over three decades), and increased predation on species such as ringed seals, narwhals and belugas will have implications for the management of subsistence harvests in the future. Increased presence of killer whales could become an additional stressor on marine mammal populations that are already experiencing changing climatic conditions and increased industrial development (Heide-Jorgensen *et al.*, 2013). Inuit observations on the behaviour, local abundance and seasonal distribution of killer whales and their marine mammal prey will be of critical importance to elucidating current and future changes to the Arctic marine system.

The use of TEK information provides a long temporal record that can facilitate retrospective analyses. For example, combining our recent interviews with other accounts of historic Inuit (and whaler and trader) knowledge and observations (Kumlien, 1879; Soper, 1944; Haller *et al.*, 1966; Reeves & Mitchell, 1988; Kilabuk, 1998) provides a time-series of relative killer whale abundance in the Cumberland Sound (Pangnirtung) area that spans approximately 150 years. Sighting effort could be estimated through analyses of hunting and travelling patterns and Inuit population growth and dispersion (e.g. Boas, 1884; Haller *et al.*, 1966; Kemp, 1976; Stevenson, 1997 with respect to Cumberland Sound), and then used in conjunction with marine mammal catch histories (e.g. Stewart, 2004; Higdon, 2010), survey results, and population growth models to examine marine mammal population trends over time and the potential impacts of killer whale predation.

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