Seasonal movements and ecological markers as evidence for migration of common minke whales photo-identified in the eastern North Pacific

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ABSTRACT

In the eastern North Pacific Ocean, common minke whales (*Balaenoptera acutorostrata*) are widespread but encountered relatively infrequently. It is generally believed that they make annual migrations between higher latitudes in the summer and lower latitudes in the winter; however, in some temperate coastal regions where common minke whales have been sighted year-round they have been referred to as resident. To determine movement patterns of common minke whales found in coastal waters of British Columbia and Washington we examined photo-identification data that were collected opportunistically from 2005–12. These data were from four non-overlapping areas between 48°N and 53°N. Despite year-round search efforts, common minke whales were only encountered between April and October. Most of the 44 unique individuals identified in 405 encounters displayed fidelity to areas both within and among years. Five of these whales made relatively large-scale intra-annual movements between areas on six occasions. They were documented to move up to 424km in a northerly direction in spring and up to 398km in a southerly direction in autumn. The seasonal patterns of these movements provide new insights into the foraging ranges and migrations of the individuals. Ecological markers provide evidence that the common minke whales photographed undertake annual long distance migrations. Scars believed to be from cookiecutter shark (*Isistius brasiliensis*) bites were observed on 43 individuals and the majority of whales documented with good quality images each year had acquired new scars since the previous year. Furthermore, the commensal barnacle *Xenobalanus globicipitis* was observed on three individuals. Since these sharks and barnacles are from relatively warm waters, it can be inferred that they interacted with the common minke whales at lower latitudes. These findings may have important implications for the definition and management of common minke whale stocks and/or populations in the eastern North Pacific.

KEYWORDS: MOVEMENTS; MIGRATION; PHOTO-ID; NORTH PACIFIC; ECOLOGICAL MARKERS; FEEDING GROUNDS; SITE FIDELITY; COMMON MINKE WHALE; NORTHERN HEMISPHERE

INTRODUCTION

The common minke whale (*Balaenoptera acutorostrata*) is found in all the world's oceans (Jefferson *et al.*, 2008). It is the smallest of all rorquals and among baleen whales, is the second smallest species (Stewart and Leatherwood, 1985). Due to its small size and cryptic lifestyle, the common minke whale can be relatively difficult to observe and to study (Martin *et al.*, 2013). Consequently, little is known about the structure of some common minke whale populations.

In the North Pacific, several populations of common minke whale exist. The IWC Scientific Committee has undertaken a thorough review of the stock structure of common minke whales in the western North Pacific (IWC, 2012; 2013; 2014). One population referred to as 'J stock' is exploited in the Sea of Japan, Yellow Sea, South China Sea and coastal waters east of Japan. This population differs both genetically and morphologically from 'O stock' minke whales primarily found in the Sea of Ohkotsk and the western North Pacific (Kato, 1992; Kato *et al.*, 1992; Ohsumi, 1983; Omura and Sakiura, 1956; Park *et al.*, 2010; Wade and Baker, 2010; Wade *et al.*, 2010). There may be other biologically distinct populations in the central and eastern North Pacific where differences in the structure of common minke whale calls have been recorded (Delarue *et al.*, 2012; Rankin and Barlow, 2005). However, common minke whales east of 180°W in the North Pacific have been collectively referred to as the remainder stock because of the lack of commercial exploitation in these waters (Donovan, 1991). For further regional management purposes the United States National Oceanic and Atmospheric Administration (NOAA) has split the remainder stock into the California/Oregon/Washington (CA/OR/WA) stock, the Hawaiian stock and the Alaskan stock.

Ship based line transect cetacean surveys in these regions have shown that common minke whales are relatively common in the central North Pacific around Alaska (Moore *et al.*, 2002; Zerbini *et al.*, 2006), uncommon in the eastern North Pacific (Barlow and Forney, 2007; Carretta *et al.*, 2013; Ford *et al.*, 2010; Williams and Thomas, 2007) and rarely observed around Hawaii (Barlow, 2006). The only research that is specifically focused on this species in these waters has been undertaken either acoustically or in coastal areas where waters favoured by common minke whales are easily accessed. Most of these studies have shown seasonal trends in common minke whale detections. For example, year-round acoustic studies have detected common minke whale calls in deep water off Hawaii from October to May, with peaks in February and March (Oswald *et al.*, 2011; Thompson and Friedl, 1982). These whales have rarely been seen so assessment of behaviour patterns has not been

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possible, but it has been suggested that the calls were related to breeding (Martin *et al.*, 2013). Further north, in the coastal waters of California, Washington and British Columbia, photo-identification studies conducted between April and October found that common minke whales were most abundant from June to September and that individuals showed fidelity to specific feeding areas within and among years (Dorsey, 1983; Dorsey *et al.*, 1990; Hoelzel *et al.*, 1989; Osborne *et al.*, 1988; Stern *et al.*, 1990).

It is generally assumed that common minke whales in the North Pacific migrate to higher latitudes in the spring to feed in cold waters during the summer and to lower latitudes in the autumn to breed in warm waters during the winter (Stewart and Leatherwood, 1985). This is consistent with seasonal trends in common minke whale detections in the eastern North Pacific and with what is known about this species in the western and central North Pacific (Delarue *et al.*, 2012; Gong, 1988; Hatanaka and Miyashita, 1997; Omura and Sakiura, 1956). However, common minke whales have been observed in the eastern North Pacific year-round (COSEWIC, 2006; Dohl *et al.*, 1983; Everitt *et al.*, 1979; Forney *et al.*, 1995; Shelden *et al.*, 2000). Consequently, the putative CA/OR/WA stock is considered to be resident and behaviourally distinct from migratory common minke whales (Allen and Angliss, 2012; Carretta *et al.*, 2013). The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has reported that common minke whales in the Pacific waters of Canada are thought to be migratory, but that this region also may include a small resident population that is an extension of the CA/OR/WA stock (COSEWIC, 2006). Stewart and Leatherwood (1985), Leatherwood *et al.* (1988) and Nagorsen (1990) state that common minke whales of the eastern North Pacific move to higher latitudes during summer and lower latitudes during winter and that some populations may also be resident.

Although some common minke whales in the eastern North Pacific may indeed be migratory while others may be resident in certain areas year-round, discrepancies in the literature indicate that further study is required to understand the movement patterns of these whales. Photo-identification can be used to document movements of individual whales (Goley and Straley, 1994; Robbins *et al.*, 2011; Weller *et al.*, 2012). It is also a useful method for documenting ecological markers on their bodies including scars from bites of cookiecutter sharks (*Isistius brasiliensis*) (Bando *et al.*, 2010; Dwyer and Visser, 2011) and barnacles such as *Xenobalanus globicipitis* (Kane *et al.*, 2008). Both of these species are known to be primarily from warm waters (Kane *et al.*, 2008; Nakano and Tabuchi, 1990) and can therefore provide evidence of the movements of whales from such regions when they are documented at higher latitudes (Bushuev, 1990; Mackintosh and Wheeler, 1929; Olafsdóttir and Shinn, 2013; Shevchenko, 1977).

To determine movement patterns of common minke whales from the eastern North Pacific this study examined photo-identification data collected in four temperate coastal areas of British Columbia and Washington between 48˚N and 53˚N. All whales were encountered from spring to autumn and some individuals were documented to make seasonally-based intra-annual movements between areas. These relatively large-scale movements provide insights into seasonally preferred foraging areas and migrations of individuals. Ecological markers observed on almost all whales identified suggest that animals from these waters make annual migrations to lower latitudes. These results may provide useful information for managing stocks and/or populations of common minke whales in the eastern North Pacific.

METHODS

Common minke whales were photo-identified opportunistically from 2005–12 using vessels primarily focused on the commercial viewing or research of killer whales (*Orcinus orca*), humpback whales (*Megaptera novaeangliae*), gray whales (*Eschrichtius robustus*) and fin whales (*Balaenoptera physalus*). Some cetacean research and commercial whalewatching vessels operated year-round, but the majority of effort occurred from spring to autumn. Whalewatching vessels operated in coastal waters off Vancouver Island, whereas research vessels operated around Vancouver Island and off the central coast of British Columbia. Vessels varied, but most were less than 10m in length with cruising speeds of at least 20 knots. Common minke whales were detected by sight, sound and smell and photo-identified in Beaufort sea-states ≤ 2. When common minke whales were located, they were approached to the minimum allowable distance (20m under research permit or 100m for whalewatching vessels) to obtain identification photographs from both the right and left sides. On occasion, common minke whales were also detected from land and then photo-identified if the animal was close enough to the shoreline. Identification photos were acquired using digital SLR cameras equipped with lenses ranging in focal length from 70–400mm.

All photographic data of common minke whales were managed and analysed using protocols similar to those used for killer whale data in British Columbia as outlined by Towers *et al.* (2012b). An encounter was defined as an event in which identification photographs were obtained from one common minke whale. Data recorded for each encounter included: the date, individual identity, best left and right side photos acquired, photo quality rating and the location. The location of each common minke whale encounter was recorded with a charted geographical place-name, the latitude and longitude and the area in which the encounter took place: NVI (Northern Vancouver Island), SVI (Southern Vancouver Island), CBC (Central British Columbia) or WVI (Western Vancouver Island). All areas were entirely within Canadian waters off the coast of British Columbia with the exception of the SVI area, which also included US waters off the coast of Washington (Fig. 1). The best identification photos from each encounter were assessed for quality and rated as poor, fair or good. Identification photographs were considered to be good when they were in sharp focus, taken from relatively close range, in good lighting conditions and perpendicular to the direction the animal was traveling. Fair quality images were those that fit two or three of these criteria, while poor quality images were those that only fit one or none at all. Positive identifications were based on the distinctiveness of identifying features on an individual and how well those features were photographed. All common minke whales included in the analysis were known from

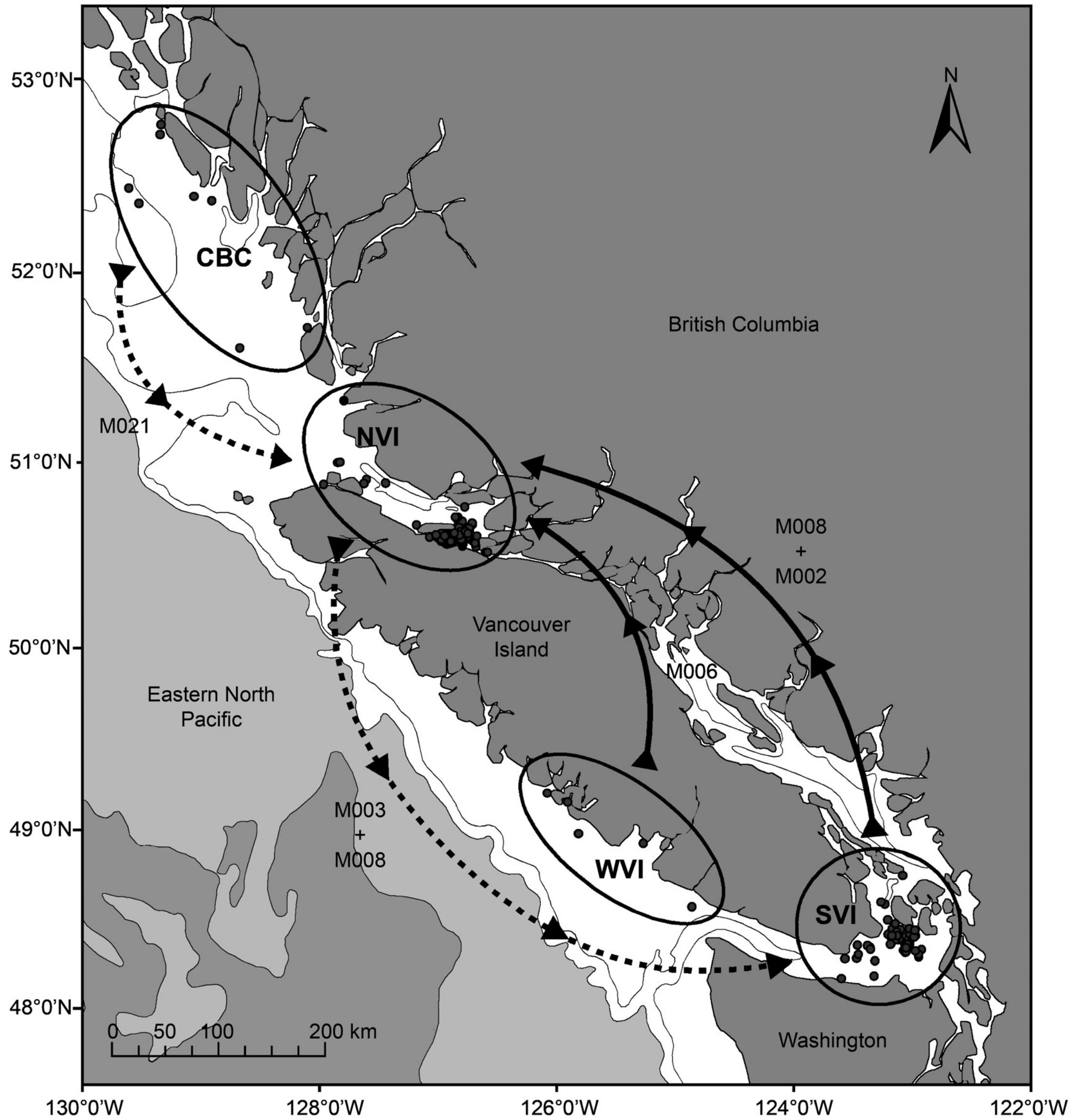

Fig. 1. Locations of common minke whale encounters (solid black circles) in four defined areas and seasonally-based intra-annual movements of five individuals between areas. Solid lines represent northerly movements made between spring and summer. Dotted lines represent southerly movements made between summer and autumn. (Lines and arrows indicate general direction of travel rather than actual travel routes).

good quality identification photos and only encounters of positively identified whales were used for analysis in this paper.

All photographs of the identified common minke whales were scrutinised for ecological markers. Body scars were considered to be from cookiecutter sharks when they were an estimated 3–7cm in size, circular, elliptical or crescent shaped (Jones, 1971) and matched the appearance of scars on other cetaceans attributed to cookiecutter sharks (Bando *et al.*, 2010; Bertulli *et al.*, 2012; Jefferson *et al.*, 2008; Miyashita *et al.*, 2010; Moore *et al.*, 2003; Shevchenko, 1977; Walker and Hanson, 1999). Scars were considered to have occurred within the year if the epidermis was white in colour (Shevchenko, 1977) or if the same individual was seen during the previous year without the scar. As the whale barnacle *Xenobalanus globicipitis* is known to colonise trailing edges of cetacean appendages (Kane *et al.*, 2008), dorsal fins of individual common minke whales were examined for this epizoic crustacean. These ecological markers aided in the identification of individuals, but because they sometimes changed in appearance over the course of a year, they could not always be used as identification features over longer periods of time.

To aid in describing seasonal trends in minke whale distribution, April to June 15 was defined as spring, June 16 to the end of August as summer and September to November 15 as autumn. Intra-annual movements of individual common minke whales between these periods were measured as the minimum by-sea travel distances between two encounter locations. The routes taken by common minke whales were likely to be less direct and/or altogether different.

RESULTS

In total, 6,990 identification photographs of common minke whales were obtained in 405 encounters. The best images were of good, fair and poor quality in 239, 111 and 55 encounters respectively. Encounters took place in all four of the defined areas (Fig. 1) between April and October. There was a steady increase in the numbers of encounters each

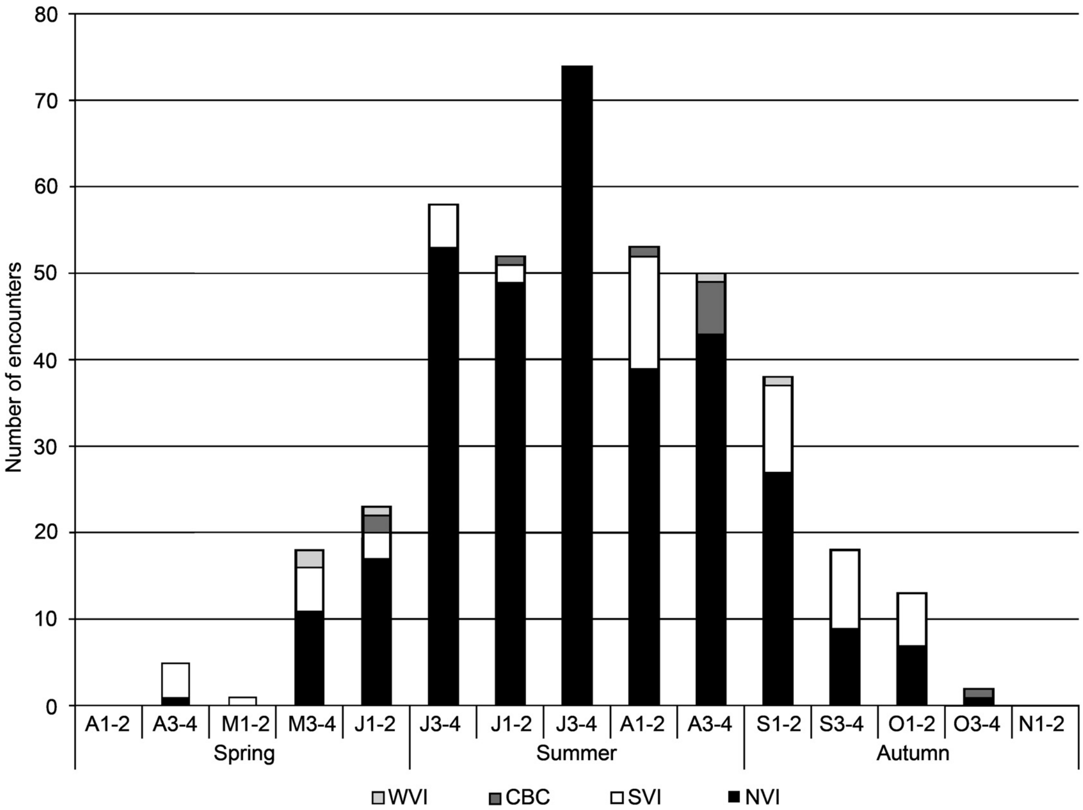

Fig. 2. Seasonal distribution of all encounters with common minke whales from 2005–12, shown for each area by two-week period and season.

month until July, then a steady decline each month thereafter in the NVI area (Fig. 2) where the majority of effort and encounters took place. In the SVI area, the number of encounters fluctuated each month between April and October. The few encounters in the CBC and WVI areas occurred sporadically between May and September (Fig. 2). No common minke whales were encountered from November through March.

A total of 44 unique individual common minke whales were photo-identified. The majority of these whales were documented in more than one encounter. Re-sights of whales within years occurred in both the NVI and SVI areas, while re-sights among years occurred in all four areas. The greatest number of encounters (331) occurred in the NVI area, which led to identifications of 15 individual common minke whales (Table 1). A further 58 encounters occurred in the SVI area where 21 individual common minke whales were identified. There were fewer encounters and identifications in the CBC and WVI areas (Table 1).

Of the 15 individuals identified in the NVI area, eight showed a moderate to high degree of site fidelity to the area as they were encountered there on several occasions during three or more years (Table 2). Three of these whales (M002, M003 and M006) were encountered in another area during years that they were also encountered in the NVI area. Of the seven whales that did not exhibit a high degree of fidelity to the NVI area, two individuals (M008 and M021) were encountered in another area during years that they were also encountered in the NVI area. Two whales known from the NVI area (M003 and M008) were also documented in the SVI area once each during years that they were not encountered in the NVI area (Table 2). In total, five common minke whales were encountered in more than one area intra-annually on six occasions. In all these cases, either the first or last encounter of an individual whale during the course of a year was used to confirm a relatively large-scale movement (Table 2). The distances between encounter locations confirming these movements ranged from 171–424km (Table 3). Temporal intervals between these encounters ranged from 32 to 93 days

Table 1

Total number of minke whale encounters by area and year (a) and number of new whales identified in each area each year, resulting in the total number of unique whales by area (b).

Year	NVI	SVI	CBC	WVI
(a)				
2005	3	4	0	2
2006	2	8	0	2
2007	12	0	0	0
2008	18	6	0	0
2009	37	12	1	1
2010	99	10	2	0
2011	72	9	3	0
2012	88	9	5	0
Total	**331**	**58**	**11**	**5**
(b)				
2005	3	4	0	2
2006	2	4	0	1
2007	2	0	0	0
2008	3	3	0	0
2009	4	3	1	1
2010	0	3	2	0
2011	1	3	2	0
2012	0	1	4	0
Total*	**15**	**21**	**9**	**4**

*Five individuals are known from more than one area.

Table 2

Numbers of encounters for each whale known from the NVI area by year and season. S: spring. S: summer. A: autumn. ***Bold italics*** indicate encounters that were not in the NVI area.

	2005			2006			2007			2008			2009			2010			2011			2012			Encounters	
Whale ID	S	S	A	S	S	A	S	S	A	S	S	A	S	S	A	S	S	A	S	S	A	S	S	A	Total	Areas
M001											2			1		2	4	4		9			19		41	NVI
M002						1		1		***1***	2		1	5		3	3			10		2	11	1	41	NVI, SVI
M003		1	***1***			***1***	1	2			7		1	5		1	8	1		14			9		52	NVI, SVI
M004		1						3	1		1			4		1	7	5	1	7		4	13	2	50	NVI
M005											1														1	NVI
M006									3				***1***	6	1	2	37	6	5	13		2	10		86	NVI, WVI
M007					1							3								3	1				8	NVI
M008		1	***1***																***1***	1				***1***	5	NVI, SVI
M009														4	3		2	5		1					15	NVI
M012														1									1		2	NVI
M018														1											1	NVI
M021														****2***	3										5	NVI, CBC
M022									1							1	6	1		6			14		29	NVI
M046												2													2	NVI
M052																			1						1	NVI

*Only the first of the two encounters was not in the NVI area.

Table 3

Details on the six intra-annual movements between areas documented for five individual minke whales.

			Encounter area details					Movement details		
Whale ID	Year	Encounters	NVI	SVI	CBC	WVI	Lat/longs (temporally closest between areas)	Distance (km)	Time (days)	Direction
M002	2008	3	14/07+16/07	25/04	–	–	48°44.7’N 123°05.1’W and 50°34.9’N 126°48.0’W	≥359	≤80	North
M003	2005	2	20/06	21/09	–	–	50°36.4’N 126°48.6’W and 48°23.4’N 123°08.2’W	≥396	≤93	South
M006	2009	8	21/07–14/09	–	–	07/06	49°09.4’N 125°54.6’W and 50°33.1’N 126°47.6’W	≥401	≤44	North
M008	2005	2	24/07	07/09	–	–	50°39.0’N 126°44.4’W and 48°23.8’N 123°10.8’W	≥398	≤45	South
M008	2011	2	05/07	22/04	–	–	48°20.4’N 123°03.7’W and 50°40.0’N 127°11.0’W	≥424	≤74	North
M021	2009	5	16/08–14/09	–	15/07	–	51°42.7’N 128°06.1’W and 51°00.0’N 127°49.8’W	≥85*	≤32	South

*Travelled ≥171km between 15/07 and 14/09 encounter locations.

(Table 3). All whales documented making intra-annual movements between areas were found furthest north in summer and furthest south in spring or autumn (Fig. 1, Table 3).

Of the 44 photo-identified common minke whales, 43 had scars believed to be from the bites of cookiecutter sharks. Most scars appeared as grey, oval shaped depressions. These were likely to be older and well-healed bites. No open wounds or fresh bites were observed. The most recently acquired scars were bright white and either circular, oval or crescent shaped (Fig. 3). White scars eventually faded in intensity and were observed as greyish depressions in subsequent years (Fig. 3). Most individuals that were documented with good quality images were found to have some white scars acquired since the previous year (Table 4). These scars were observed on heads, flanks and dorsal fins of common minke whales from all of the four areas.

The commensal barnacle *Xenobalanus globicipitis* occurred on three common minke whales, each identified in one of the three areas around Vancouver Island. Two whales were each host to a single barnacle attached to the trailing edge of the tip of their dorsal fins. The remaining whale had four barnacles attached to the upper trailing edge of its dorsal fin and one at the base (Fig. 4).

DISCUSSION

The seasonal movements and ecological markers documented in this study together provide new insights into the ranges of eastern North Pacific common minke whales. Almost all individuals had ecological markers on their bodies and the majority of individuals documented with good quality images each year were found to have acquired some of these ecological markers since the previous year. Furthermore, common minke whales were only encountered from spring to autumn despite year-round search effort and five individuals were documented to move up to 424km in a northerly direction in the spring and up to 398km in a southerly direction in the autumn.

Most of the 44 individuals identified during this study, including those documented to make movements between areas, showed fidelity to specific areas within and among years similar to the results of Dorsey *et al.* (1990) and Dorsey (1983). Based on the strong site fidelity exhibited by some of these individuals during summer, it is not surprising that the only encounters confirming large-scale intra-annual movements occurred during spring or autumn when whales would be expected to be migrating. The individuals documented making these movements were animals known from the NVI area, perhaps only because this area had the

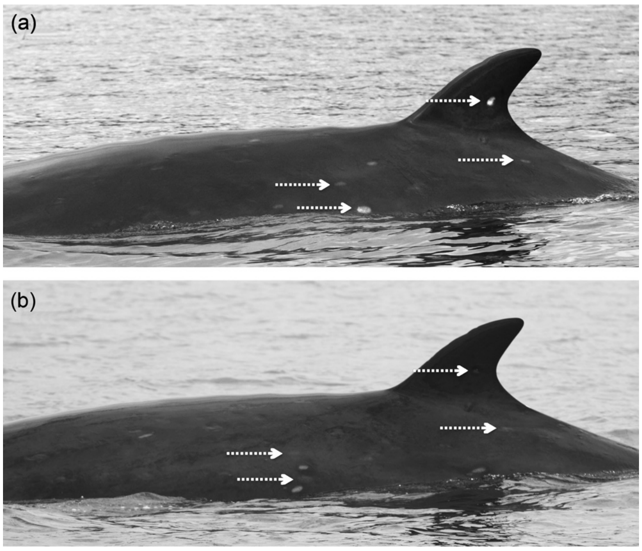

Fig. 3. Identification photographs of common minke whale M001 showing scars believed to be caused by cookiecutter sharks. Photograph (a) was taken on 27 June 2010. Photograph (b) was taken on 8 July 2011. White arrows in both photographs point to the same scars showing how they fade over time. Photograph (b) also shows white scars acquired since the previous year.

most effort, highest number of encounters and is centrally located between other areas where common minke whales were documented. Most of these movements took place between locations in the NVI and SVI areas where common minke whales have previously been observed feeding (Dorsey *et al.*, 1990; Hoelzel *et al.*, 1989; Towers, unpublished data). This suggests that as individuals migrate, they pass through and may stop in other feeding areas along the way. Individuals of other species of baleen whale have also been known to use more than one feeding area while migrating to or from breeding areas (Mate *et al.*, 2010; 1999; Stockin and Burgess, 2005) and in some cases, can be found to move between feeding areas earlier or later than expected (Baker *et al.*, 1985; Barendse *et al.*, 2010; Mizroch *et al.*, 2009; Stern, 2002; Straley, 1990). Although common minke whales in the present study were only encountered from spring to autumn, the few winter sightings of this species reported in the same waters (COSEWIC, 2006; Everitt *et al.*, 1979) could have been individuals feeding or migrating

Table 4

Total number of encounters from all areas that included good quality identification images each year, the number of unique whales in those encounters and the number of individuals found to have white scars on their bodies believed to have been caused by cookie-cutter sharks since the previous year.

Year	Encounters with good quality images	Unique individuals	
		Annual total	With white scars
2005	5	4	4
2006	8	8	7
2007	1	1	1
2008	16	11	10
2009	32	15	14
2010	63	14	13
2011	56	18	17
2012	58	15	12

Fig. 4. Photograph of common minke whale M017 from 1 September 2005 with five *Xenobalanus globicipitis* barnacles attached to the trailing edge of its dorsal fin.

earlier or later than the rest of the population. If a large proportion of the population did not regularly migrate between the eastern North Pacific and warmer waters further south, it would be expected that more of the individuals documented in this study would not have had ecological markers.

Scars believed to have originated from the bites of cookiecutter sharks were observed on 43 of the 44 common minke whales photo-identified. No open bite wounds were documented and partially healed white scars from bites acquired since the previous year were observed on most individuals. It is possible that the individual without noticeable scars and the few common minke whales that did not appear to have white scars in some years were not photographed extensively enough to see any of the scars they may have possessed. It is also possible that these individuals had not made recent movements into the range of the cookiecutter shark. This shark species primarily occurs within 20° of the equator but has been found to range as far as 38°N in the western North Pacific and 34°N in the eastern North Pacific (Nakano and Tabuchi, 1990). It is primarily known to inhabit oceanic waters (Castro, 1983) with surface temperatures of 18°C or higher (Nakano and Tabuchi, 1990)[4]. Cookiecutter sharks consume a wide variety of prey including tissue from live cetaceans (Jahn and Haedrich, 1987). Open scars from the bites of these sharks have been observed on many species of cetaceans known to be permanent or seasonal inhabitants of warm oceanic waters (Dwyer and Visser, 2011; Gasparini and Sazima, 1996; Jones, 1971; Pérez-Zayas *et al.*, 2002; Shevchenko, 1977; Smultea *et al.*, 2010). Dorsey *et al.* (1990) observed white scars on common minke whales in the eastern North Pacific but despite discussing potential causes and suggesting that the scars were not acquired during the summer, they did not make any conclusions about their origin. It is now widely accepted that scars identical in appearance to those described in the present study and by Dorsey *et al.* (1990) are caused by cookiecutter sharks (Bando *et al.*, 2010; Bertulli *et al.*, 2012; Jefferson *et al.*, 2008; Miyashita *et al.*, 2010; Moore *et al.*, 2003; Pérez-Zayas *et al.*, 2002; Wade *et al.*, 2010; Walker and Hanson, 1999). Other species known to parasitise common minke whales including lampreys (*Petromyzontidae*) (Nichols and Tscherter, 2011; Olafsdóttir

[4]During the course of this study sea surface temperatures at sampling stations in the NVI and SVI areas ranged from 7°C in winter to 12°C in summer and stations in the WVI and CBC areas reported sea surface temperatures ranging from 6°C in winter to 14°C during summer (*http://www.pac.dfo-mpo.gc.ca/science/oceans/data-donnees/lighthouses-phares/index-eng.html*).

and Shinn, 2013) and the copepod *Pennella balaenopterae* (Bertulli *et al.*, 2012; Dorsey *et al.*, 1990) also cause scars on other cetaceans (Andrews, 1916; Ivashin and Golubovsky, 1978; Pike, 1951; van Utrecht, 1959). However, the scars from these species differ in appearance from those that can be attributed to cookiecutter sharks (Bertulli *et al.*, 2012; Dorsey *et al.*, 1990; Jones, 1971; Mackintosh and Wheeler, 1929; Nemoto, 1955; Samarra *et al.*, 2012; Walker and Hanson, 1999).

The other ecological marker observed on three common minke whales during this study was the commensal barnacle *Xenobalanus globicipitis*. Despite a widespread distribution during its sedentary phase, little is known of this barnacle's larval stage. It has been suggested, however, that this epizoic originates in warm waters and is sometimes carried by its cetacean hosts to higher latitudes during migration (Bushuev, 1990; Olafsdóttir and Shinn, 2013). Fertl (2002) reported that the breeding season of this barnacle is synchronous with the breeding season of its migratory cetacean host. Kane *et al.* (2008) found that *Xenobalanus* is not host-selective and is known to occur on nearly every species of cetacean found in the eastern tropical Pacific. Significantly however, this barnacle species has not been recorded on cetaceans with ranges restricted to cold temperate or polar waters (Kane *et al.*, 2008; Rajaguru and Shantha, 1992). For example, reviews of photographic catalogues of killer whale populations that range within cold temperate coastal waters extending to the north and south of the areas where we encountered common minke whales (Ellis *et al.*, 2011; Ford and Ellis, 1999; Ford *et al.*, 2000; Towers *et al.*, 2012a) showed no occurrence of *Xenobalanus* (Kane *et al*., 2006) or scarring from cookiecutter sharks. This provides further indication that the common minke whales identified during this study move far beyond the areas in which they were encountered.

Although it is not known exactly where the common minke whales encountered during this study migrate to in winter, the seasonal movements and ecological markers documented in this study suggest that their destinations lie somewhere in warm waters to the south of British Columbia and Washington. Considering this, it is clear that common minke whales found in the eastern North Pacific range over a large geographical area. Any non-invasive research focused on determining migration routes and winter destinations of common minke whales in the North Pacific Ocean would be useful for further understanding their population structures.

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