

Killer whales (*Orcinus orca*) in waters adjacent to the Chukotka Peninsula, Russia

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ABSTRACT

Chukotkan hunters were employed as observers between 1990 and 2000 to document the occurrence of killer whales off the coast of the Chukotka Peninsula throughout the year. The study area was divided into three parts: the south, north and east coasts and all showed a significant negative correlation between sea-ice coverage and number of killer whales sighted ($r = -0.76$, -0.64 and -0.74 respectively). For all areas, the majority of whales were sighted during the summer months (June–September), but during years with late ice-destruction, whales arrived a month later than in ‘warm’ years. Killer whales were sighted three times as often per observation off the north coast than the east and twice as often when compared with the south coast and were also more likely to be part of a group off the north coast. The former was thought to be due to prey availability and the latter to increase the success of the hunt when targeting large prey species. Although the aim was not to determine abundance, a crude estimate of 56 was obtained, since this was the maximum number of killer whales ever reported independently on the same day. The data presented could be used to improve predictions of the most likely/unlikely times that killer whales are present off the Chukotka Peninsula, which would be beneficial to those conducting, for example, photo-identification surveys, or conversely seismic surveys.

KEYWORDS: KILLER WHALE; NORTHERN HEMISPHERE; CHUKCHI SEA; BERING SEA; DISTRIBUTION; SURVEY-SHORE-BASED; SURVEY-VESSEL

INTRODUCTION

The killer whale (*Orcinus orca*) is the most widely distributed marine mammal species in the world. Although found in tropical seas and the open ocean, they are most numerous in high latitude coastal waters (Dahlheim and Heyning, 1999). To date, there has been little research on killer whales in the Asian waters of the Bering and Chukchi seas and only a few, mostly Russian, publications note their presence in waters adjacent to the Chukotka Peninsula. Zenkovich (1939) reported sightings of killer whales off Chukotka in groups of 5–10 to several dozen and Vladivasov (1946) reported that in 1942, the Aleut whaling fleet observed a total of 110 killer whales in the Gulf of Anadyr. Nikulin (1946) recorded 17 killer whales, sighted in the Bering Strait area in 1938, 16 in 1939, and 90 in 1941 and in 1942, 112 killer whales were sighted, but this count also covered the Gulf of Anadyr. The presence of killer whales in the Bering and Chukchi Seas was noted by Sleptsov (1961) and Tomilin (1957). Sleptsov (1961) reported that killer whales were consistently sighted in the Chukchi Sea, and that in 1948, groups of 5–30 animals could be seen. Blokhin (1988), without indicating specific areas, noted that during a shipboard survey of gray whales, 136 killer whales were sighted in the Bering and Chukchi seas. During 1979–1992, small pods of 3–10 killer whales were sighted in the coastal waters of the Chukchi Sea and about 50 killer whales were sighted in the Bering Sea in the area between Cape Dezhnev and Cape Oliutorsky (Vladimirov, 1994). Finally, Grachev *et al.* (2002) provide brief information concerning the dates when killer whales arrive in the waters off eastern Chukotka, total numbers and observations on predation.

Of the few studies described above, only that of Grachev *et al.* (2002) is available in English. Thus, new information from this area, particularly in English, is essential in order for the true extent of killer whale habitat to be understood.

This paper provides new information of the seasonal and annual distributions of killer whales inhabiting the waters off Chukotka and their relationship with sea-ice conditions.

MATERIALS AND METHODS

Native hunters make good observers of marine mammals, since they spend much of their time at sea and some previous research has used their traditional ecological knowledge of marine mammals (George and Suydam, 1998; Huntington *et al.*, 1999). For this study, hunters were used to organise and document marine mammal observations. To aid distinction between species, observers were given the manuscript of a guide book which was later published (Melnikov, 2001).

The observation of killer whales was conducted concurrently with that of other marine mammal species. In some years, up to 30 native Chukotkan observers were employed, some watching from observation posts in villages onshore, others from motorboats during hunting trips to obtain marine mammals as food and to fulfil other needs of the population (Fig. 1; Table 1). The authors of this paper also took part in the observations. Observations were conducted mainly from April to November, but some were conducted year round. Since killer whales come inshore only when the water is ice-free, the data presented here reflect the period from the time the shore-fast ice began to break, up to the time it began to reform. In 1996, however, observations ended in September for reasons unconnected to ice conditions.

Throughout the project binoculars were used to make observations. Data collected included: elevation of the observation perch; duration of observation; observation conditions (direction and force of wind, visibility, presence or absence of whitecaps); percentage ice cover; number of killer whales sighted; approximate distance from shore;

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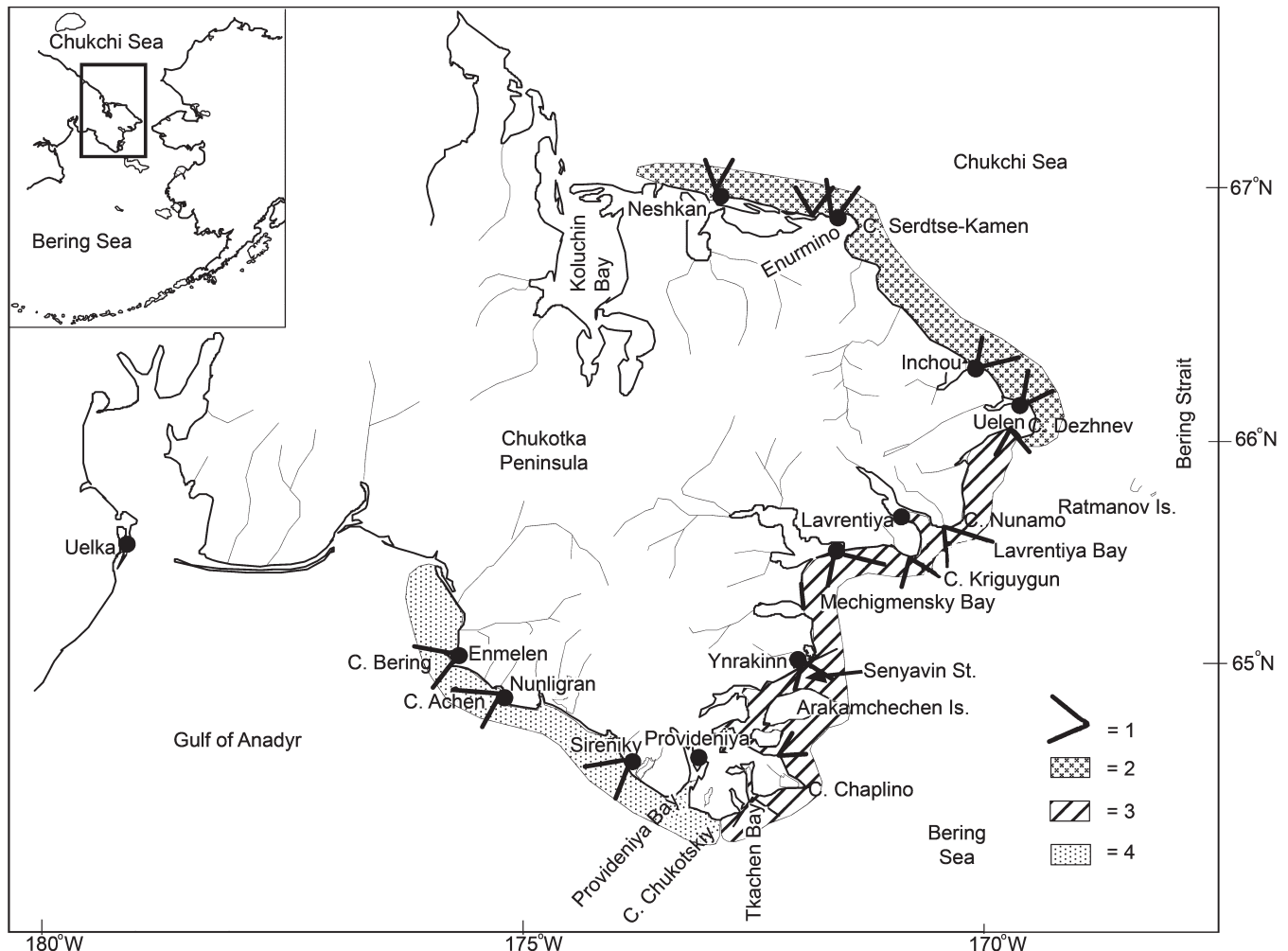


Fig 1. Map of the Chukotka Peninsula study area. 1=observation posts; 2=north coast of the Chukotka Peninsula; 3=east coast of the Chukotka Peninsula; and 4=south coast of the Chukotka Peninsula.

Table 1

Observations in waters adjacent to Chukotka. Effective observation occurred only in fair, good or very good visibility.

Year	Chukotka coast	Number of observers	Start date (dd/mm)	End date (dd/mm)	Duration of effective observation (hours)
1990	North	1	14/6	30/11	640
1991	North	1	30/6	07/11	558
1992	North	2	1/6	21/10	1,422
	East	1	9/6	18/11	376
1993	North	3	1/7	30/10	786
	East	2	20/5	20/11	638
1994	North	9	1/7	10/10	4,218
	East	10	1/6	31/10	4,358
1995	South	7	10/5	15/11	6,825
	North	10	1/6	30/11	8,044
1996	East	12	20/5	30/11	8,753
	South	6	1/5	31/12	8,374
1997	North	10	1/6	30/11	6,199
	East	13	15/5	30/09	10,271
1998	South	7	10/5	30/09	8,820
	North	3	1/6	30/10	548
1999	East	2	1/6	30/10	422
	South	4	20/5	30/11	1,601
2000	North	4	1/6	31/10	1,680
	East	9	1/6	30/11	2,373
2001	South	6	1/5	30/11	4,129
	North	4	1/6	31/10	1,920
2002	East	9	1/6	31/10	3,752
	South	7	1/5	31/12	4,614

swim direction; hunting activity; and results of hunting activity. In addition, the presence of stranded and dead animals was noted, with or without traces of a killer whale attack (Fig. 2).

During the course of the observations, observer performance and organisation improved. The relative lack of data collected in the initial period was largely due to lack of experience, while poor organisation was responsible for the lack of data for 1997 and limited information for 1998.

The task of recording the length of an observation on any particular day was a difficult organisational issue. It took only 30 minutes of actual observation time to determine the numbers and species of animals in the area, yet most observers recorded the duration of observations as the length of the working day (up to 18 hours in length). This obviously bore little relation to reality, since observations were conducted sporadically and were always augmented by information received from other villagers looking out to sea. Moreover, there is a constant exchange of information between hunters, whether from their home villages or a hunters' base camp. Boat-based observers may have been hindered by their low vantage point, limiting their field of vision, but they were constantly on the move and all crew members watched for marine mammals, often from dawn to dusk.

Имя наблюдателя район (место) наблюдения откуда велось наблюдение (берег вельбот)
 высота над уровнем моря Куттегин Л.С. Энмитагино от 4-300м.

Дата	Время набл.		Напр сила ветра м/с от-до	Белые буруны (нет, слаб, сильн.)	Занято льдом в %	Виды китов (км)	К-во (от-до) и характеристика наблюдаемых китов (ГК-гренланд, СК-серый, К-касатка, Б-белуха)				
	от	до					К-во и вид	Раст. от бер.	Напр дв.	Быстр. дв.	Питание
29/08	7	17	себ. 3-5	нет	чисто	90-10	СК-1, К-5	2-4	вост.		
30/08	7	16	3-5	---	---	90-15	ГК-3	5-6	с/зам	умер.	
31/08	6	16	с/вост	---	---	90-20	ГК-6	3-5	вост	---	
3/09	7	16	себ 15-20	шторм	---	90-10	---				
4/09	7	15	себ 10-15	шторм	---	90-5	---				
5/09	7	16	себ 10-15	шторм	---	90-3	---				

Observers name, area (place) of observation, locality (shore or boat), observation height (above the sea level): <i>Keutegin M.C. Enmitagino 4-300m.</i>										
Date	Observation time		Direction and strength of wind	White cap (no, weak, strong)	Ice cover %	Number (from-to) and characteristic of observation whales (ГК = bowhead, СК = gray whales, К = killer whales, Б = belukha whales)				
	From	To				Number and species	Distance off shore	Direction of movement	How quick	Feeding
29.08	7	17	N 3-5	No	Clear	CK1, K5	2-4	E		
30.08	7	16	3-5	No	Clear	ГК3	5-6	NW	Gently	
31.08	6	16	NE	No	Clear	ГК6	3-5	E	Gently	
3.9	7	16	N15-20	Storm	Clear	-				
4.9	7	15	N 10-15	Storm	Clear	-				
5.9	7	16	N 10-15	Storm	Clear	-				

Fig. 2. A typical observation record. (Top) = original; (Bottom) = partial translation.

During hunting trips, observations were not conducted consistently throughout the day since they were interrupted by hunting activity and bringing harvested animals back to shore. For the reasons described above, each period of observation (during acceptable weather conditions) was regarded as a statistical unit, termed 'effective observation' regardless of its length. Data were then normalised based on this parameter and measured with units of whales day⁻¹.

In order to cross-check information, most villages in neighbouring areas had several observers working independently. To minimise errors resulting from individuals, data from all observers in one area were averaged.

Owing to differences in conditions (habitat and hydrological), data for analysis were divided into three areas (Fig. 1): (1) the north coastal waters of the Chukotka Peninsula, including the southwestern Chukchi Sea; (2) the east coastal waters of the Chukotka Peninsula, including the north-westernmost part of the Bering Sea adjacent to the Bering Strait; and (3) the south coastal waters of the Chukotka Peninsula, including the northern part of the Gulf of Anadyr.

Data were analysed using the programmes *Excel*, *Access* and *GrafPad Prism 4*.

RESULTS OF OBSERVATIONS

Ice conditions

The ice conditions in the coastal waters of the Chukotka Peninsula are quite dynamic. In the spring, a system of

shore-fast polynyas develops near the edge of the shore-fast ice, then in May the Chukotsky shore-fast ice lead forms off the northern coast of Chukotka.

During the summers of warm years (1990-93, 1995-96) in August-September, the ice-free areas of the Chukchi Sea extended north, reaching 80°N and westward into the East Siberian Sea (Fig. 3). Consolidation of the ice in the Chukchi Sea in 1995 did not begin until late October and it was not until late November-early December that new ice began to form in the Chukchi Sea, as did shore-fast ice along the northern coast of the Chukotka Peninsula.

During the cold years of 1994 and 1998-2000 pack ice was carried out through Long Strait into the Chukchi Sea and often formed a barrier blocking the exit of the Strait. The summer was short during these years and although by August the edge of the ice was at the 75°N, a mass of 60-90% pack ice still remained in Long Strait. In early September, Long Strait was completely blocked by thick, heavy ice owing to severe storms. This led to the formation of an extensive area of broken pack ice from Wrangel Island to the entrances to Kolyuchin Bay in 1994 and Cape Serdse-Kamen in 1998. By the beginning of October, the entire coastline of Chukotka was locked in by a 70-100% cover of broken ice.

Killer whale distribution

Observations off the south coast of the Chukotka Peninsula
 Observations of killer whales along the south coast of the Chukotka Peninsula were conducted from 1994 to 2000, excluding 1997 (Table 2).

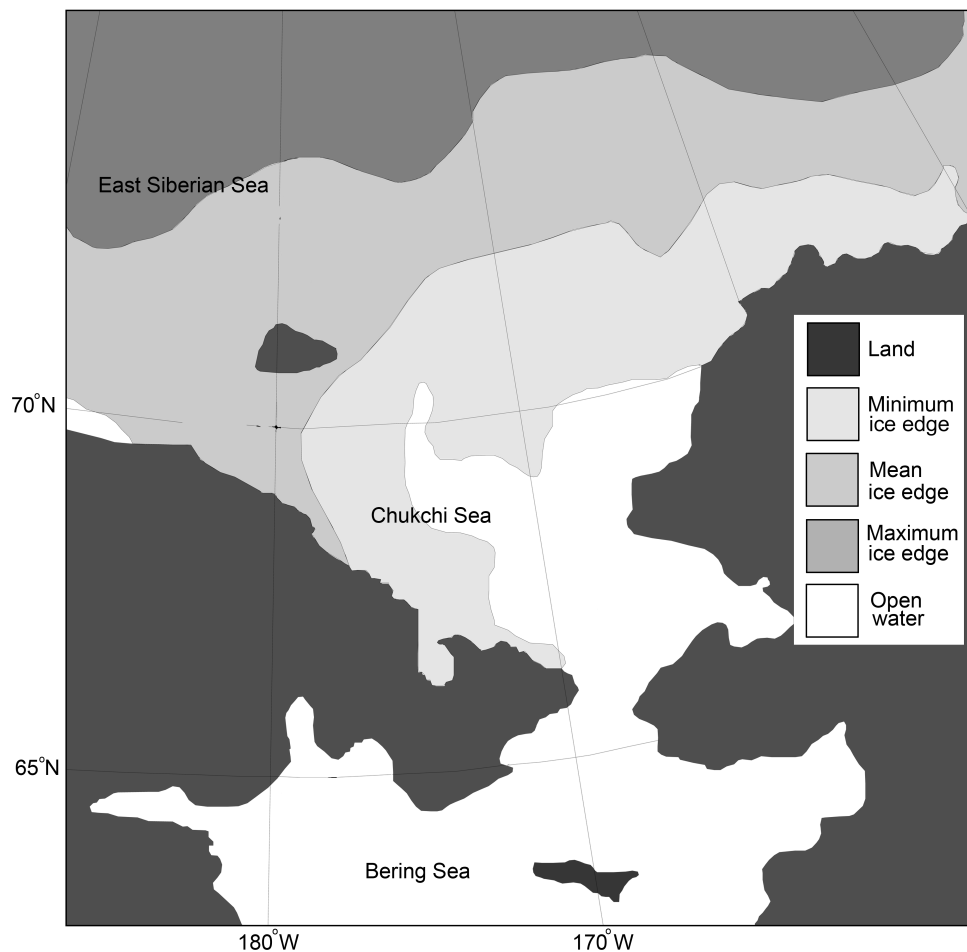


Fig. 3. Maximum, mean and minimum extent of ice edges for September 1 in the region of Bering Sea and Chukchi Sea. Ice data are means for 1973-1986. (Redrawn from Burns *et al.*, 1993).

Table 2
Killer whale observations off the south coast of the Chukotka Peninsula.

Year	Number of observers	Observation period (dd/mm)	Number of effective observations	First sighting (dd/mm)	Last sighting (dd/mm)	Average per observation	Standard error	95% confidence interval	
								Lower	Upper
1994	7	10/05 - 15/11	719	05/06	25/10	0.29	0.04	0.20	0.37
1995	6	01/05 - 31/12	895	07/06	22/12	0.41	0.05	0.31	0.51
1996	7	10/05 - 30/09	547	11/06	27/09	0.60	0.08	0.43	0.76
1998	4	20/05 - 30/11	516	14/06	12/11	0.34	0.06	0.23	0.46
1999	6	01/05 - 30/11	766	07/06	24/11	0.39	0.05	0.29	0.50
2000	7	01/05 - 30/11	889	06/06	23/11	0.35	0.05	0.25	0.45
All years			4,332	05/06	24/11	0.4	0.02	0.36	0.45

Under favourable ice and weather conditions, killer whales appeared in the northern Gulf of Anadyr in the first half of June, mainly in small groups of up to ten animals, which would immediately begin hunting for marine mammals. Killer whales were present when ice cover in this area was lower than 10% (Fig. 4), although large expanses of open water developed sporadically early in the spring along the entire south coast of Chukotka.

Off the south coast of Chukotka, killer whales were sighted principally in the summer months (Figs 5 and 6). Sightings July-October constituted 81.4% of the total number, with the entire southern coastline patrolled by groups of killer whales in search of prey. Killer whales were almost constantly sighted off Cape Bering, particularly in autumn. This may well have been due to the proximity of the Rudder walrus rookery, since killer whales feed on walrus. Killer whales were also regularly sighted around Enmelen

and Nunligran and less frequently off Sireniki village (Figs 5 and 6). Although there were sudden rises in numbers in certain (usually warm) years, killer whale sightings off the south coast, averaged over the entire observation period, rose gradually in summer, peaked in September, then declined until December (Fig. 4; Table 2). Year-to-year fluctuations in the average number of killer whale sightings per effective observation were significant ($p=0.007$, Fig. 4). In the warm years of 1995 and 1996, the average number of killer whales sighted per effective observation during a ten day period in this area was nearly 1.5-2 times that of the cold years of 1994, 1998 and 1999 (Table 2).

Killer whales stay in the northern part of the Gulf of Anadyr late into autumn and sometimes until the end of December. A group of eight killer whales that were hunting white whales (*Delphinapterus leucas*) was sighted on 22 December 1995 in the area of Preobrazheniya Bay. The last

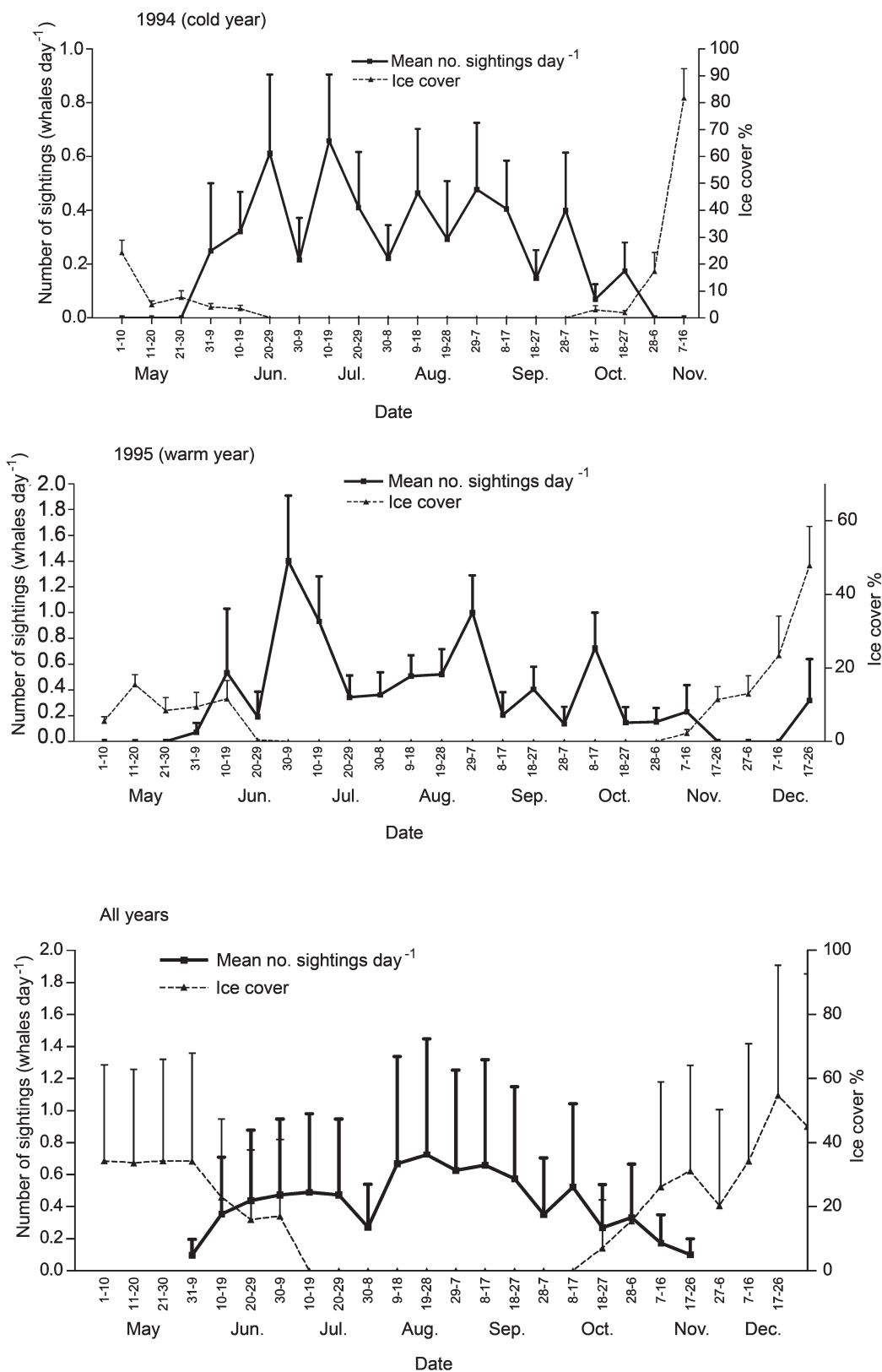


Fig. 4. Year-to-year fluctuations in the average number of killer whales sighted off the south coast of the Chukotka Peninsula by one observer during a single day (whales day⁻¹) averaged over 10-day periods.

killer whales to be seen in these parts, as in other places along the coastlines of Chukotka, were some moving through fields of shuga¹, as they continued to hunt marine mammals.

¹ Shuga: an accumulation of spongy white ice lumps, a few centimetres across, they are formed from grease ice or slush and sometimes from anchor ice rising to the surface.

Periods of presence of killer whales in the northern Gulf of Anadyr are apparently determined by the presence of ice (Fig. 4) and this relationship was confirmed since the Pearson correlation coefficient between the average number of killer whales sighted per observation during a ten day period and the average rate of ice cover was significant ($r = -0.76$, p (two tailed) = 0.0003).

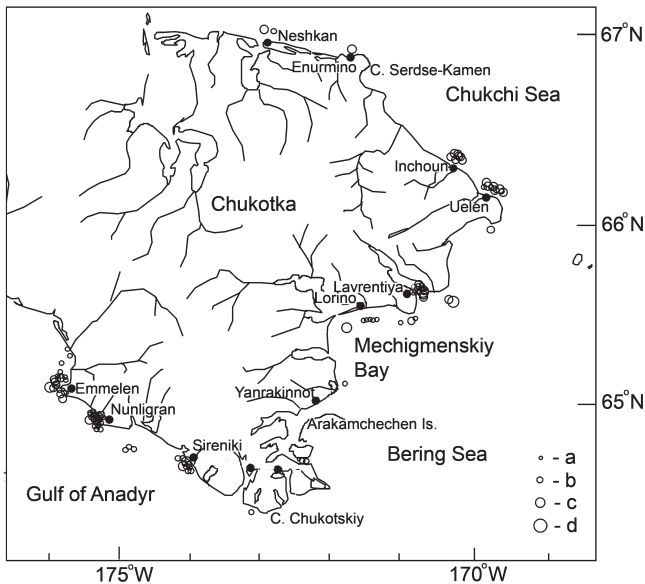


Fig. 5. Sightings of killer whales in waters off the Chukotka Peninsula in 1994. a=1 sighting; b=2-5 sightings; c=6-10 sightings; d=>10 sightings.

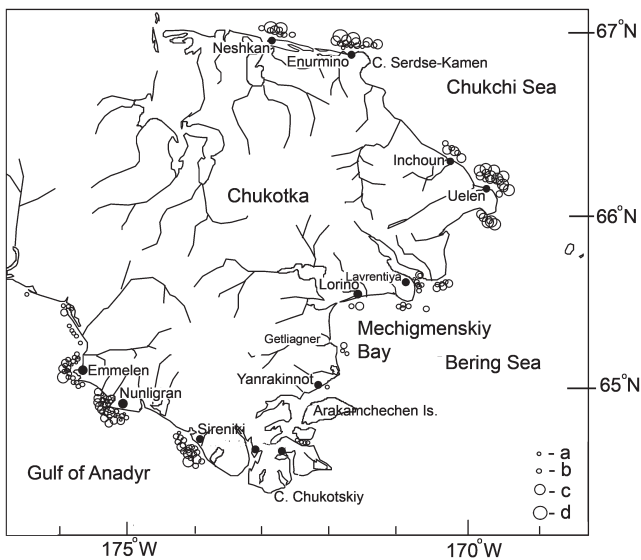


Fig. 6. Sightings of killer whales in waters off the Chukotka Peninsula in 1995. a=1 sighting; b=2-5 sightings; c=6-10 sightings; d=>10 sightings.

Observations off the east coast of the Chukotka Peninsula

In spring-time, killer whales off the eastern coast of Chukotka were sighted 5-15 days later than off the south coast. The first appearance of killer whales near the east coast occurred when the cover of floating ice was lower than 20% (Fig. 7). They approached the east coast as the shore-fast ice disintegrated and ice moved out of the bays. During years with favourable ice conditions (1995, 1996), the first killer whales were sighted in early June (Table 3). During years in which ice-destruction was delayed (1999, 2000) killer whales appeared a month later.

During the summer, killer whales in this area generally stayed close to the capes, at the entrances to large bays (Figs 5 and 6). They were sighted with relative frequency off capes Nunyamo and Kriguygun, located at the entrance to Lavrentiya Bay and there was also a considerable presence

in Mechigmen Bay. Killer whales were also commonly sighted at the southern end of the Senyavin Strait (Chechekuyim Strait). These areas are known to be feeding grounds for gray whales and contain large walrus rookeries (Arakamchechen Island, Kriguygun and Nunamo cape). The daily and seasonal walrus migrations also pass through this area. There were significant year-to-year fluctuations in the average number of killer whales sighted per observation during a ten day period off the east coast of Chukotka (Figs 5, 6, 7 and Table 3). The average number of killer whale sightings per observation in the waters off Chukotka's east coast over all years gradually rose during late June and early July, stayed stable until September, then declined until November (Fig. 7). In years with late ice destruction (1999, 2000), the figure was almost three times that for the warmer years of 1995 and 1996 ($p=0.01$). Killer whales left the Bering Sea coast of the Chukotka Peninsula when ice began to form (usually October) and in years with favourable ice conditions, killer whales remained until the end of October. The last killer whales of the year were seen in openings in the fields of shuga.

As for the northern Gulf of Anadyr, the presence of killer whales off the eastern coast of Chukotka was determined by the presence of ice. Observations for all years were averaged and Pearson's correlation coefficient of the average number of killer whales sighted per observation during a ten day period with the average rate of ice cover was significant ($r=-0.64$, p (two tailed) = 0.0044).

Observations off the north coast of the Chukotka Peninsula

The Chukchi Sea typically has a high inter-yearly variation in ice condition (Fig. 3). Although the southern Chukchi Sea becomes free of its shore-fast ice 1-2 weeks later than the Bering Sea shore of Chukotka, in those years in which break-up did occur early, in the west part of the Chukchi Sea, the first killer whales arrived off the north coast of the Chukotka Peninsula at the beginning of June (Table 4, Fig. 8). Killer whales first appeared when the cover of ice was approximately 50% (Fig. 8). In years with heavy ice conditions, killer whales arrived later, in July or even August, but consistently after the break-up of the shore ice. In the warm years of 1995 and 1996, the first killer whales arrived in the Chukchi Sea via channels of open water inshore of the edge of the disintegrating shore-fast ice.

The average number of killer whales in the summer off the north coast of the Chukotka Peninsula gradually rose as a rule, peaked in mid-September, then diminished until the end of October (Fig. 8; Table 4). In the southern Chukchi Sea, in the area of Cape Inchooun and Cape Uelen, killer whales were sighted both in years with favourable ice conditions and years with heavy ice conditions (Figs 5 and 6). In the western Chukchi Sea during cold summers, when Long Strait and the westernmost part of the Chukchi Sea were closed off by drifting ice and the edge of the shore ice was located to the east of Kolyuchin Bay (as occurred in 1994 and 1998), killer whales were rare or altogether absent. In August 1994, when the ice edge extended as far as Koliuchin Bay, the only sighting was a group of killer whales that got through as far as Neshkan village. In summers when ice conditions were favourable, there was a constant killer whale presence, spread over the entire coastline of the western Chukchi Sea. Even though the average number of killer whales sighted during one observation in the warm years of 1995 and 1996 was only 0.1-0.2 higher than that for the cold year of 1994, the difference was still significant ($p=0.02$).

Table 3
Killer whale observations off the east coast of the Chukotka Peninsula.

Year	Number of observers	Observation period (dd/mm)	Number of effective observations	First sighting (dd/mm)	Last sighting (dd/mm)	Average per observation	Standard error	95% confidence interval	
								Lower	Upper
1992*	1	09/06 – 18/11	31	08/09	27/09				
1993*	2	20/05 – 20/11	104	08/06	29/10				
1994	10	01/06 – 31/10	567	12/06	13/10	0.26	0.05	0.15	0.37
1995	12	20/05 – 30/11	1,046	22/06	09/11	0.10	0.02	0.07	0.14
1996	13	01/06 – 30/09	915	16/06	27/09	0.28	0.05	0.19	0.37
1998*	2	01/05 – 31/10*	80						
1999	9	01/06 – 30/11	443	01/07	13/11	0.22	0.05	0.13	0.32
2000	9	01/06 – 31/10	601	05/07	28/10	0.15	0.03	0.10	0.21
All years			3,787	08/06	13/11	0.19	0.02	0.16	0.22

*Results were not averaged owing to an insufficient number of observations.

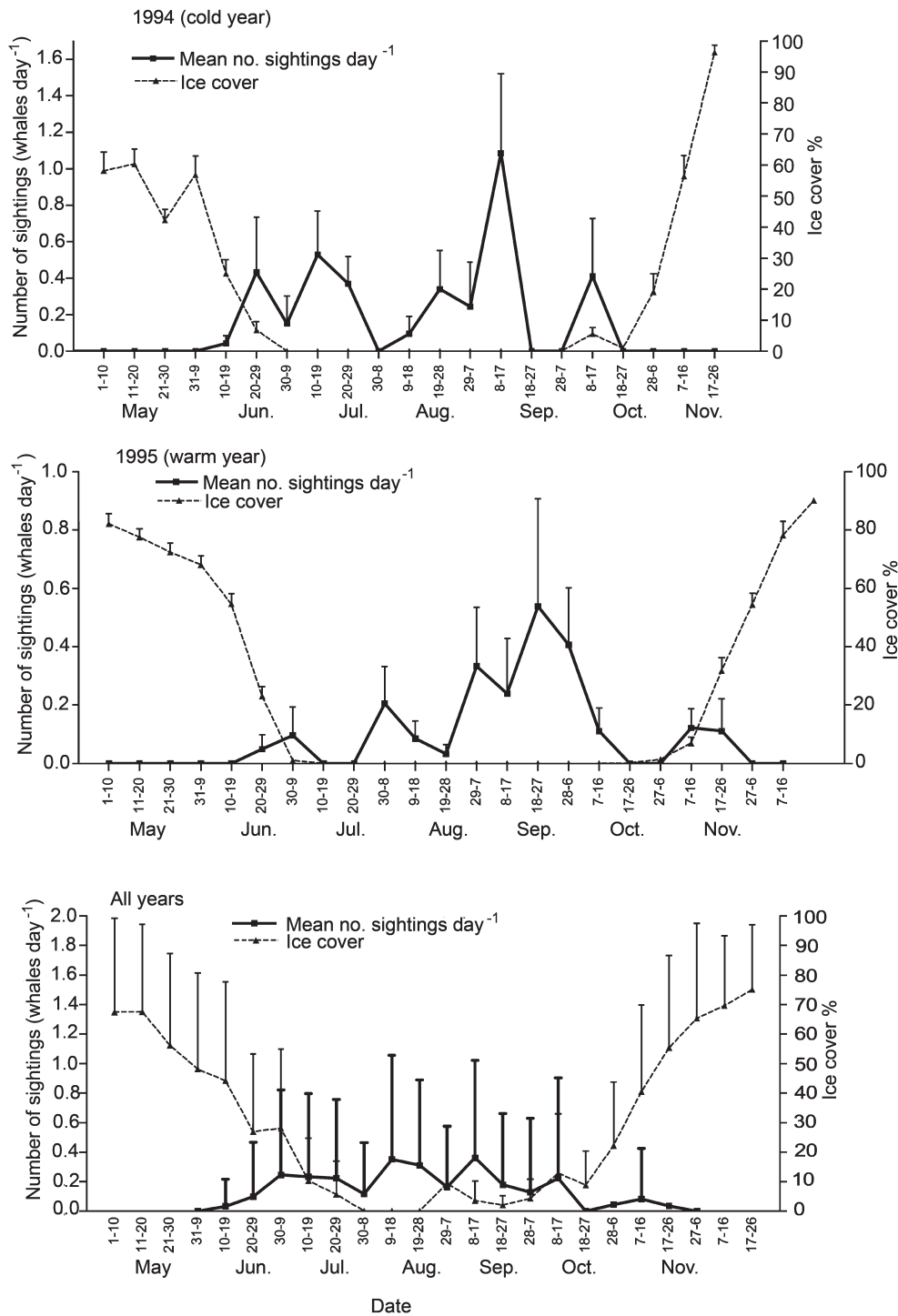


Fig. 7. Year-to-year fluctuation in the average number of killer whales sighted off the east coast of the Chukotka Peninsula by one observer during a single day (whales day⁻¹) averaged over 10-day periods.

Table 4
Killer whale observations off the north coast of the Chukotka Peninsula.

Year	Number of observers	Observation period (dd/mm)	Number of effective observations	First sighting (dd/mm)	Last sighting (dd/mm)	Average per observation	Standard error	95% Confidence interval	
								Lower	Upper
1990*	1	14/06 - 30/11	73	16/08	01/11	1.0	0.45	0.12	1.91
1991*	1	01/07 - 07/11	61	31/07	31/10	1.6	0.42	0.77	2.43
1992	2	01/06 - 21/10	157	03/07	28/09	0.9	0.23	0.47	1.38
1993	3	01/07 - 30/10	170	14/08	29/10	0.2	0.13	0.001	0.50
1994	9	01/07 - 10/10	522	24/07	12/09	0.3	0.06	0.16	0.38
1995	10	01/06 - 30/11	1,042	06/06	29/09	0.4	0.07	0.29	0.56
1996	10	01/06 - 30/11	775	23/06	03/10	0.5	0.08	0.34	0.67
1998	3	01/06 - 31/10	112	22/06	15/10	1.0	0.26	0.49	1.54
1999	4	01/06 - 31/10	284	11/06	11/10	0.9	0.18	0.53	1.24
2000	4	01/06 - 31/10	364	05/07	28/10	0.7	0.17	0.40	1.06
All years			3,560	06/06	11/01	0.6	0.05	0.50	0.69

Killer whales typically migrated from the Chukchi Sea before ice formation began, mostly in October. At times they were seen moving eastward along the shore through water that was free of ice, between the shore and young pack ice drifting by, or even between ice floes. On 14 September 2000, killer whales off Uelen village were seen hunting gray whales (*Eschrichtius robustus*) in shuga.

As for other areas, the presence of killer whales was determined by the presence of ice (Fig. 8). Observations for all years were averaged and Pearson's correlation coefficient of the average number of killer whales sighted per observation during a ten day period with average rate of ice cover was significant ($r = -0.74$, p (two tailed) = 0.0012).

Group size

Killer whales usually occur in small groups. Off the south shore of the Chukotka Peninsula a total of 356 killer whale pods and 59 single whales were sighted between 1994 and 2000. The average number of individuals in a group varied slightly from year to year with 4.5-5.8 killer whales to a group (Table 5) and the largest comprised 30 individuals.

Off the east coast of the Chukotka Peninsula a total of 166 killer whale pods and 9 single individuals were sighted between 1992 and 2000 (Table 6). The mean group size varied from 3 to 5.7 animals and the largest comprised 15 individuals.

Off the north coast of the Chukotka Peninsula (the west part of the Chukchi Sea) from 1990 to 2000, the average group size ranged from 6.8 to 11.6 animals, with an average size of 8.6 animals (Table 7). The largest group comprised 30 individuals.

Number of killer whales observed on a single day

The largest number of killer whales reported on a given day (barring duplicates) increased from 17 in 1998 to 56 in 1996 (14 September) (Table 8). This was the largest number of whales recorded on a single day during the entire observation period.

DISCUSSION

To date, there have been relatively few studies on killer whale abundance in the northern North Pacific, and those that have been done were confined to the southern part of the Bering Sea (Leatherwood *et al.*, 1983; Waite *et al.*, 2002). The number of killer whales in waters off the Chukotka Peninsula was not studied but analysis of killer whale sightings on the same day gave an estimate of the

minimum abundance of the local population. Based on data collected from all Chukotkan waters, no less than 60 killer whales spend summer in near-shore waters of the Chukotka Peninsula.

The data obtained over recent years show that whenever these waters are free of ice, killer whales are constantly found and are most numerous off the north coast of Chukotka. The average number sighted there in the course of one observation was three times as great as that off the east coast, and twice as great as off the south coast (Tables 2, 3 and 4). There were more killer whales observed off the south coast than off the east coast, so that the comparative size of the killer whale population in different places along the coasts of Chukotka is thought to be different, possibly stemming from varying ecological conditions in the regions, and principally, the numbers of marine mammals to be found in each during the ice-free period. For a more definite answer as to the reason underlying this, further study is clearly required.

Killer whales are generally sighted in small groups of fewer than 40 related individuals, such as a male, two or three females and their young. The males are often apart from the rest, but close by. The number of killer whales in a pod is hard to determine, because a pod can be dispersed over a large area. Large groups can be formed when smaller ones join together at the seasonal peak in prey numbers, or during the reproductive period (Norris and Prescott, 1961). Killer whale groups merge or split depending on the available prey, particularly when hunting large whales (Goley and Straley, 1994; Guinet *et al.*, 2000). In Japanese waters, Kasuya (1971) found that the mean group size was 6 and in Alaskan waters Braham and Dahlheim (1982) observed that pod size varied from 2 to 100, but only 1% consisted of 20 or more individuals. In the warm waters of the eastern Pacific Ocean, the largest group found by Dahlheim and Heyning (1999) was 75 whales, but the average was 5.3 and 91% of the groups sighted consisted of 5-10 whales.

In different areas of Chukotkan coastal waters, the number of individuals in killer whale groups varies considerably. In the Chukchi Sea, for example, the average size of a killer whale pod is 8.6 animals, while in the Bering Sea off the eastern shore of the Chukotka Peninsula, the figure is 4.7 and in the Gulf of Anadyr it is 4.9. As a rule, only adult male killer whales swim alone, but it is rare (Norris and Prescott, 1961). In Chukotkan coastal waters, the percentage of single killer whales as a proportion of all killer whales sighted, varies considerably by year (Tables 5, 6 and 7). In waters off the south coast of the Chukotka

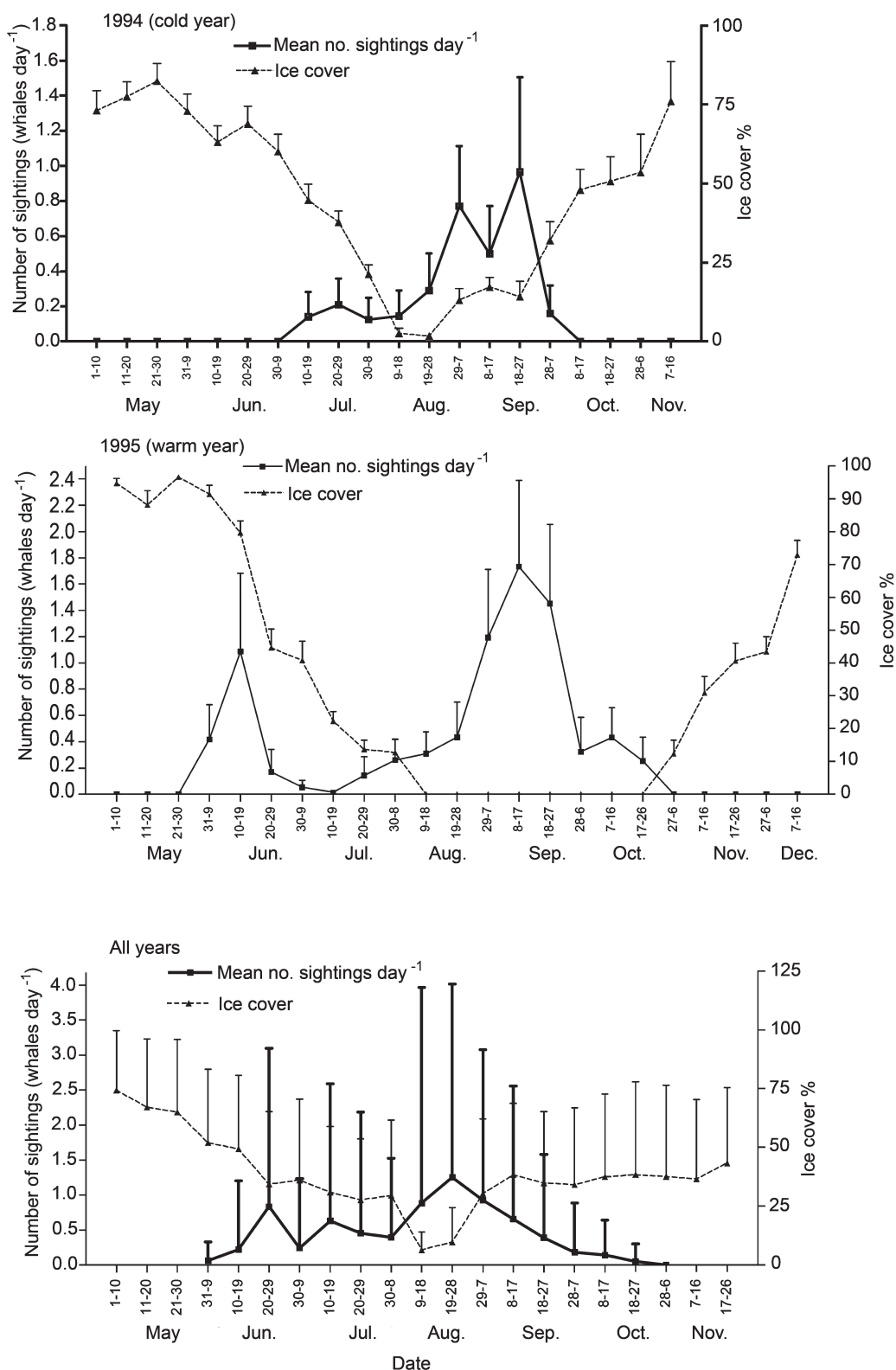


Fig. 8. Year-to-year fluctuation in the average number of killer whales sighted off the north coast of the Chukotka Peninsula by one observer during a single day (whales day⁻¹) averaged over 10-day periods.

Peninsula, the percentage is, on the average, ten times greater than for off the north coast. Thus, killer whale groups in the Chukchi Sea off the north coast of the Chukotka Peninsula are significantly larger than those off the south or east coasts, and there are fewer single animals off the north coast. This could be attributed to ecological conditions in the Chukchi Sea, where whales that unite in larger groups (probably to hunt larger animals) have a better chance of

success in the hunt. Another possibility is that there has also been an increase in the number of animals upon which killer whales prey.

In the northeastern Pacific, killer whale have been categorised into two ecotypes (e.g. Heimlich-Boran, 1988; Saulitis *et al.*, 2000): the 'residents', which feed mainly on fish, and the 'transients', which favour marine mammals. As has been seen in Alaska (George and Suydam, 1998), in the

Table 5
Killer whale groups sighted off the south coast of the Chukotka Peninsula.

Year	Number of pods	Total in pods	Singles	Singles (% of total no.)	Size of pod			Standard error	95% confidence interval	
					Average	Min.	Max.		Lower	Upper
1994	57	259	3	1.1	4.5	2	13	0.33	3.89	5.20
1995	78	368	16	4.2	4.7	2	16	0.30	4.12	5.31
1996	56	345	6	1.7	5.8	2	15	0.42	4.90	6.60
1998	37	175	3	1.7	4.7	2	11	0.33	4.06	5.40
1999	65	299	14	4.5	4.6	2	15	0.32	3.97	5.23
2000	63	309	17	5.2	4.9	2	30	0.50	3.91	5.90
All years	356	1,755	59	~3.4	4.9	2	30	0.16	4.58	5.19

Table 6
Killer whale groups sighted off the east coast of the Chukotka Peninsula.

Year	Number of pods	Total in pods	Singles	Singles (% of total no.)	Size of pod			Standard error	95% confidence interval	
					Average	Min.	Max.		Lower	Upper
1992*	3	9	0	0	3.0	2	4			
1993*	3	14	1	6.7	4.6	2	6			
1994	30	162	1	0.6	5.2	2	15	0.58	3.99	6.39
1995	28	110	1	0.9	3.9	2	9	0.39	3.13	4.73
1996	49	247	0	0	5.4	2	15	0.49	4.39	6.39
1999	27	97	4	4.0	3.7	2	10	0.44	2.83	4.65
2000	26	104	2	1.9	4.0	2	8	0.33	3.30	4.70
All years	166	743	9	~1.2	4.7	2	15	0.22	4.22	5.10

* Data were not processed owing to an insufficient number of observations.

Table 7
Sizes of killer whale pods sighted off the north coast of the Chukotka Peninsula.

Year	Number of pods	Total in pods	Singles	Singles (% of total no.)	Size of pod			Standard error	95% confidence interval	
					Average	Min.	Max.		Lower	Upper
1990*	5	48	0	0						
1991	13	96	0	0	7.4	4	14	0.63	6.02	8.75
1992	24	123	0	0	7.4	2	20	1.05	5.21	9.59
1993*	5	45	1	2.2						
1994	24	137	1	0.7	6.8	5	10	0.43	5.91	7.67
1995	51	439	1	0.2	8.9	2	28	0.84	7.23	10.62
1996	48	257	2	0.8	9.0	2	30	0.79	7.37	10.54
1998	14	114	0	0	8.1	7	12	0.53	6.99	9.29
1999	33	254	2	0.8	7.3	2	23	0.94	5.40	9.23
2000	23	268	0	0	11.6	2	30	1.26	9.03	14.27
All years	240	1,781	7	0.4	8.6	2	30	0.34	7.96	9.30

*Average pod size was not calculated owing to an insufficient number of pods

Table 8
The highest number of killer whales reported by observers for a single day.

Year	Date of observation	Number of whales
1994	11/09	19
1995	13/09	38
1996	14/09	56
1998	28/08	17
1999	13/08	40
2000	25/08	40

coastal waters of Chukotka, killer whales have been observed feeding on marine mammals. Care must be taken in interpreting these results as it is unclear if this adaptation occurs in regions other than the northeastern Pacific. To determine whether the killer whales off the Chukotka Peninsula can be categorised in this way requires further work in fields such as photo-identification, tagging and

biopsy sampling. The present study indicates when surveys off the Chukotka Peninsula could be carried out in order to maximise sightings. Similarly, the data could be used to identify times when whales are least likely to be in the area, to minimise the impact of, for example, seismic surveys, which have been linked to mass strandings of cetaceans (IWC, 2005, pp.267-75). Further work in the area is needed to understand the special variations in killer whale populations that are described here.

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