

Cetacean observations during a winter voyage into Antarctic sea ice south of Australia

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Abstract: Cetacean observations were made from a platform of opportunity (a winter sea ice and oceanography research voyage) in Antarctic sea ice south of Tasmania. Minke whales and killer whales were sighted well within the sea ice. Minkes were found between 180–350 km south of the ice edge, while killer whales were nearly 450 km south of the ice edge. Minkes were sparsely distributed throughout the seasonal sea ice, even in areas of apparent total ice cover. Killer whales (including calves) were found at the northern edge of a major coastal polynya system. The winter sea ice is a complex and dynamic environment in which lead and polynya systems may enable travel and foraging by some cetacean species. While biological productivity is known to be reduced from summer levels, large numbers of seals, penguins – and possibly small numbers of whales – may be supported by krill and other biota intimately associated with the sea ice habitat during winter.

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Introduction

Several long-term biological programmes have been directed at understanding cycles of natural variability in the Southern Ocean ecosystem. Predator–prey responses may indicate perturbations within this system (van Franeker 1992). While certain seabirds, penguins, seals, fish and squid have been designated as key species for predator–prey research, cetaceans have not, despite their longevity, high trophic position, high individual consumption of prey biomass, total biomass, historical biomass, and seasonal behaviour. Minke (*Balaenoptera acutorostrata*) and killer (*Orcinus orca*) whales meet the criteria established by GLOBEC for key species categorization (Hofmann 1995).

To understand the role of cetaceans and their interactions with other species, it is important to investigate their activities in all seasons. Antarctic cetacean observations are usually made in the spring and summer when most migratory species arrive to feed (Mackintosh 1965, Kasamatsu *et al.* 1996). Many of the baleen whale species are known to fast throughout most of the Southern Hemisphere winter whilst on migration. Some cetacean species have been reported in winter sea ice. Minke, killer and Arnoux's beaked (*Berardius arnuxii*) whales were recorded in sea ice in winter 1955 (Taylor 1957). More recently, low numbers of minke and killer whales have been sighted in winter in the Weddell–Scotia Sea area (Ribic *et al.* 1991, Plotz *et al.* 1991). However, there is little information regarding the winter distribution, abundance and ecology of whales in Antarctic waters.

The cetacean study described here was a response to the inception of the Southern Ocean Whale Sanctuary in 1994, and is part of a long-term interdisciplinary research programme

which integrates biological studies with oceanographic and glaciological research in the sea-ice zone. The aim of this study was to investigate which cetacean species inhabit the sea ice zone to the south of Australia in the winter (during the first winter voyage into sea ice in this region), the extent to which the sea ice is penetrated by these species, their habitat preferences and how these relate to food sources.

Methods

During the winter of 1995 a sea-ice and oceanography research programme was conducted aboard the icebreaker *Aurora Australis*. The vessel departed Hobart, Tasmania on 17 July 1995 for 44°00'S, 146°19'E, where the first of a series of CTDs was initiated as part of WOCE (World Ocean Circulation Experiment). The CTD programme proceeded south-west until the 139°50'E meridian was intercepted, thence due south into the sea-ice until a designated sea ice study area was reached. Within the sea ice, oceanography and glaciology programmes determined the ship's track, which remained in an area between 64°S and 65°S, and between 137°E and 142°E. Ancillary biological programmes included phytoplankton sampling, zooplankton sampling, a zooplankton hydroacoustic survey, and bird, seal and cetacean observations. The vessel was in sea ice between 31 July 1995 and 27 August 1995, and returned to Hobart on 2 September 1995.

Cetacean observations were conducted by the authors during all 'daylight' hours. 'Daylight' was defined as first light to last light. During winter in the Antarctic the angle of the sun to the horizon is low, with the sun exhibiting influence for approximately eight hours per day at this latitude. We found

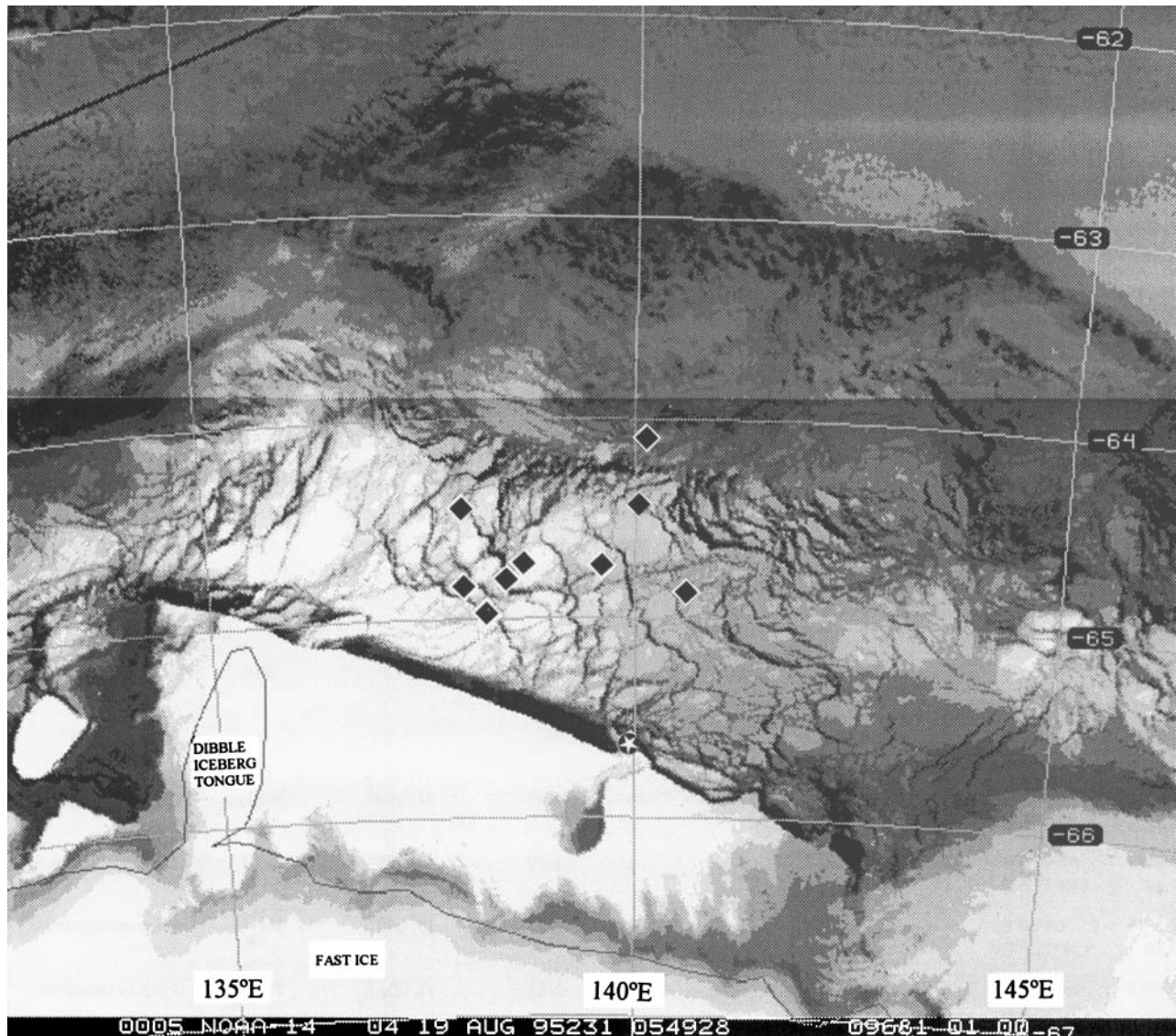


Fig. 1. NOAA-14 thermal infrared ice photograph of the study area, 19 August 1995. Killer whales were sighted at ★, lower centre, at the edge of the coastal polynya (seen as the elongated dark area along the edge of the fast ice). Minke whale sightings in the sea ice are shown by ◆. Extensive lead systems are seen within the sea ice, the northern portion of which is obscured by cloud. The ice edge was at about 62°S. (Image courtesy of Roger Lurz and Steve Pendlebury, Australian Meteorological Bureau, Hobart, and Glen Hyland and Neal Young, Antarctic CRC, Hobart).

the low light or 'twilight' effect to be particularly conducive to detecting cues such as blows, splashes (which stood out against the grey-blue water and sky), and the body of an animal (which stood out against the ice). Both authors are experienced in at-sea observations of cetacean species found in the Antarctic. While two observers were present, each searched a 90° arc to the horizon from the trackline to abeam of the ship. Searching was carried out in most conditions during available daylight hours, although during very poor sighting conditions (fog or blizzard) only one observer remained on watch searching the full 180° area. A 'group' of cetaceans is defined in this paper as a grouping of a species, the individuals of which are within five body lengths of each other and separated by >1 n mile

from any other grouping. Line transect methodology was deemed inappropriate due to continual speed and course variation according to ice conditions and the need to stop for sea ice sampling, CTDs and helicopter operations.

Results

Sea-ice

The vessel encountered the ice edge at 61°45'S, 139°50'E on 31 July 1995 and was then continuously in sea-ice until 27 August 1995, when it left the ice at 63°05'S, 139°50'E on the way north. The ice edge had moved considerably further

Table I. Cetacean sightings from *Aurora Australis* – voyage 1, 1995.

Date/ Time (GMT)	Position	Species (number)	No. of groups	Depth (m)	Sea temp °C	Beaufort wind- force/direction	Ice concentration	Ice type
17/7/95 22.41	44°22.8'S 146°11.0'E	sperm whales (15–20)	2	–	10.6	f6, 279°	0	open water
25/7/95 13.45	55°01.8'S 141°00.6'E	hourglass dolphins (5)	1	3017	1.37	f3, 121°	0	open water
26/7/95 23.35	57°14.2'S 139°51.9'E	hourglass dolphins (25)	1	4093	1.14	f1, 277°	0	open water
31/7/95 01.10	63°22.1'S 139°46.7'E	minke whale (1)	1	3725	-1.68	f5, 028°	5/10	young ice
3/8/95 02.55	64°49.8'S 141°35.6'E	minke whale (2)	1	3474	-1.8	f5, 108°	9/10	young ice, some old floes
**8/8/95 * 02.50	64°26.5'S 139°57.6'E	minke whales (2)	1	–	–	f4, 240°	8/10	young ice with brash
**10/8/95 * 02.18	65°37'S 139°48'E	killer whales (15)	1	–	–	–	–	–
* 10/8/95 05.00	65°42'S 139°56'E	killer whales (40)	5	c. 300	–	f2, 360°	5/10	heavy floes & young ice: grounded bergs
* 14/8/95 04.45	64°28'S 138°01'E	minke whale (1)	1	–	–	–	“heavy”	lead in heavy pack
* 20/8/95 04.30	64°41'S 138°44'E	minke whales (2)	1	–	–	–	9/10	lead 3m wide
* 24/8/95 03.50	64°40'S 139°33'E	minke whale (1)	1	–	–	–	–	“in large lead”
14/8/95 14.15	64°46'S 138°29'E	minke whales (3)	1	2469	-1.83	f4, 110°	9/10+	large heavy floes
15/8/95 22.46	64°07.5'S 140°11.3'E	minke whales (4)	1	–	-1.79	f4, 106°	8/10	broken refrozen floes
18/8/95 23.40	64°54'S 138°11.6'E	minke whales (2)	1	2538	-1.83	f3, 240°	10/10	nilas in large lead
19/8/95 06.20	64°43.9'S 137°55.6'E	minke whale (1)	1	2892	-1.81	f3, 251°	10/10	nilas in large lead
19/8/95 06.55	64°36'S 137°50'E	unidentified whale (1)	1	2865	-1.81	f3, 251°	9/10	lead among heavy floes

*Cetacean sightings from helicopters, Voyage 1 1995.

**Sightings not identified by one or both of the authors.

south (148 km) during the intervening period, presumably because of strong northerly winds towards the end of this period. In this longitude, sea ice extends less distance offshore from the coast than almost anywhere else around the continent (Jacka 1983).

During the first few days within the sea ice, relatively high air temperatures ($\leq -0.4^{\circ}\text{C}$) inhibited freezing of leads, and open water was common. After 2 August air temperatures dropped rapidly, and remained below -10°C for 22 days. Local noon air temperature was below -20°C on nine days. The lowest temperature recorded was -30.0°C on 18 August. During this cold period constant processes of ice formation and deformation highlighted the dynamic nature of the effects of changes in air–sea–ice temperature exchange on lead

systems and open water in winter sea ice.

Near the northern end of the survey area, the marginal sea ice (see Eicken 1992) was characterized by relatively small floes (< 50 m diameter), pancake or brash ice, and frequent large open pools. Further in where ocean swell was negligible, the closed seasonal pack ice consisted of large (often > 200 m) floes drifted over with snow, appearing like a uniform plain. Ice thickness was generally 0.4–0.7 m. Leads were sporadic in this consolidated ice. Large recently opened leads were occasionally encountered, with nilas and other young ice formation within them.

125 cetaceans were sighted during the voyage. Details of sightings are given in Table I. The sperm whale and hourglass dolphin sightings were made north of the sea ice. These

observations have been included here for information due to the lack of cetacean research in the Southern Ocean during winter and the consequent paucity of winter sightings of any species.

Minke whales

Minkes were the most frequently sighted cetaceans. Nineteen animals were sighted in 11 groups (average group size 1.73). All sightings appeared to be of the dark shoulder form (Best 1985, Arnold *et al.* 1987). Although there was noticeable size variation, no obvious juveniles or calves were noted. The northernmost sighting occurred at 63°22'S, 139°46.7'E, 180 km south of the 31 July ice edge. Sightings occurred as far south as 64°54'S, 138°11.6'E, 350 km south of the 31 July ice edge.

All minke whale sightings occurred well into the sea ice, in ice concentrations between 5/10 and 10/10, with 8 of 9 sightings (where ice concentration was recorded) occurring in ice of 8/10 or heavier concentration. Sightings occurred in all ice types from nilas (young, flexible, grey ice) in refreezing leads, to narrow leads in heavy cover of large consolidated floes. Sometimes they surfaced in leads so narrow that the rostrum was pointed vertically to enable the whale to breathe (also described by Taylor 1957, Naito 1982, Ensor 1989).

Killer whales

Killer whales were sighted twice on 10 August 1995, at two locations 11 km apart. The first sighting occurred at 02h18 GMT, when about 15 whales were sighted from the ship's helicopters at 65°37'S, 139°48'E. After collecting the authors from the ship, the helicopters returned to the area of the sighting, and killer whales were located at 05h00 GMT, at 65°42'S, 139°56'E. This location was 438 km south of the 31 July ice edge.

The second sighting has been described in detail elsewhere (Gill & Thiele 1997). It is probable that the whales were the same group as those seen at 02h18, as the helicopters searched the area in fair visibility, and only one group was seen during each visit. In this area a line of icebergs was aground on a bank, with associated systems of leads as sea ice moved through the area with prevailing easterly currents. This site was near the edge of shore-fast ice, and a large coastal polynya which lay along it (see Fig 1).

An estimated 40 animals were in the area, including mature animals of both sexes, immatures, and at least one calf, apparently only a few months old (< 3m length). Emperor penguins (*Aptenodytes forsteri*), Adélie penguins (*Pygoscelis adeliae*), a leopard seal (*Hydrurga leptonyx*) and crabeater seals (*Lobodon carcinophagus*) were seen on the ice in this vicinity. Small groups (of up to seven individuals) of whales were seen from the aircraft, dispersed over 1000–2000 m, surfacing in open pools and in young ice between ice floes.

Sperm whales

Sperm whales were sighted at 44°22.8'S, 146°11.0'E on 17 July, while the ship was at a CTD station for over two hours. There appeared to be two distinct groups of whales. The first group of about 15 animals of mixed sizes was visible between 22h44–23h10 GMT before moving off to the south-west. A large flock of Cape petrels (*Daption capense*) and unidentified albatrosses (*Diomedea* spp.) appeared to feed in the area where these whales were first seen. These whales were within 500 m of the buoys of a tuna longline. The second group consisted of about 20 larger animals of roughly uniform size, and was visible between 00h04–01h06 GMT 18 July, heading slowly north. Few fluke up dives were noted during either observation. Both groups remained relatively compact.

Hourglass dolphins

Two groups were sighted in open water well north of the ice. The sighting on 25 July was brief, and the dolphins did not approach the ship. In the sighting on 26 July, the dolphins appeared to attempt to join the ship, approaching it obliquely from the starboard side to within 400 m, but seemed unable to catch it due to its speed (nearly 26 km h⁻¹). The ship stopped for a CTD station while the dolphins were still in sight, but they did not approach the stationary vessel. No calves were noted in either sighting.

Discussion

It is sometimes suggested that Antarctic waters in winter constitute a "biological desert" after the productivity of summer months has declined. Yet clearly this ecosystem sustains seals, penguins, and seabirds which remain in the sea ice through the winter months (Stonehouse 1953, Plotz *et al.* 1991, Ribic *et al.* 1991, Nordøy *et al.* 1995, Davis *et al.* 1996, Gill & Thiele 1997). Our sightings support earlier observations and suggestions (Ensor 1989) that some cetaceans may overwinter in the Antarctic sea ice. Further work will be required to determine whether these reports are indicative of adaptation by these species to sea ice habitat year round or infrequent events due to unusual physical conditions.

Krill were rarely detected hydroacoustically, or caught using nets lowered through holes in ice, but were frequently noted in excreta of seals and penguins on ice floes, and were occasionally observed when ice floes were overturned by the ship.

Little is known of the distribution of zooplankton throughout winter sea-ice. In summer, krill has a patchy distribution (Nicol 1994). High density of cetaceans in summer has been related to upwelling of nutrient-rich water over a major bathymetric feature, such as the southern flank of the Kerguelen Plateau, an area of wide sea ice extent in winter (Tynan 1996). In the Weddell Sea in winter 1986, krill and their predators were abundant in the vicinity of the Maud Rise, where upwelling

of warm water is thought to melt ice and release algae (Plotz *et al.* 1991). In the absence of such concentrating features, winter krill distribution may be sparse and patchy, and predators may forage widely. Low densities of minke whales, crabeater seals, leopard seals, Adélie penguins, Antarctic petrels (*Thalassoica antarctica*) and snow petrels (*Pagodromanivea*) were observed throughout the study area away from the polynya.

Summer sightings of minke whales have been reported 167 km inside sea ice, and in areas of heavy (8/10–9/10) ice concentration (Naito 1982). Naito (1982) considered that minke whales enter the sea ice in early summer. However, Ensor (1989) sighted minke whales about 900 km south of the ice edge in October–November, when sea ice conditions are little changed from winter, and surmised that some whales probably over-winter in the ice. Taylor (1957) reported the first winter sighting of minke whales in 1955, in open pools in coastal fast ice on the Antarctic Peninsula, but thought that they had been prevented from migrating north by the sea freezing to seaward of them. Only in recent years have vessels entered Antarctic winter sea ice and routinely encountered minke whales in the marginal and seasonal sea ice zones (Ribic *et al.* 1991, Plotz *et al.* 1991). Ribic *et al.* (1991) only entered 100 km into the ice, finding minke whales mainly associated with new ice and pancake ice, both early stages in ice formation. Plotz *et al.* (1991), however, found a minke whale 1300 km south of the ice edge in the eastern Weddell Sea, in heavy ice close to the coast.

In the present study, minke whales were seen in narrow leads in very heavy ice cover, up to 350 km into the sea ice. They may be able to forage in heavy ice conditions throughout the year, or there may be no necessity to feed during winter given the tendency for baleen whale species to fast on migration. Observations from subsequent surveys by the authors of minke whales utilizing heavy ice habitat throughout the year would seem to indicate that this species is not unused to such conditions (unpublished data). The advantage to some animals (whether particular age classes or some other grouping) of remaining in the Southern Ocean sea ice over winter, rather than participating in a northern migration to breeding areas, needs to be determined if overwintering by cetacean species in this region is shown to be the norm rather than the exception.

There has only been one report of killer whales in winter since 1955 (Taylor 1957). Plotz *et al.* (1991) noted positions of killer whales sighted in open leads in the north-eastern Weddell Sea in winter 1986, without further details or discussion. Killer whales have been previously recorded as occurring only in the outer fringe of the summer sea ice, leaving Antarctic waters in early autumn (Leatherwood & Dahlheim 1978, Jehl *et al.* 1980, Mikhalev *et al.* 1981, Kasamatsu & Joyce 1995), their migration “linked to that of . . . prey species, in particular the minke whale” (Mikhalev *et al.* 1981).

The locality of the killer whale sighting in a polynya to the

south of the main survey area is described in detail in Gill & Thiele (1997). This system of icebergs and leads may enhance local marine productivity throughout winter, through upwelling of nutrients on the bank, and increased light levels into the water. Although the vessel was unable to approach this area to sample for krill and other plankton, extensive algal growth was noted on the underwater surface of icebergs, and two species each of seals, penguins and seabirds were observed in the immediate area of the killer whale sighting. It is possible that one of the contributing factors to the formation and maintenance of coastal polynyas is an upwelling of the relatively warm Circumpolar Deep Water (N. Bindoff, personal communication 1998).

Observations made during this study add insights into the way in which marine wildlife utilises winter sea ice. Aerial and satellite views confirm that lead systems permeate the sea ice, a dynamic environment in which leads are constantly closed by strong winds, reformed, and frozen over (I. Allison, personal communication 1995). Minke whales, seals and penguins were distributed widely throughout the sea ice in the study area, often in heavy ice with few leads. The cues used by minke whales to navigate in sea ice are unknown, but they do not appear to avoid areas of compacted or heavy ice. Arctic bowhead whales (*Balaena mysticetus*), another mysticete well adapted to heavy ice, may use reverberation of their calls from the underside of ice floes, to determine the nature of the ice ahead (Ellison *et al.* 1987).

The presence of prey species in the winter sea ice suggests the energetic advantages to killer whales in remaining to exploit them. The killer whales observed were in the vicinity of large areas of open water which may concentrate prey species, so that killer whales need not forage throughout the main body of the sea ice, where prey species occur in low densities. A winter polynya study is planned in this area in July 1999, which we hope will provide more data on the behaviour and predator-prey dynamics of killer whales in winter, and on the possible use of this, and the surrounding heavy ice areas by other cetacean species.

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