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Aerial surveys for pack-ice seals along the Ingrid Christensen and Princess Astrid Coasts, East Antarctica

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Abstract: We conducted aerial surveys in the austral summer of 2009–2010 to count and record the spatial distribution patterns of pack-ice seals hauled-out along the Ingrid Christensen and Princess Astrid coast of East Antarctica. A total of 3,601 hauled-out seals were counted from six aerial surveys totalling a length of approx. 1,200km, with each survey lasting about two hours. Weddell Seal *Leptonychotes weddellii* was the most commonly sighted species in both the areas surveyed (98.2%), and had an encounter rate of 2.9 seals/km. The other species encountered during the survey were Crabeater Seal *Lobodon carcinophaga* (1.7%) and Leopard Seal *Hydrurga leptonyx* (0.03%). Group size of hauled-out Weddell Seals varied considerably and ranged from solitary to maximum of 42 individuals. The median group size of Weddell seals hauled-out along the Ingrid Christenson Coast was found to be significantly different between the December 2009 and January 2010 survey. Further, along this coast Weddell Seals were found hauled-out mainly close to the ice shelf and their spatial distribution appeared to be influenced by the extent of sea ice in the area.

Keywords: Aerial census, Crabeater Seal, encounter rate, group size, *Hydrurga leptonyx*, *Leptonychotes weddellii*, Leopard Seal, *Lobodon carcinophaga*, spatial distribution, Weddell Seal.

Hindi Abstract: इनग्रिड किसटेनसेन तथा प्रिन्सेस एस्ट्रिड कोस्ट, पूर्वी अंटार्कटिका के आस–पास, वर्ष 2009–2010 के दक्षिण ग्रीष्मकाल में खींच कर बाहर लायी गई प्रवाही हिमपुंज सील्स की स्थानिक वितरण को रिकार्ड करने एवं उनकी संख्या का अनुमान लगाने की दृष्टि से हमने हवाई सर्वेक्षण किये। दो घंटे के प्रत्येक सर्वेक्षण के साथ 1200 किमी की लम्बाई का क्षेत्र कवर करते हुए कुल छह सर्वेक्षण के साथ बाहर लाई गई सील्स कुल मिलाकर 3601 थी। सर्वेक्षण किये गये (98.2%) दोनो ही क्षेत्रों में वैडल सील लैप्टोना. इकोटस वैडेली को सबसे अधिक संख्या में देखा गया तथा इसकी टकराव दर 2.9 सील्स/प्रति किमी थी। सर्वेक्षण के दौरान अन्य प्रजातियों में टकराव दर केबीटर सील लोबोडोन कार्सीनोफागा (1.7%) तथा लैपर्ड सील हाईडर्गा लैपटोनिक्स (0.03%). रही। बाहर लाई गई वैडल सील्स के समूह आकर में भिन्नता पराई गई तथा इनकी संख्या क्षेत्रवार एक से लेकर अधिकतम 42 के समूह में देखी गई। दिसम्बर 2009 व जनवरी 2010 के सर्वेक्षण के बीच इनग्रिड किसटेनसेन तट के आस–पास बाहर लाई गई वेडल सील्स के मध्यम समूह आकार में महत्वपूर्ण विभिन्नता पाई गई। इसके पश्चात इस तट के आस–पास वैडल सील्स बर्फीली सतह के समीप मुखय रूप से पायी गई एवं इनका स्थानिय वितरण उस क्षेत्र में पाई जाने वाली समुद्री बर्फ के आकर से भी प्रभावित हुआ था।

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INTRODUCTION

Five of the 18 extant species of true or earless seals of the family Phocidae: the Southern Elephant Seal *Mirounga leonina*, Weddell Seal *Leptonychotes weddellii*, Crabeater Seal *Lobodon carcinophaga*, Leopard Seal *Hydrurga leptonyx* and Ross Seal *Ommatophoca rossii* occur exclusively in the southern Hemisphere. They have a circumpolar distribution around the Antarctic Continent and also occur a little further north in the southern Ocean and on sub-antarctic islands (Folkens et al. 2008). Being amongst the dominant top predators in the Antarctic ecosystem they likely play an important role (Bowen 1997), however the role of marine mammals in aquatic ecosystems is poorly understood (Yodzis 1994, 2001; Bowen 1997; Mackinson et al. 2003; Morissette et al. 2006).

The population status of the Antarctic pack-ice seals except for the Southern Elephant Seal until recently was unknown and, therefore, a continent-wide census under the Antarctic Pack Ice Seals (APIS) program was initiated by the Scientific Committee on Antarctic Research Group of Specialists on Seals (Southwell et al. 2012). In the 19th and early 20th centuries, the Southern Elephant Seal was hunted almost to extinction, while the other species were free from commercial exploitation (Shirihai 2008). These other species escaped by virtue of their range being in dangerous and ice-filled seas (Testa & Siniff 1987). All of these five species of seals are currently protected under the Antarctic Treaty and there has been no commercial sealing in Antarctica since the 1950's, though there have been Norwegian and Russian experimental commercial seal harvests since that time. Due to the present widespread occurrence and large population size globally all of the Antarctic pack-ice seals are classified as Least Concern by the IUCN.

In recent times, loss of sea ice due to climate change has been reported or anticipated to have an impact on marine mammals including pinnipeds (see Learmonth et al. 2006). Loss of suitable breeding and resting habitats of pack-ice seals due to loss of sea ice, coupled with changes in food web dynamics may negatively impact seal populations, specifically the Crabeater and Weddell seals (Siniff et al. 2008; Costa et al. 2010; Forcada et al. 2012). Considering the potential threat to Antarctic pack-ice seals it becomes important to monitor their habitats and track population trends.

The National Centre for Antarctic and Ocean Research (NCAOR), Ministry of Earth Sciences, India, has been undertaking annual expeditions to the Antarctic continent since 1981. As part of NCAOR's "Long-term monitoring of wildlife and their habitats in Antarctica", primarily focussed in areas where the Indian research stations are located, regular counts of sea birds, seals and other marine mammals are conducted during the austral summer through aerial and ship based surveys (Sathyakumar 1998; Bhatnagar & Sathyakumar 1999; Hussain & Saxena 2000; Sathyakumar & Sivakumar 2009). Here we report the findings of an ice seal survey carried out during the austral summer of 2009–2010 along the Ingrid Christenson and Princess Astrid coasts in East Antarctica as part of the 29th Indian scientific expedition to the continent.

MATERIAL AND METHODS

Study area

Seal surveys were conducted near two Indian research stations: Bharti and Maitri in Antarctica (Image 1). The first station visited was Bharti located in the Larsemann Hills along the Ingrid Christenson Coast, East Antarctica. There, surveys were carried out during December 2009 and January 2010 within the Prydz Bay between 74–77 ^{0}E longitudes. This coastline is characterised by coastal hills and ice shelves including that of the Amery Ice Shelf, and several rocky islands. Fast ice stretched to over 25km offshore until the third week of January 2010, and gradually declined in its extent, and later became entirely ice free. The second station, Maitri, located in the Princess Astrid Coast was visited in February 2010, where surveys were carried out between 11–14 ^{0}E longitudes. Here the coastline was completely unlike that of the Prydz Bay region, and is primarily composed of the Fimbul and Lazarev ice shelf margins. During the time of visit to the site, most of the area surveyed was open water and pack ice.

Methods

Aerial surveys using a single-engine Eurocopter AS 350 B2 were conducted for pack-ice seals at both the study sites. Due to limitations in the availability and operational capacity of the helicopter no systematic design could be followed for the surveys. In the Prydz Bay region, two surveys were made in each of the two months surveyed, while at the Fimbul Ice Shelf site only two aerial surveys were made in February 2010. Using the ship as the base, surveys were made to the east and to the west of the region, and each trip covered a distance of about 200 to 250 km, lasting on average two hours. Each flight followed a pattern of first flying along the contour of the coastline covering on average 100km,

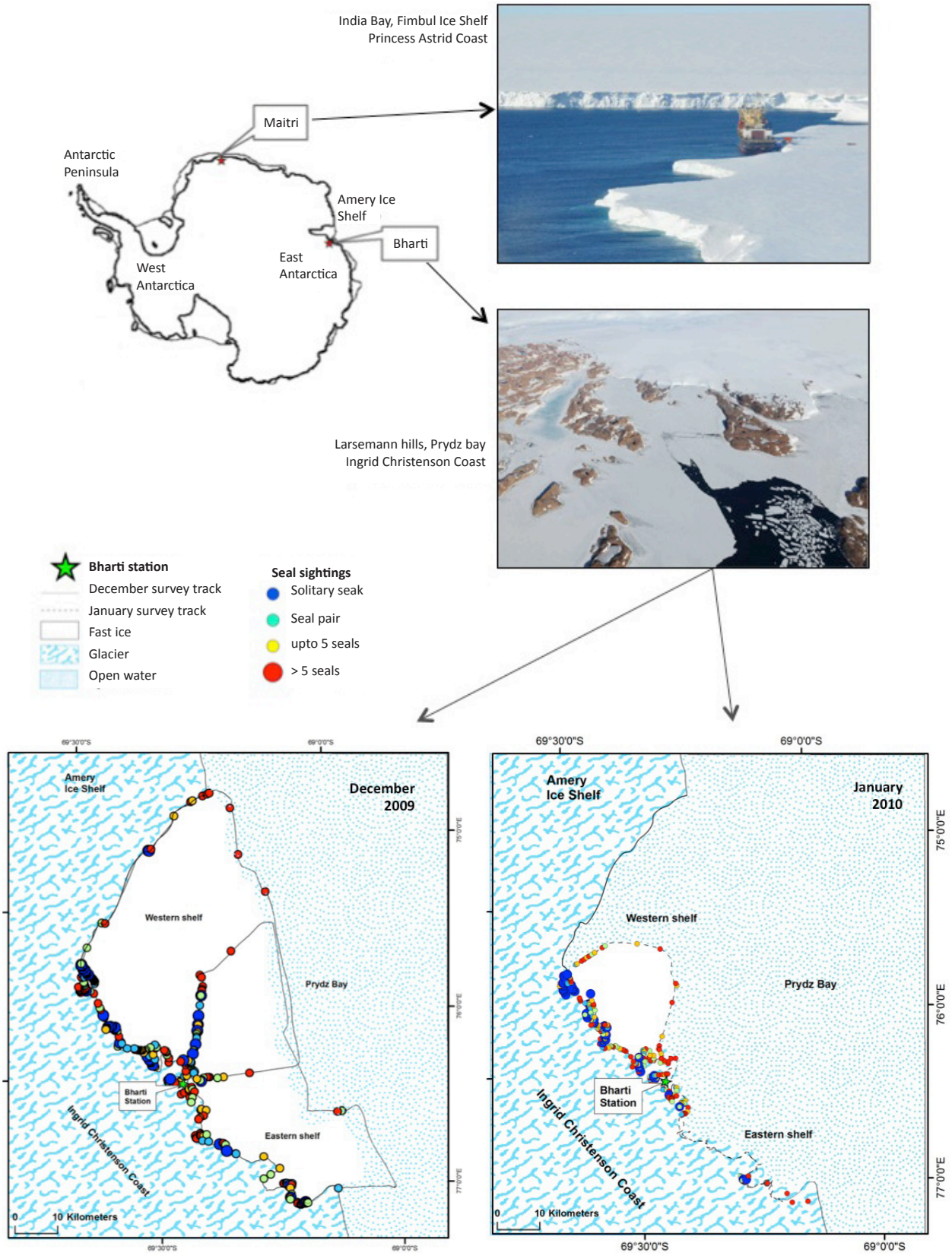

Figure 1. Map of Antarctica showing the locations of the two Indian research stations Maitri, in the Princess Astrid Coast and Bharti located in the Larsemann Hills, Ingrid Christenson Coast. The aerial survey routes and the Weddell Seal sighting locations in the Prydz Bay region during December 2009 and January 2010 are shown in the figures below. The fast ice cover observed during the two survey months is only an approximate rendition, though drastic reduction in the spread of fast ice was observed in January.

then flying out over the fast ice and up to the pack ice edge, and then surveying all along the pack ice edge and over fast ice before returning to the ship. Censuses of Weddell Seals in particular are recommended to be carried out after 1430 and before 1700 hr local time, especially in the moulting season, which is from January to March (Lake et al. 1997). While our study partly overlapped this period we could not conduct surveys during the recommended time due to logistic difficulties, and all surveys were made between 0900 and 1100 hrs local time.

Two observers along with the pilot searched for hauled-out seals on either side of the helicopter. The helicopter was flown at a constant speed on average 90 knots and at an altitude of approx. 80m. The pilot and the observer seated next to him reported the seal sightings, the species, and group size, while the observer seated behind the pilot recorded the data. The observer in the front also estimated visually the perpendicular distance of the seal from the track-line and marked the location on a hand-held GPS at every sighting. To take counts of seals in a large congregation the helicopter was slowed down. On a few occasions when the seal species could not be identified or the number of seals in a large congregation could not be counted, a photograph of the same was taken. The photographs were later examined in camp to identify and or count the number of seals recorded at that point. Following Erickson et al. (1993) all seals occurring within 20m of each other were considered as a group.

Analysis

A general summarisation of the seal sightings as encounter rates was made since the survey effort was low and not allocated in a manner that would support design-based estimates of density and distribution. The seal sighting data were segregated according to the sighting location such as shelf-ice/edge, fact ice and pack ice.

RESULTS

Seal survey

A total of six aerial surveys were flown during this study, totalling a length of approx. 1200km, comprising four surveys in the Prydz Bay region totalling 800km, and two surveys along the Fimbul Ice Shelf totalling 400km. Except for the Southern Elephant Seal and Ross Seal all the other species of pack-ice seals were recorded during the aerial surveys (Image 2).

Encounter rate

A total of 3645 seals that included Weddell, Crabeater and Leopard seals were counted during the six aerial surveys; of these in the Prydz Bay region alone 3273 seals were counted (see Table 1a & 1b). A total of 41 seals in the Prydz Bay and three in the Fimbul Ice Shelf sites could not be distinguished as to whether they were Weddell or Crabeater Seals. Weddell Seals were the most commonly sighted species in both the areas surveyed (97.0%), and had an encounter rate of 2.9 seals/km. This was followed by the sightings of Crabeater Seals (1.7%) and a single record of a Leopard Seal (0.03%). Ross Seals were not encountered during the aerial surveys, however a pair was seen once from the ship en route to the Fimbul Ice Shelf, hauled out on fast ice.

The encounter rate of Weddell Seals in Prydz Bay (4.0 seals/km) was much higher compared to that of the Fimbul Ice Shelf site (0.8 seals/km). Within Prydz Bay the encounter rate of Weddell Seals differed between the months of survey; there 2.7 seals/km were recorded during December while in January 6.1 seals/km were encountered. Also, Weddell Seal encounters for the two months combined were greater in the western shelf (5.4 seals/km) than in the eastern shelf (2.2 seals/km). The encounter rate of Weddell Seals also differed with respect to location and sea ice conditions. Maximum sightings occurred along the shelf-ice/edge with an encounter rate of 6.8 seals/km, while over the fast ice and pack ice 2.3 and 0.1 seals/km were recorded respectively.

Group size

A total of 668 Weddell Seal groups with sizes ranging from solitary to maximum of 42 individuals were sighted during the surveys in the Prydz Bay site. Maximum numbers of Weddell Seals were observed solitary (n = 237) and accounted for 35.5 % of all groups sighted. More solitary individuals were sighted during surveys in January (40.8 %) than in December (27.7 %) in the Prydz Bay (Fig. 1). A higher number of groups with >5 individuals was seen in January (n = 103) as compared to December (n = 86).

DISCUSSION

The high number of Weddell Seal encounters during this expedition in both Prydz bay and the Fimbul Ice Shelf site is because the survey tracks there were almost entirely near the coast of Antarctica, where the species

Table 1a. Details of the aerial survey for seals carried out in the Prydz bay during December 2009 and January 2010.

Region & Date	Survey stretch	Distance (km)	Duration (hr:min)	Weddel (seal/ km)	Crabeater (seal/ km)	Leopard (seal/ km)	Unknown (seal/ km)
Eastern Shelf							
20.xii.2009	Temperature = -2^{0}C; Wind speed = 10.7 knots; Cloud cover = 0%						
	Shelf-ice/edge	93	00:54	271 (2.9)	0	0	2 (0.02)
	Fast Ice	76	00:34	261 (3.4)	0	0	4 (0.05)
	Pack Ice	79	00:27	12 (0.2)	1 (0.01)	0	0
	Total	248	01:55	544 (2.2)	1 (0.004)	0	6 (0.02)
18.i.2010	Temperature = -2^{0}C; Wind speed = 10.7 knots; Cloud cover = 0%						
	Shelf-ice/edge	94	00:50	257 (2.7)	0	0	3 (0.03)
	Fast Ice	-	-	-	-	-	-
	Pack Ice	19	00:06	3 (0.2)	0	0	0
	Total	113	00:56	260 (2.3)	0	0	3 (0.03)
Eastern Shelf Total		**361**	**02:51**	**804 (2.2)**	**1 (0.003)**	**0**	**9 (0.02)**
Western Shelf							
22.xii.2009	Temperature = -2^{0}C; Wind speed = 10.7 knots; Cloud cover = 0%						
	Shelf-ice/edge	100	00:56	708 (7.1)	0	0	12 (0.12)
	Fast Ice	78	00:30	99 (1.3)	0	0	1 (0.01)
	Pack Ice	76	00:27	3 (0.03)	0	0	0
	Total	254	01:53	807 (3.2)	0	0	13 (0.05)
17.i.2010	Temperature = -2^{0}C; Wind speed = 7.8 knots; Cloud cover = 0%						
	Shelf-ice/edge	130	01:20	1580 (12.2)	0	0	19 (0.15)
	Fast Ice	15	00:05	25 (1.7)	0	0	0
	Pack Ice	48	00:20	15 (0.3)	0	0	0
	Total	193	01:45	1620 (8.4)	0	0	19 (0.09)
Western Shelf Total		**447**	**03:38**	**2427 (5.4)**	**0**	**0**	**32 (0.07)**
Prydz Bay (Overall)		**808**	**06:29**	**3231 (3.9)**	**1 (0.001)**	**0**	**41(0.05)**

Table 1b. Details of the aerial survey for seals carried out in the Fimbul Ice Shelf site during February 2010.

Region & Date	Survey stretch	Distance (km)	Duration (hr:min)	Weddel (seal/ km)	Crabeater (seal/ km)	Leopard (seal/ km)	Unknown (seal/ km)
Fimbul Eastern Shelf							
15.ii.2010	Temperature = -2^{0}C; Wind speed = 15 knots; Cloud cover = 0%						
	Shelf-ice/edge	205*	01:55	94 (0.4)	3 (0.01)	0	0
	Fast Ice	-	-	-	-	0	0
	Pack Ice	-	-	-	-	0	0
	Total	205	01:55	94 (0.4)	3 (0.01)	0	0
Fimbul Western Shelf							
21.ii.2010	Temperature = -10^{0}C; Wind speed = 25 knots; Cloud cover = 0%						
	Shelf-ice/edge	125#	01:30	181 (1.4)	42 (0.3)	0	3
	Fast Ice	-	-	-	-	0	0
	Pack Ice	75	00:30	31 (0.4)	17 (0.2)	1 (0.01)	0
	Total	200	02:00	212 (1.1)	59 (0.3)	1 (0.005)	3 (0.01)
Fimbul Ice Shelf (Overall)		**405**	**03:55**	**306 (0.8)**	**62 (0.2)**	**1 (0.002)**	**3 (0.01)**

* Of a total of 205km surveyed only 80km was on fast ice while the rest was open water conditions
# Of a total of 125km surveyed only 107km was on fast ice while the rest 18km was open water conditions

Image 2. The four species of pack ice seals. (a) Weddell Seal *Leptonychotes weddellii*; (b) Crabeater Seal *Lobodon carcinophaga*; (c) Leopard Seal *Hydrurga leptonyx* and (d) Ross Seal *Ommatophoca rossii* encountered during the surveys in the Prydz Bay and Fimbul Ice Shelf during the expedition

is known to largely inhabit (Lugg 1966; Stirling 1969a; Kooyman 1975; Testa & Siniff 1987). The presence of fast ice does not necessarily limit Weddell Seal occurrence as they can maintain breathing holes by abrading the sea ice with their canine teeth (Stirling 1969a). Moreover, in inshore fast ice areas, Weddell Seals use ice breaks or cracks caused by tidal action and glacial movement for breathing, hauling out and pupping (Stirling 1969a). This was typical of the surveyed site in the Prydz Bay, which is located far inshore and with smaller bays sheltered by the rocky slopes of the Larsemann Hills, and is possibly the reason why more Weddell seals were encountered there. In the western Ross Sea counts of Weddell Seals in a square mile of pack ice were reported to be low when compared to a similar track length in fast ice where more than 100 seals were recorded (Stirling 1969), consistent with the species' preference for fast ice during the summer.

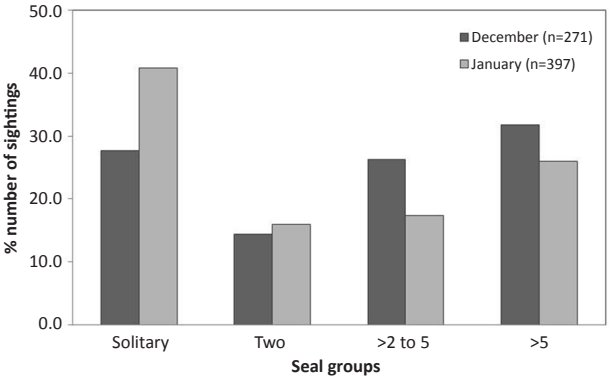

Figure 1. The percentage distribution of different seal groups observed in the Prydz Bay during December 2009 and January 2010.

Sathyakumar & Sivakumar (2009) encountered 7.2 Weddell seals/km during January 2009 in the Prydz Bay, and 1.2 seals/km during February 2009 in the Fimbul Ice

Image 3. Large aggregations of Weddell Seal were only observed when there were a few tidal cracks available for hauling out along a vast stretch of thick fast ice and may not represent any sociality.

Shelf area, which is similar to our observations of this study. The lower encounter rate of Weddell seals at the Fimbul site recorded during 2009 and the current study is also perhaps related to the time of survey. The visit to this site was in late summer when much of the fast ice cover was reduced to open water, resulting in poor detectability of seals.

Within the Prydz Bay site the higher encounters of Weddell Seals in the western shelf than in the east during this study appeared to be as a result of availability of fast ice in the area. Much of the fast ice cover along the eastern shelf was reduced to open water earlier than the western parts. In a span of a month the fast ice cover in the entire area observed in mid-December of approx 2500km^2 reduced to approx. 600km^2 in January, much of which remaining in the western parts. Along the western parts the break-away ice sheets from the Amery Ice Shelf provided hauling sites for seals, which likely lead to the crowding of Weddell Seals there and thus resulted in higher encounters. Along the Princess Martha Coast seal densities were reported to increase as the amount of pack ice diminishes with the advance of summer (Bester et al. 1995).

Weddell seals are known to form large aggregations in breeding colonies (Stirling 1969a), but females are reported to be solitary after giving birth; the pupping season being late September to early November (Smith 1965; Stirling 1969a). By the end of November, Weddell Seal females are known to wean their pups (Lake et al. 1997), which may be a reason for the high number of solitary Weddell Seals seen here. Further, during January, the progressing austral summer in Prydz Bay resulted in sea ice melt and innumerable cracks in the fast ice became available for seals to haul-out along, leading to higher number of solitary Weddell Seal sightings. Large aggregations of up to 42 individuals were found in the Prydz Bay area when there was a single tidal crack along a vast stretch of thick fast ice (Image 3). These groups may not represent any sociality and are probably a result of limited number of natural openings in the fast ice.

The low occurrence of other species such as Crabeater and Leopard Seal particularly in the Prydz Bay area during this study is possibly because these seals are inhabitants of the pack-ice edge. Their absence may also be related to their seasonal movements

associated with breeding and feeding. Crabeater Seals are predominantly krill feeders and use pack ice to haul out upon (Gilbert & Erickson 1977; Kooyman 1981; Nordøy et al. 1995; Bengtson & Cameron 2004). Krill is typically abundant near pack-ice and occurs in proximity to the 1000m isobaths around the Antarctic coast during summer (Ichii 1990; Hosie et al. 2000). Consistent with this Southwell et al. (2005), using a presence-ocean depth model predicted Crabeater Seal distribution to be in a band extending northwards by 1.5–5.0^0 latitude from the continental shelf-break. The Prydz Bay area is located much further south from the predicted distribution range of Crabeater Seals and thus, may have resulted in our low encounters of the species. Similarly, Leopard Seals are believed to breed on the outer fringes of the pack ice in summer, when they are solitary and sparsely distributed (Erickson et al. 1971; Sniff & Stone 1985). In the adjoining Vestfold Hills in the Prydz Bay encounter rates of Leopard Seals during austral spring and summer surveys in 1992 and 1993 were only 0.06 and 0.14, and seals were reported confined to the very outer edge of the fast ice (Rogers & Bryden 1997).

Since our survey effort was only minimal no conclusions could be made, though it appears that seal abundance particularly within the Prydz Bay is related to the extent of fast ice cover available in the area. It is possible that more hauled-out seals may have been encountered had the aerial surveys been conducted mid-day as recommended by Lake et al. (1997), and if more frequent surveys were conducted within and between seasons. We, therefore, recommend that future surveys in the area take into account the time of the aerial surveys and adopt standardized, quantitative methods for design or model-based estimates such as those used by Southwell (2005), Conn et al. (2013), and ver Hoef et al. (2014).

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