Assessing the Potential Effects of Near Shore Hydrocarbon Exploration on Ringed Seals in the Beaufort Sea Region 2003-2006

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EXECUTIVE SUMMARY

The objectives of this study were to identify and evaluate any potential impacts of offshore industrial activities on the resident seal populations, with a view to providing advice on any mitigating measures and monitoring studies which might be employed effectively in the future. We studied ringed seals, *Phoca hispida*, during February to June 2003-2006 in the fast ice habitat north of the Mackenzie River estuary in the Beaufort Sea, Northwest Territories, Canada.

The study area for the early spring work was located approximately 30 km to the NW of Garry Island in the south-eastern Beaufort Sea. This study area, at the 12 m isobath, was a 6 x 8 km plot, with Devon Canada's 2006 Paktoa drilling site (N69° 39' 8.880"; W136° 29' 12.128") at its approximate center. Paktoa is located close to the edge of the fast ice which is a highly important feature of the arctic marine ecosystem and important for seals, for establishing and defending mating territories, giving birth to and nurturing their pups, breeding and basking.

The first three years of our study (2003, 2004, 2005) were conducted prior to industry activity at Paktoa, while our fourth year of study (2006) was conducted during the latter part of a single exploratory drilling season from 5 December 2005 to 8 April 2006. Additional industry exposure years would have been desirable to enhance the sample size obtained in this study. In 2006, Devon successfully completed drilling operations at Paktoa and abandoned the well, then discontinued their Beaufort Sea exploration drilling program.

Using detection dogs, we found the mean density of subnivean seal structures along 500 m wide transects to be within the range of 1.02 - 2.17 structures/km². Actual densities resulting from repeated searches of a small sub-area in 2005, were 2.6 times higher that those obtained from transect surveys and could be as high as 4.57 structures/km². The density of all seal structure types considered together was statistically higher in 2006 than in 2004, with these differences being attributed to higher densities of adult males in 2006 than in the other years.

The mean distance of birth and resting lairs used by adult females, lairs and breathing holes used by rutting adult males (tiggak) and breathing holes from Paktoa, were not significantly different among the non-industry (2003, 2004) and industry (2006) years studied. The same was true for frozen and active seal structures, and for male and female structures, which showed no significant differences among those same years with respect to distance from the Paktoa site. In 2006, the frequency distribution of distances of seal structures from the ice road, the airstrip and from our research camp showed no tendency toward avoidance or attraction to these sites of activity. Natural abandonment of seal structures ranged from 21-26% in 2003, 2004 and 2005, with a lower rate (10%) in 2006 being attributed to the significantly later date of freeze up in that year.

In total, 20 ringed seals were captured, instrumented with satellite-linked transmitters, and released near the Paktoa site. The movements and size of the Essential Operating Area (EOA) of these tagged seals did not vary statistically between 2005 (n=8) and the year 2006 (n=10), when ice conditions were vastly different. The size of the EOA's also did not vary between males and females, averaging approximately 14 structures/km^2. The movements, behaviour and size of the EOA of 10 seals tagged in 2006 also did not vary statistically between the 19 days when industry was active (20 Mar to 8 Apr) and the following 19 days when industry operations were completed.

In total, 68 ringed seals were collected from an area 90-130 km east of Paktoa in May 2004, 2005 and 2006, in order to examine body condition and reproductive status of the local seal population. The collected specimens showed the ringed seals in this area to be in good body condition with ample fat stores, in normal reproductive status, with none or negligible levels of PAH's, and most (40/54 stomachs = 74%) with prey in their stomachs. They had eaten recent meals of invertebrates, particularly isopods (78% of items). Ringed seals were found to successfully use this highly variable offshore fast ice of the south-eastern Beaufort Sea, both as feeding and breeding areas, even during winters such as 2005 when storms caused a major perturbation in the stability and quality of their fast ice habitat.

During the month of June, we conducted systematic aerial surveys over the fast ice, and found basking ringed seals to be widely distributed in the license areas, at densities in the range of 13.0 - 42.4/100 km^2. With the exception of 2003, when the survey was flown later in the season, the density of basking seals was not significantly different among the different study years and comparable to densities found in this same area during surveys conducted by the Canadian Wildlife Service during the period of 1974-1979. There was a significant increase in the densities of basking seals near the floe edge compared to farther from it, but no detectable relationship between the distribution of basking seals and the Paktoa site in any year.

Overall, the study provides important baseline information on the use of the near shore Beaufort Sea by ringed seals during spring, and is a benchmark for any future studies involving multiple or longer term drilling operations. The results suggest that one-season of drilling by industry at the Paktoa site had no detectable effect on ringed seals in the study area. While the aerial surveys revealed bearded seals were present in the area at low densities, too few individuals were observed in any part of the study to draw conclusions about the possible industrial effects on this species.

During the 2006 study period, Devon was active with well testing, well abandonment, and demobilization activities, and had constructed and maintained their ice road and airstrip. Our approach of obtaining three lines of evidence (density and distribution of subnivean structures; movements and behaviour of tagged animals during 19 days when industry was active; and the distribution of seals during basking) each revealed a similar result of no direct adverse effects as a result of the level of industry activity at Paktoa in 2006. The effects of longer exposures to industrial activity, or exposure to multiple industrial sources, remain unknown. Recommendations for mitigation, monitoring and future studies are included.

Over the four years of the study, the work was greatly enhanced by the involvement of 19 Inuvialuit field technicians, in roles ranging from seal live capture (core crew), handling the search dogs, collection of seal specimens, expediting, camp construction, camp maintenance, and aerial surveying. In addition, specialized nets and electronic traps for the live capture of ringed seals in the fast ice were purchased for this study. This equipment is available for future work in the Beaufort Sea along with the Inuvialuit technicians that are now fully trained for these kinds of projects.

Key to the study of ringed seals in their fast ice breeding habitat is the use of trained detection dogs, which have been recognized as the only effective means of finding the completely hidden subnivean seal structures. The method, first developed for ringed seal studies in the Canadian western arctic in the early 1970's (Smith and Stirling 1975,1978) has been used since then in Alaska, Norway, Finland and Russia. Other techniques such as Forward Looking Infrared Sensors (FLIR) have been tried, but are not effective. In The United States the National Marine Fisheries Service (NMFS) under the Marine Mammal Protection Act (16 USC 1361 *et seq*) specifies the use of trained seal detection dogs before issuing Incidental Harassment Authorization (IHA) for industrial activities on the sea ice beyond the three meter depth contour.

RÉSUMÉ

Les objectifs de cette étude étaient d'inventorier et d'évaluer les incidences éventuelles des activités industrielles extracôtières sur les populations de phoques, afin de pouvoir donner des conseils sur les mesures d'atténuation et études de surveillance qui pourraient être utilisées ultérieurement. Nous avons étudié le phoque annelé *(Phoca hispida)* de février à juin pendant les années 2003 à 2006 dans l'habitat de banquise côtière du nord de l'estuaire du fleuve Mackenzie dans la mer de Beaufort au large des Territoires du Nord-Ouest, au Canada.

La zone d'étude où les travaux ont eu lieu, au début du printemps, était située à environ 30 km au nord-ouest de l'île Garry, dans la partie sud-est de la mer de Beaufort. Cette zone (isobathe de 12 m) était une parcelle de 6 x 8 km, dont le centre coïncidait à peu près à l'emplacement de forage Paktoa 2006 de Devon Canada (N69° 39'8.880"; O136° 29' 12.128"). Cet emplacement n'est pas loin du bord de la banquise côtière, caractéristique très importante de l'écosystème marin arctique, et lieu d'importance capitale pour les phoques, qui y établissent et défendent leurs territoires de reproduction, de mise bas et d'alimentation, et d'exposition au soleil.

Les trois premières années de l'étude (2003, 2004 et 2005) ont précédé l'activité industrielle à Paktoa, tandis que la quatrième (2006) a coïncidé avec la dernière partie d'une seule saison de forage exploratoire, soit du 5 décembre 2005 au 8 avril 2006. Il aurait été souhaitable que l'étude se déroule pendant d'autres années où de l'activité industrielle avait lieu, afin d'accroître la taille de l'échantillon. En 2006, Devon a terminé ses activités de forage à Paktoa et abandonné le puits, pour ensuite cesser son programme de forage exploratoire dans la mer de Beaufort.

Travaillant à l'aide de chiens, nous avons détecté des structures subnivales/km^2, sur des transects de 500 m de large, d'une densité moyenne de 1,02 à 2,17. Les densités réelles obtenues à la suite de recherches répétées effectuées dans une petite sous-zone en 2005 étaient 2,6 fois plus élevées que celles découlant des relevés des transects et pouvaient même atteindre 4,57 structures/km^2. La densité globale, tous types de structures confondus, était statistiquement plus élevée en 2006 qu'en 2004, les différences étant attribuées aux plus fortes densités de mâles adultes en 2006 par rapport aux autres années.

En ce qui concerne la distance moyenne entre Paktoa et les gîtes utilisés par les femelles adultes pour la mise bas et l'exposition au soleil, ainsi que les gîtes et trous de respiration des mâles adultes en rut (tiggak) et les trous de respiration, on n'a pas relevé de différence importante entre les années d'absence d'activité industrielle (2003, 2004) et l'année d'activité industrielle (2006). Il en est de même pour la distance entre Paktoa et les structures de phoques inactives (mer englacée) et actives. En 2006, la distribution statistique des distances entre les structures de phoques et la route de glace, la piste d'atterrissage et le campement des chercheurs n'indiquait

aucune tendance à l’évitement ou à l’attirance de ces lieux d’activité. L’abandon naturel des structures de phoques s’est situé dans une fourchette de 21 à 26 % en 2004, 2004 et 2005, mais à un taux moins élevé (10 %) en 2006 en raison de l’englacement considérablement plus tardif cette année-là.
P
Au total, 20 phoques annelés ont été capturés, munis de transmetteurs à liaison par satellite et relâchés près de Paktoa. Le déplacement et la taille de l’aire d’activité essentielle (AAE) de ces phoques annelés n’ont pas varié statistiquement de 2005 (n=8) à 2006 (n=10), même si l’état des glaces étalent extrêmement différent d’une année à l’autre. De plus, la taille de l’AAE était la même pour les mâles et les femelles et se situait à une moyenne d’environ 14 structures/km^2. Les déplacements, le comportement et la taille de l’AAE de 10 phoques marqués en 2006 n’ont également pas varié statistiquement entre les 19 jours d’activité industrielle (du 20 mars au 8 avril) et les 19 jours suivants après lesquels les activités ont cessé.

Au total, on a recueilli 68 phoques annelés dans une zone située de 90 à 130 km à l’est de Paktoa en mai 2004, 2005 et 2006 afin d’examiner l’état corporel et reproducteur de la population locale. Les spécimens en question étaient dans un bon état corporel et disposaient d’amples stocks de gras, leur état reproducteur était normal, avec des niveaux de d’HAP inexistants ou négligeables, et la plupart (40 sur 54 = 74 %) avaient des restes de proie dans leur estomac. Ils s’étaient nourris peu avant d’invertébrés, surtout des isopodes (78 % des articles). On a constaté une utilisation fructueuse de cet habitat de banquise côtière à forte variabilité dans le sud-est de la mer de Beaufort par les phoques annelés, tant pour leur alimentation que pour la reproduction, même durant les hivers comme celui de 2005 alors que des tempêtes avaient fortement perturbé la stabilité et la qualité de l’habitat.

En juin, nous avons effectué des levés aériens systématiques au-dessus de la banquise côtière. Nous avons constaté que des phoques annelés s’exposant au soleil étaient distribués sur une grande partie de la concession, les densités se situant dans une plage de 13,0 à 42,4/100 km^2. Exception faite de l’année 2003, où les levés ont été menés plus tard dans la saison, la densité de phoques se prélassant au soleil n’était pas considérablement différente d’une année d’étude à l’autre et était comparable à celles qui avaient été constatées dans la même zone lors de levés effectués par le Service canadien de la faune de 1974 à 1979. Il y avait un fort accroissement de densités de phoques au repos près de la limite de dislocation comparativement aux endroits plus éloignés de cette dernière, sans qu’il y ait toutefois de rapport observable entre la distribution de phoques au repos et l’emplacement du projet Paktoa dans une année quelconque.

L’étude a permis d’obtenir d’importantes données de base sur l’utilisation de la zone près des côtes de la mer de Beaufort par les phoques annelés au printemps, et elle constitue un point de repère pour toute étude future en marge d’activités de forage multiples ou à moyen terme. Les résultats obtenus à ce jour portent à croire qu’une saison de forage à l’emplacement du projet Paktoa n’a pas eu d’effet observable sur les phoques annelés dans la zone d’étude. Bien que les levés aériens aient révélé la présence d’une faible densité de phoques barbus dans la région, il y avait trop peu d’individus, quelle que soit la zone observée, pour pouvoir tirer des conclusions sur les effets possibles d’activités industrielles sur cette espèce.

Au cours de la période d’étude de 2006, Devon s’est livrée à des forages de puits d’essai, à l’abandon de puits et à des activités de démobilisation; elle avait également construit une route de glace et une piste d’atterrissage et en avait assuré l’entretien. Notre démarche fondée sur trois sources de données (densité et distribution des structures subnivales; déplacements et comportement de spécimens marqués durant 19 jours d’activité industrielle; distribution des phoques s’exposant au soleil) a donné des résultats similaires, soit aucun effet négatif direct par suite du niveau d’activité industrielle à l’emplacement du projet Paktoa en 2006. Les effets d’expositions de plus longue durée à des activités industrielles, ou de l’exposition à plusieurs sources d’activités industrielles, demeurent inconnus. Nos recommandations concernant l’atténuation, la surveillance et les études futures sont incluses dans le rapport.

Pendant les quatre années qu’elle a duré, l’étude a profité énormément de la contribution de 19 techniciens Inuvialuit qui ont joué plusieurs rôles au cours des travaux : capture de phoques vivants (équipe principale), conduite des chiens de recherche, collecte des spécimens, contrôle du déroulement des travaux, construction et entretien du campement et levés aériens. En outre, des filets spéciaux et pièges électroniques pour la capture des phoques annelés vivants sur la banquise côtière ont été achetés pour les besoins de cette étude. Ce matériel pourra servir à des travaux ultérieurs dans la mer de Beaufort et des techniciens Inuvialuit rompus à ce genre de travail pourront y participer. Le recours à des chiens spécialement formés à la détection est devenu un facteur clé de l’étude des phoques annelés dans leur habitat de reproduction sur la banquise côtière car il est reconnu comme étant le seul moyen efficace de repérer les structures de phoques subnivales, lesquelles sont entièrement dissimulées. Cette méthode, employée pour la première fois lors des études de phoques annelés menées dans l’ouest de l’Arctique canadien au début des années 1970 (Smith et Stirling 1975,1978) a été employée en Alaska, en Norvège, en Finlande et en Russie. D’autres techniques, comme celle qui fait appel au système FLIR (de l’anglais Forward Looking Infrared Sensors, c’est-à-dire système infrarouge à vision frontale), ont été mises à l’essai, mais ne sont pas efficaces. Aux États-Unis, le National Marine Fisheries Service (NMFS), en vertu de la loi intitulée *Marine Mammal Protection Act* (16 USC 1361 *et seq*), rend obligatoire le recours à des chiens formés pour la détection de phoques avant de délivrer toute autorisation de harcèlement imprévu pour des activités industrielles sur une aire de glace marine à une profondeur plus grande que l’isobathe de trois mètres.

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INTRODUCTION AND BACKGROUND

The near-shore area of the Canadian Beaufort Sea has in recent years again been the subject of exploration for hydrocarbon reserves. Industrial activities recommenced in the offshore in 2000 culminating in the drilling, testing and abandonment of an exploratory gas well 30 km NW of Garry Island in 12 m of water at a site called Paktoa (N69° 39' 8.880" W136° 29' 12.128") from 5 December 2005 to 20 March 2006. The Paktoa site is one of 10 prospects of Devon Canada, and is located in their western Block D of Exploration License (EL) 420 (Fig 1).

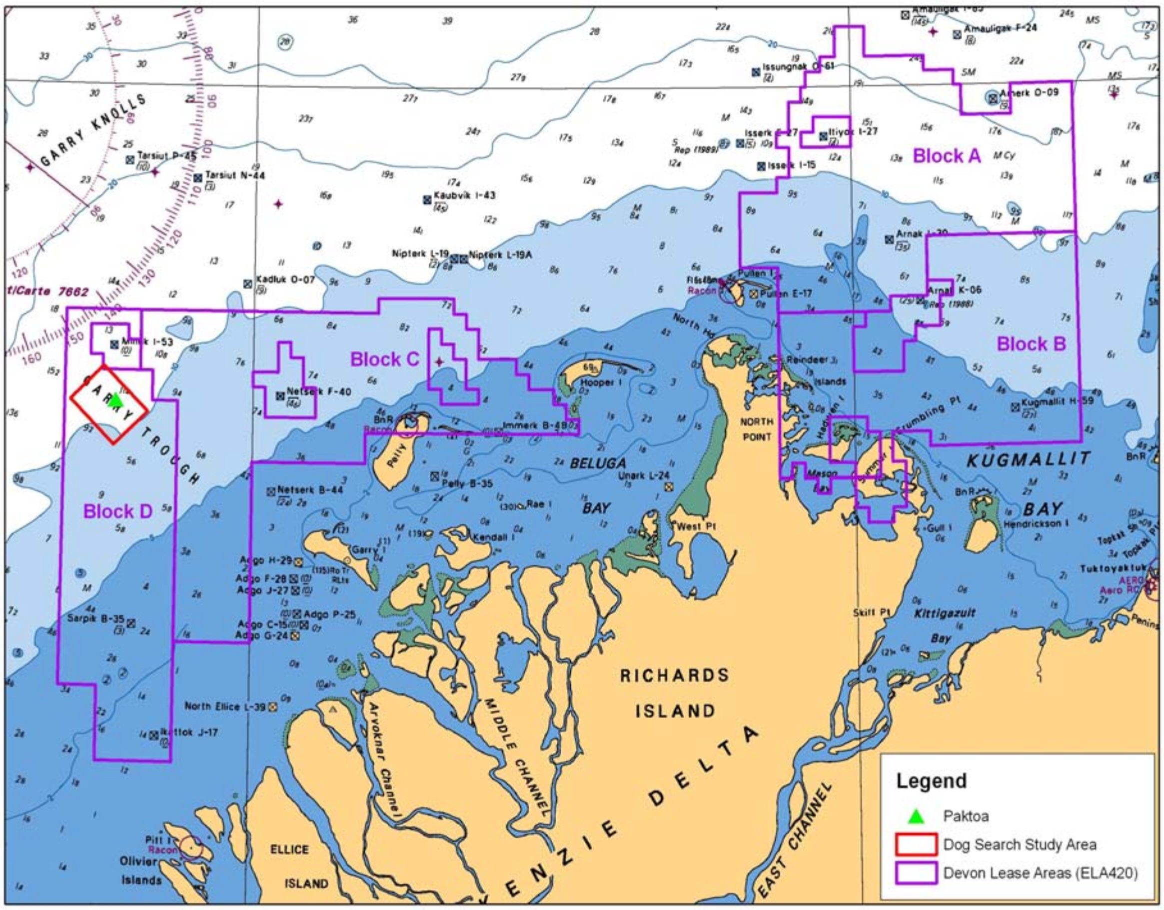
The impact of hydrocarbon exploration activities on local populations of ringed seals, *Phoca hispida,* their major predator the polar bear, *Ursus maritimus*, and on the less abundant bearded seal, *Erignathus barbatus,* was identified as a major concern during a workshop held in Inuvik in January 2002 on knowledge gaps associated with renewed oil an gas development in the Beaufort Sea (Kavik Axys Inc. 2002). Ringed seals and bearded seals are known to occur throughout the area during the late spring months (Stirling *et al* 1977, Stirling *et al* 1982) and years of polar bear research indicates that they are feeding on seals throughout this region during the late winter period (Stirling and Archibald 1977; Stirling, 2002).

This study was designed to determine the distribution, densities, baseline behavioural patterns, body and reproductive condition of ringed and bearded seals in the near shore fast ice of the Beaufort Sea, in an area that would be subject to winter exploratory drilling during the course of the study. The goals of the study were to increase the knowledge base on the impact of the winter exploration activities on the local seal population, and serve to:

- Provide advice on appropriate mitigating measures, which could be employed to avoid or reduce the impact of hydrocarbon exploration and development activities conducted during the ice covered period on local seal populations;
- Provide advice on suitable monitoring programs, which could be implemented to assess the longer term implications of hydrocarbon exploration and development activities on the local seal populations;
- Evaluate the methods and techniques used during the course of the study; and
- Incorporate the traditional knowledge of the Inuvialuit in the planning and implementation of the research.

To date, no studies have been conducted in the winter sea-ice habitat of ringed and bearded seals known to live in this region, or in areas as far from shore as our study area located 30 km from the nearest point of land. Ringed seals (McLaren 1958, Smith 1973, 1987) and to a lesser extent bearded seals (Smith 1981) are known to occupy the forming fast ice in early winter where they maintain breathing holes by abrading the thickening ice with their strong claws on their front flippers. As the snow drifts over their breathing holes, ringed seals excavate subnivean lairs in which they haul out to rest (Smith and Stirling 1975, 1978). During the period mid-March to late April, pregnant females give birth to their single pup in these lairs and suckle them for approximately six weeks (Smith 1987, Kelly and Quakenbush 1990, Hammill *et al* 1991). By early June most of the lairs have melted open and ringed seals are basking on the surface of the ice. It is during this period that they undergo their annual moult (McLaren 1958, Smith 1973), and are visible for counting by aerial surveys used to obtain an index of their abundance in the region (Kingsley 1984; 1986).

Figure 1 Location of Devon Lease areas, Paktoa, project study area (2003-2006) and bathymetry for the southeast Beaufort Sea



Our studies from 2003 to 2006 spanned the period from mid February to mid June (Smith and Harwood 2003, 2004, 2005, 2006). To study the potential effects of industry activities on ringed seals, we located, captured and satellite-tagged ringed seals in their fast ice breeding habitat in the vicinity of the Paktoa site. In May of 2004-2006, we obtained biological specimens of a sample of ringed seals from within and east of Devon's Eastern license area, Blocks A and B (Fig. 1), to examine health and status of individuals as close to the study area as possible. In early June (late May in 2006), we counted basking ringed and bearded seals on the sea ice from aircraft in all license area blocks, and seaward of those blocks to the edge of the fast ice with a view to long-term monitoring of these habitats through comparison to past (1974-1979) surveys and providing a benchmark for similar comparisons in the future (Table 1).

Table 1. Summary of research activities during studies of ringed seals in the Paktoa area, 2003-2006

Research Activity Schedule	2003	2004	2005	2006
Sea ice surveys with dogs	April 10-21	Feb 28-March 14	March 22 - April 4	March 17-30
Tagging and Tracking	April 22-25	April 27-June 5	March 23-May 31	March 20-June 9
Specimen Collection	N/A	May 28-31	May 6-17	May 12-19
Aerial Survey	June 13 & 17	June 1-4	June 4	May 28-30

Among the least well-examined classes of contaminants in marine mammals are the petroleum hydrocarbons (HCs). More specifically, the polycyclic aromatic hydrocarbons (PAHs) represent the most toxic fraction of oil, and 16 PAHs are included on lists of priority chemical contaminants by the World Health Organization. These contaminants may enter local environments in a variety of ways, including natural seeps, discharges from tanks and vessels, industrial activities associated with escalating oil and gas development, and catastrophic spills. The health effects of chronic oil contamination are a concern and could include a range of conditions, such as carcinogenesis and mutagenesis; disruption of immune and endocrine system function; dermal irritation; and other ailments (Wetzel 2007). In light of such possibilities, one of the objectives of this project was to collect fat and tissue samples needed to assess potential PAH levels in ringed seals in the study area to obtain a pre-development database.

THE ICE REGIME OF THE STUDY AREA

Because of the important role sea ice plays in the ecology of the ringed seal, we describe the annual ice regime over the study period to provide some context to the habitat that was available to the seals. Paktoa is located in 12 m of water, approximately 30 km north-west of Garry Island in the Mackenzie Delta. Our survey block for the years 2003, 2004 and 2006 was a 6 km x 8 km area centered at Paktoa (Fig. 1). In 2005, unworkably rough ice in the survey block forced us to work in three smaller expanses of smoother ice (20.7 km^2) that were approximately 6-10 km south-west of Paktoa (Fig. 2).

In the Canadian Beaufort Sea, a zone of fast (viz. immobile[1]) ice lies between ice frozen to the seabed in shallow (less than 2m) and the intermittently mobile pack ice to the north. The band of bottom-fast ice is the nearshore anchor for the fast ice. The seaward anchors are stamukhi, large pressure ridges grounded at various depths to a maximum of 20-25 m by late winter. In an average year, Paktoa and eight other sites of potential interest for exploratory drilling are enveloped by the fast ice around the end of December. However, the date varied from mid October to late February during the decade preceding this study (Canatec Associates 2002).

Because sea ice has little strength in tension to resist offshore movements, grounded ice ridges (stamukhi) within and at the seaward edge of the fast ice zone are critical to its stability. The stamukhi are formed during extreme events within a recurring cycle of ice interaction at the fast ice edge that is driven by winter storms. On the Mackenzie shelf, strong south-east wind initiates the cycle by forcing the mobile pack seaward; this movement opens a flaw lead that in winter quickly develops a cover of young (less than 30 cm) ice.

Strong north-west wind behind a passing storm brings on the next stage of the cycle. Wind from this quadrant drives the mobile pack shoreward, causing the young ice in the intervening flaw lead to be fractured and piled into ridges. Initially these ridges deepen with continued compression, but ultimately their draft reaches a limit imposed by the strength of level ice; further growth is in width only (Amundrud *et al* 2004). Until the lead is completely closed, the ridges are shallow because surrounding level ice is thin and weak. Subsequently, the ridges grow deeper because the thicker floes of the

[1] Immobile sea ice is variously known as bottom-fast, shore-fast or land-fast depending on the reason for its immobility. Bottom-fast ice is actually bonded by freezing to the seabed; adjacent shore-fast ice is a relatively narrow band in waters less than a few metres deep; land-fast ice owes its stability to embedded islands and convoluted coastal geometry (e.g. bays and straits). Because none of these terms applies to seasonally immobile ice at Paktoa, which is stabilized by grounded ridges, we refer to it herein using the noncommittal phrase, ‘fast ice’.

fast and mobile ice zones come into play. If the seasonal ice reaches a thickness of 1.8 m in late winter, its strength can support the building of keels to a depth of about 25 m (Amundrud *et al* 2004).

The edge of fast ice will advance seaward during a north-west gale if the ridges produced are deep enough to have grounded further offshore than the present ice edge; the result is a level extension of the fast ice bordered by new stamukhi. If the new ridges are not deep enough to ground, the result is more rubble at the fast ice edge. The storm cycle is critical not only to fast ice stability but also to the creation of lightly ridged habitat for the ringed seal. Without storms the fast ice would be generally featureless, infrequently grounded and likely to drift away.

The annual development of fast ice is driven by meteorological events that vary in intensity and timing from year to year. Continuous measurements of ice drift over the Mackenzie shelf (70° 20' N, 133° 45' W), acquired by Doppler sonar (Melling, 1998), are invaluable in the identification of those events critical to the development of fast ice at Paktoa during this study.

Figure 2 Dog search survey areas (A, B, C) and seal structures located by dogs, spring 2005 (Paktoa Proxy in Area A for 2005 shown as white star)

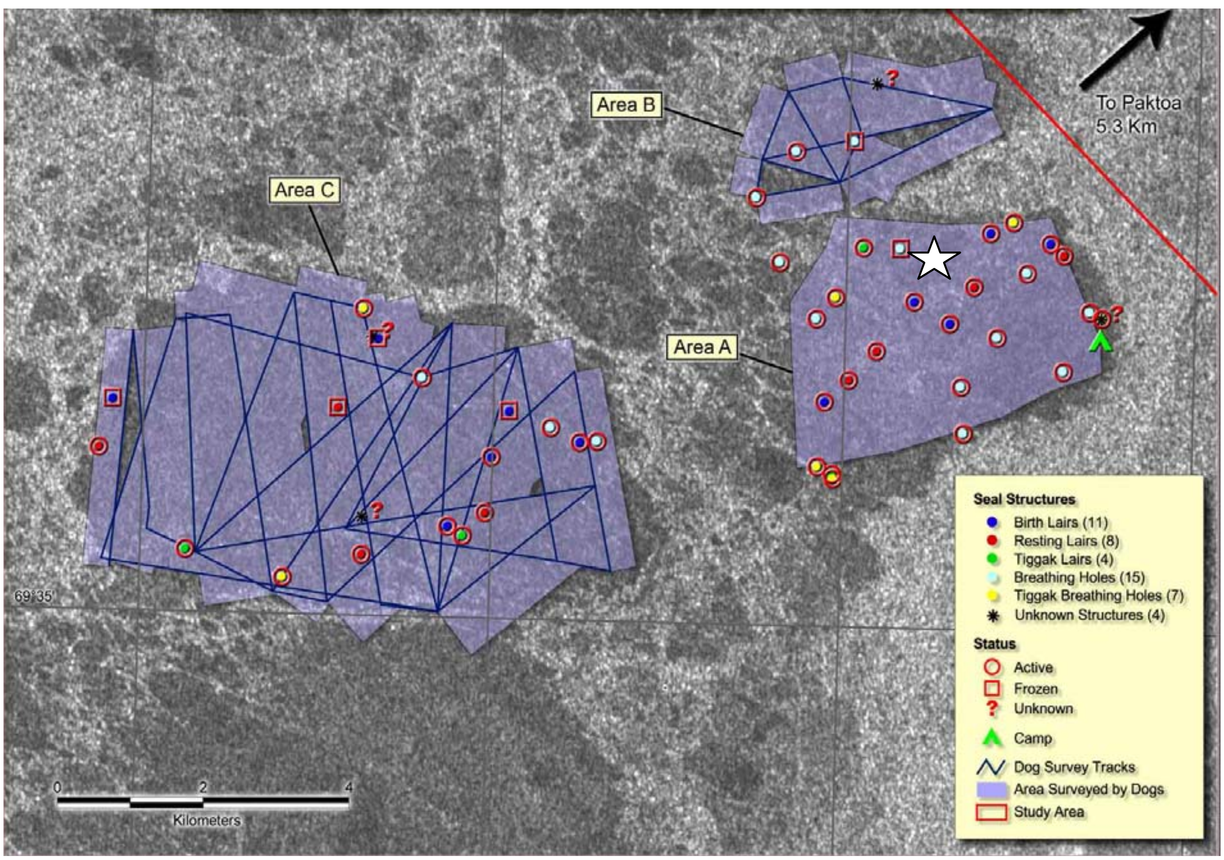


Table 2 summarizes the significant storm-driven movements of pack ice over the Mackenzie shelf during the months of November through May when fast ice was developing. The numbers in the fourth column indicate the component of movement directly towards the fast ice edge during each closing event. Focusing on the period before the on-ice surveys in April, one can identify clear differences from year to year in the number of events capable of building stamukhi, in the size of each shoreward movement and in the accumulated shoreward movement. In particular, the winter of 2004-2005 stands out with the largest number of events (7), the largest single shoreward movement (80 km) and the second largest number of big events (9), the largest single shoreward movement (125 km) and the largest cumulative shoreward movement (334 km). The second winter was at the other end of the scale, with only 4 big events; the total onshore movements was only 162 kim in 2003-2004.

The date at which fast ice first encompassed the Paktoa survey block varied appreciably during the four years (Fig. 3). The earliest appearance of fast ice was in the second winter on 5 December 2003, at the end of the first stamukhi-building event of the winter. The latest was in the fourth winter, during the 20-23 February 2006 closing event (Table 2)[2].

Timing of fast ice break-up at Paktoa varied by 6 weeks during our four-year study; the earliest was in 2006 (June 19) and the latest in 2005 (August 1) (Table 2; Fig. 4). The duration of fast ice at Paktoa was longest in 2003-2004 (213 days), shortest in 2005-2006 (118 days) (Table 3). Since 1988-1989, the duration has ranged between 0 days (1989-1990) and 231 days (1992-1993).

The winter of 2004-2005 was notable in many respects. The number of freezing degree days was above average and greater than in the other three years of our survey (Fig. 5). Storms early in the winter produced extensive fields of ice ridges and rubble. The storm of 9-12 January 2005 was an extreme event not experienced for at least half a century; north-west winds reached 90 km/h at Tuktoyaktuk. The storm accomplished the "disappearance" of a 125-km expanse of pack ice into a broad zone of ice rubble and ridges (see photo right, note rubble field beyond camp location) that was so extensively grounded as to persist well into August. The deep ice keels that delayed break-up in the summer of 2005 also prohibited work during the preceding April in our regular 48 km^2 study block, of which we had surveyed 62-73% during the other three winters (red rectangle on Fig. 1).

[2] For year-to-year consistency, the date of fast-ice appearance has been derived for all years using the ice charts from the Canadian Ice Service and DFO data on storm winds and ice drift. However, much more detailed information is available for 2005-2006 via on-site environmental monitoring at Paktoa conducted by Devon Canada Corporation (Horizon systems Group 2006). The on-site data indicate that ice was unresponsive to moderate south-east wind stress during 4-6 February, somewhat earlier than indicated in Table 2. It remains likely, however, that the ice sheet at Paktoa was vulnerable to break-out until the westerly gale of 21-23 February 2006, when new stamukhi were built.

Table 2. Significant storm driven movements of pack ice over the Mackenzie shelf during the months of November 2003 through May 2006 when fast ice is developing

Winter	Flaw lead opening			Flaw lead closing			Ice ridged km	Event #	Cumulative km
2002-2003	01-Nov	to	02-Nov	03-Nov	to	04-Nov	28	1	28
	23-Nov	to	30-Nov	01-Dec	to	06-Dec	**45**	2	73
	10-Dec	to	12-Dec	14-Dec	to	15-Dec	37	3	110
	22-Dec	to	25-Dec	26-Dec	to	30-Dec	40	4	150
	03-Jan	to	04-Jan	05-Jan	to	07-Jan	30	5	180
	09-Jan	to	13-Jan	17-Jan	to	17-Jan	10		180
	19-Jan	to	28-Jan	28-Jan	to	29-Jan	30	6	210
	31-Jan	to	02-Feb	04-Feb	to	05-Feb	8		210
	26-Feb	to	04-Mar	05-Mar	to	11-Mar	70	7	280
	13-Apr	to	20-Apr						
	24-Apr	to	29-Apr						
2003-2004	03-Nov	to	05-Nov	06-Nov	to	12-Nov	**50**	1	50
	13-Nov	to	15-Nov	16-Nov	to	16-Nov	10		50
	21-Nov	to	21-Nov	23-Nov	to	23-Nov	6		50
	24-Nov	to	24-Nov	25-Nov	to	26-Nov	22	2	72
	27-Nov	to	29-Nov	02-Dec	to	05-Dec	41	3	113
	07-Dec	to	08-Dec	09-Dec	to	09-Dec	9		113
	11-Dec	to	23-Dec	26-Dec	to	26-Dec	6		113
	29-Dec	to	30-Dec	03-Jan	to	06-Jan	49	4	162
	11-Jan	to	11-Jan						162
	15-Jan	to	18-Jan	19-Jan	to	24-Jan	8		162
	10-Feb	to	11-Feb	12-Feb	to	15-Feb	4		162
	22-Feb	to	23-Feb	29-Feb	to	01-Mar	3		162
	26-Apr	to	02-May						
2004-2005	02-Nov	to	03-Nov	04-Nov	to	06-Nov	45	1	45
	07-Nov	to	08-Nov	10-Nov	to	11-Nov	15	2	60
	12-Nov	to	15-Nov	16-Nov	to	18-Nov	14	3	74
	19-Nov	to	23-Nov	25-Nov	to	26-Nov	16	4	90
	28-Nov	to	29-Nov	30-Nov	to	03-Dec	14	5	104
	16-Dec	to	22-Dec	23-Dec	to	26-Dec	51	6	155
	30-Dec	to	03-Jan	04-Jan	to	10-Jan	**125**	7	280
	18-Jan	to	23-Jan	25-Jan	to	28-Jan	36	8	316
	08-Feb	to	11-Feb						316
	14-Feb	to	15-Feb	18-Feb	to	20-Feb	18	9	334
	05-Mar	to	05-Mar						
	10-Mar	to	11-Mar						
	25-Apr	to	29-Apr						
2005-2006	31-Oct	to	01-Nov	02-Nov	to	04-Nov	28	1	28
				06-Nov	to	12-Nov	**39**	2	67
				19-Nov	to	20-Nov	8		67
	23-Nov	to	23-Nov	25-Nov	to	27-Nov	18	3	85
	07-Dec	to	08-Dec	09-Dec	to	13-Dec	26	4	111
	14-Dec	to	15-Dec	16-Dec	to	23-Dec	15	5	126
	30-Dec	to	01-Jan	02-Jan	to	08-Jan	20	6	146
				11-Jan	to	12-Jan	7		146
				21-Jan	to	24-Jan	10		146
	04-Feb	to	07-Feb	08-Feb	to	10-Feb	11	7	157
	11-Feb	to	13-Feb	14-Feb	to	14-Feb	6		157
	16-Feb	to	16-Feb	17-Feb	to	18-Feb	6		157
	19-Feb	to	19-Feb	20-Feb	to	23-Feb	15	8	172
	25-Feb	to	27-Feb	28-Feb	to	01-Mar	5		172
	04-Mar	to	05-Mar	06-Mar	to	10-Mar	18	9	190
	18-Mar	to	18-Mar	19-Mar	to	26-Mar	20	10	210
				31-Mar	to	14-Apr	17	11	227
				26-Apr	to	01-May	10		

Year	Freeze-up	Break-up	Survey period	Days of ice prior to dog surve	Total ice days for winter
2002/2003	09-Jan	30-Jun	April 10-21, 2003	90	172
2003/2004	05-Dec	05-Jul	Feb 28-March 14, 2004	84	213
2004/2005	05-Jan	01-Aug	March 22 - April 4, 2005	75	207
2005/2006	21-Feb	19-Jun	March 17-30, 2006	24	118

Table 3. Ice conditions at Paktoa, 2003-2006

There was also an intense westerly gale during 21-23 February 2006 (Table 2). Oceanographic data from the northern Alaskan coast indicate that winds drove sea ice eastward at 1 m/s during this storm and raised a 1.5 m storm surge. Instrumentation on Devon's SDC at Paktoa recorded west wind (275°T) in excess of 45 km/h from noon on 21 February 2006 until 11 am 23 February 2006, with 65-85 km/h winds typical during this 47 hour period (Horizon Systems Group 2006). However, shoreward displacement of the pack ice capable to generate stamukhi was relatively modest, only about 15 km, because of the generally westward direction of the wind.

Ringed seals specimens were collected in Devon's EL420 from Block B (2005) and 5-40 km east of Block B (2004 and 2006) (Fig 1). Collection areas were located approximately 20-40 km landward of the fast ice edge, and over water depths ranging from 10-20 m (Fig 6). Although these collection sites were located 90-130 km NE of Paktoa, they were collected from similar ice conditions and water depths to those that existed at the Paktoa site.

Figure 3 Advance of the land fast ice in the SE Beaufort Sea, including our study area at Paktoa (rectangle), for winters of 2002/03, 2003/04, 2004/05 and 2005/06

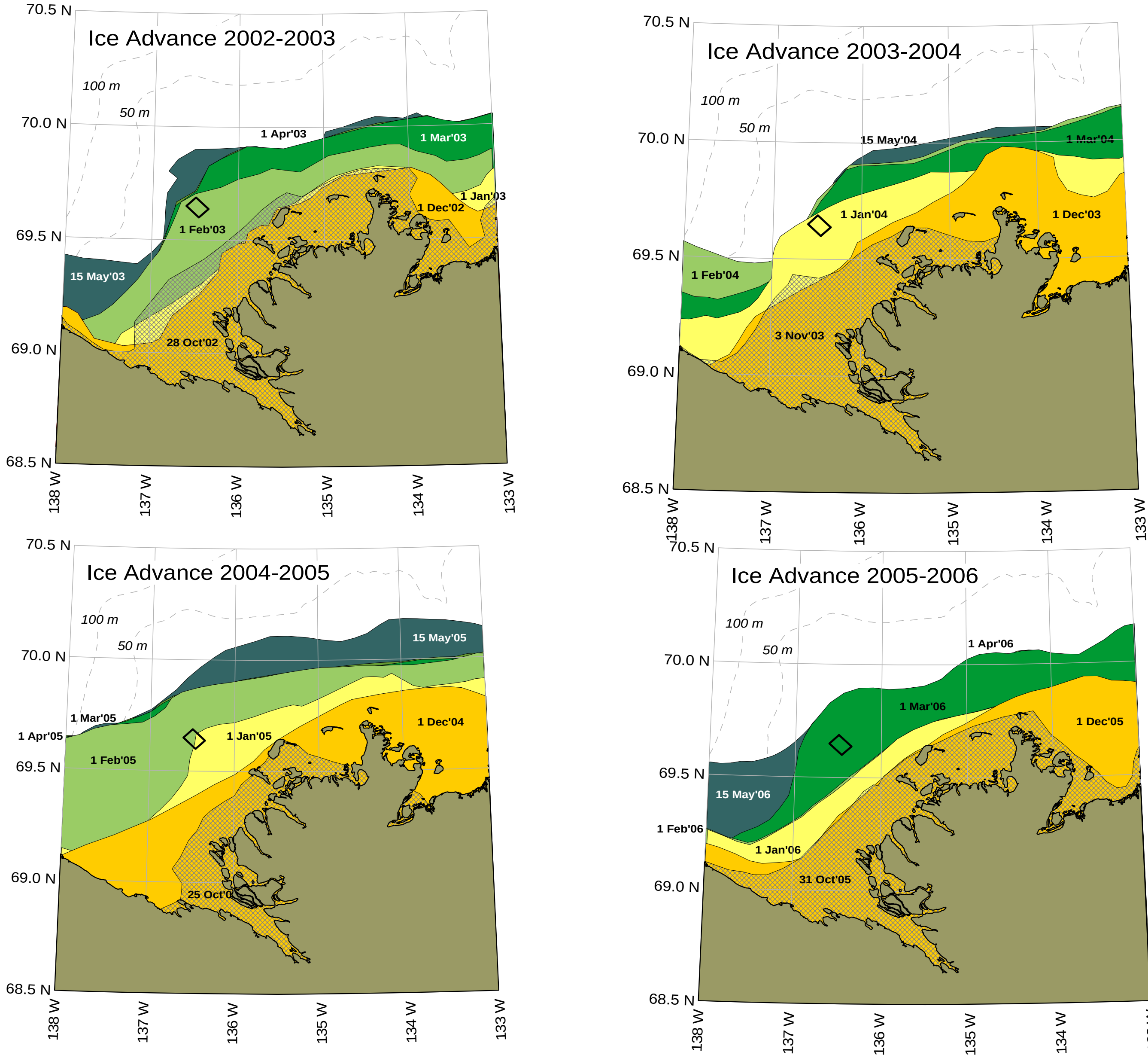


Figure 4 Retreat of the land fast ice in the SE Beaufort Sea, including our study area at Paktoa (rectangle), during spring 2003, 2004, 2005 and 2006

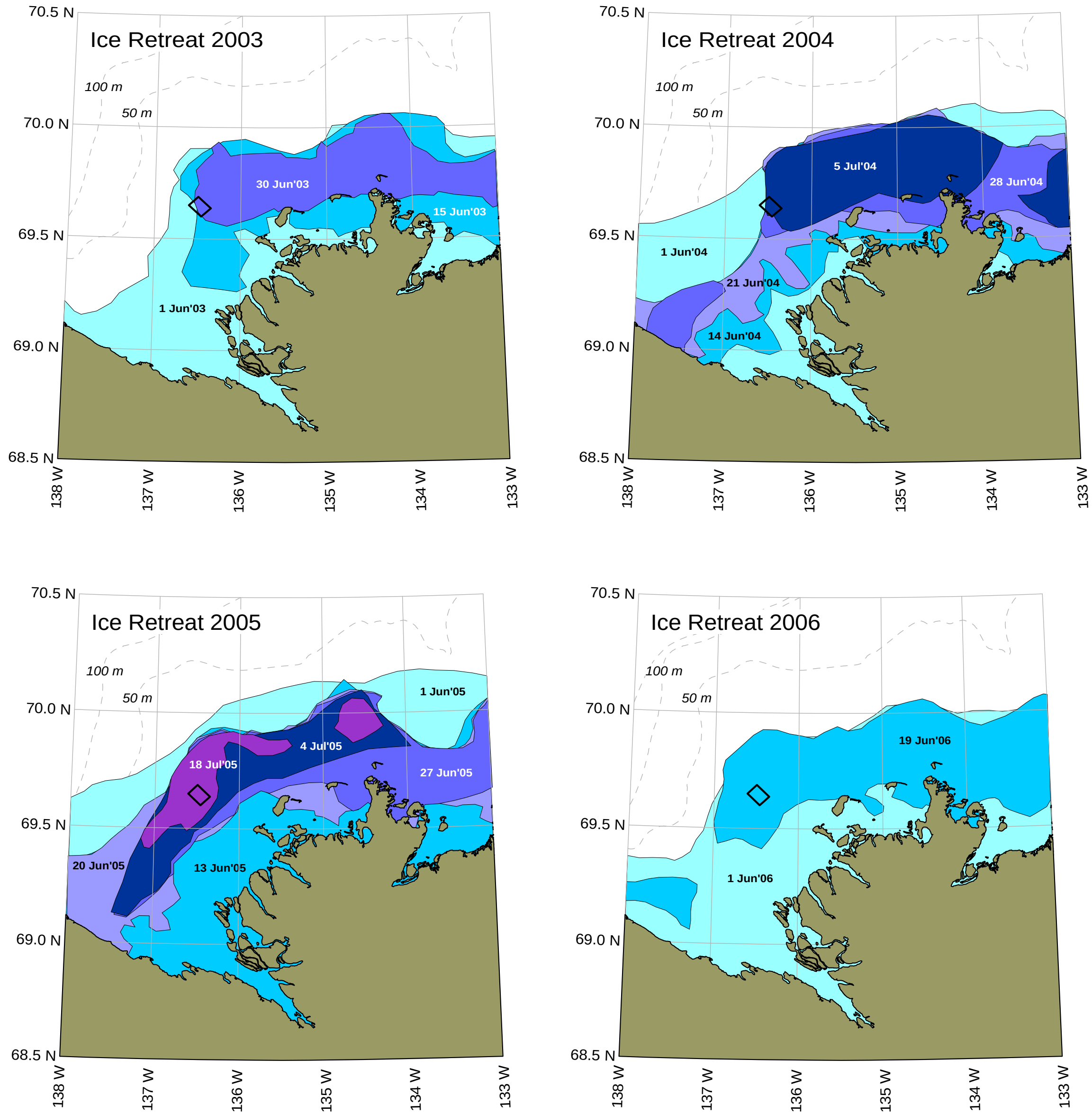


Figure 5 Freezing Degree Days at Tuktoyaktuk, NT, during the four winters of the seal study at Paktoa

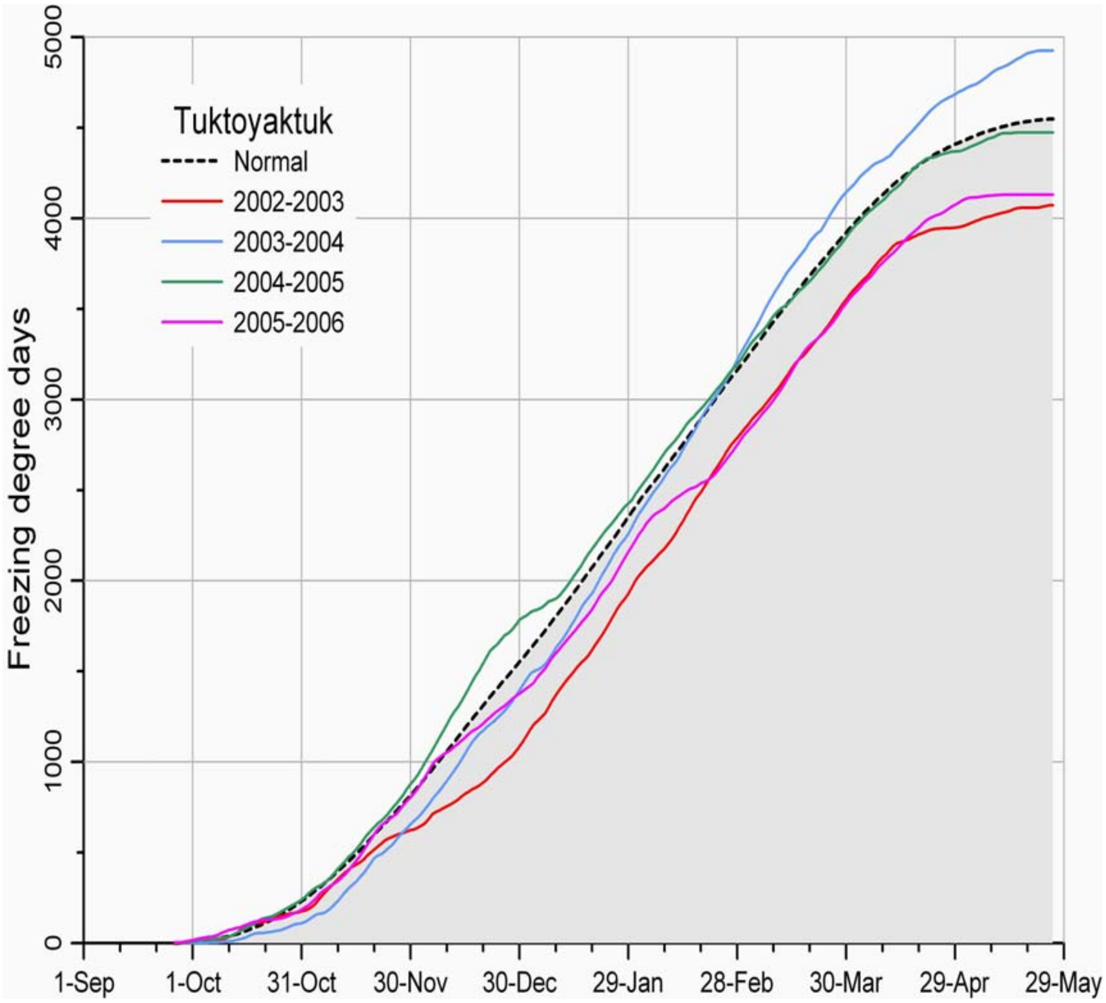
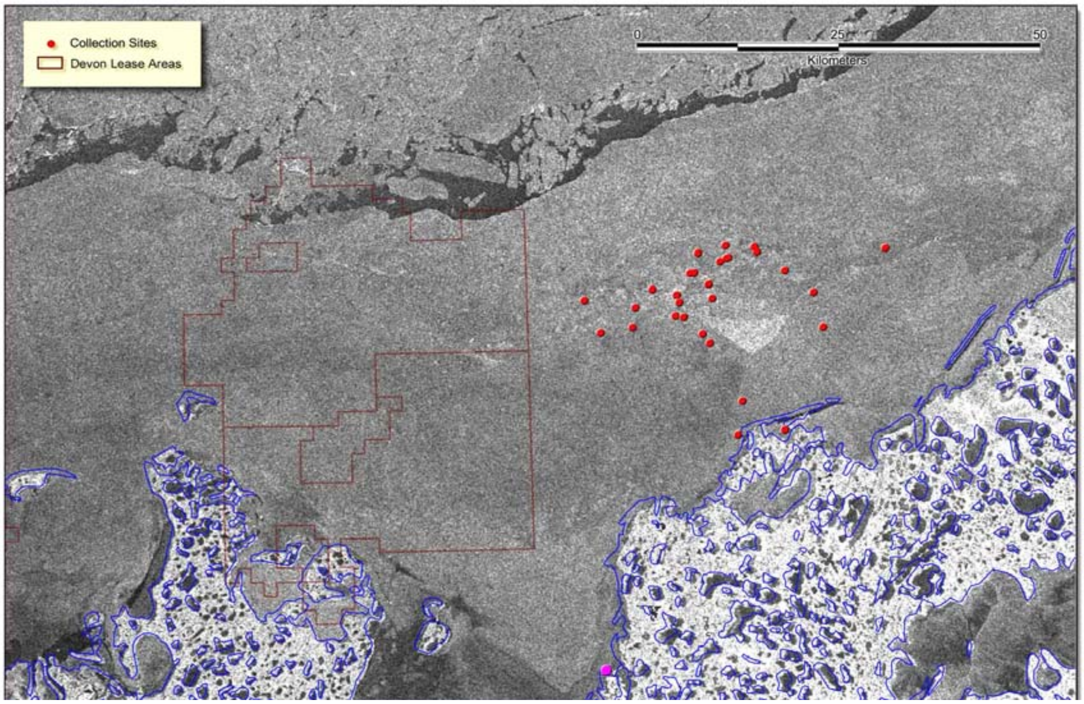
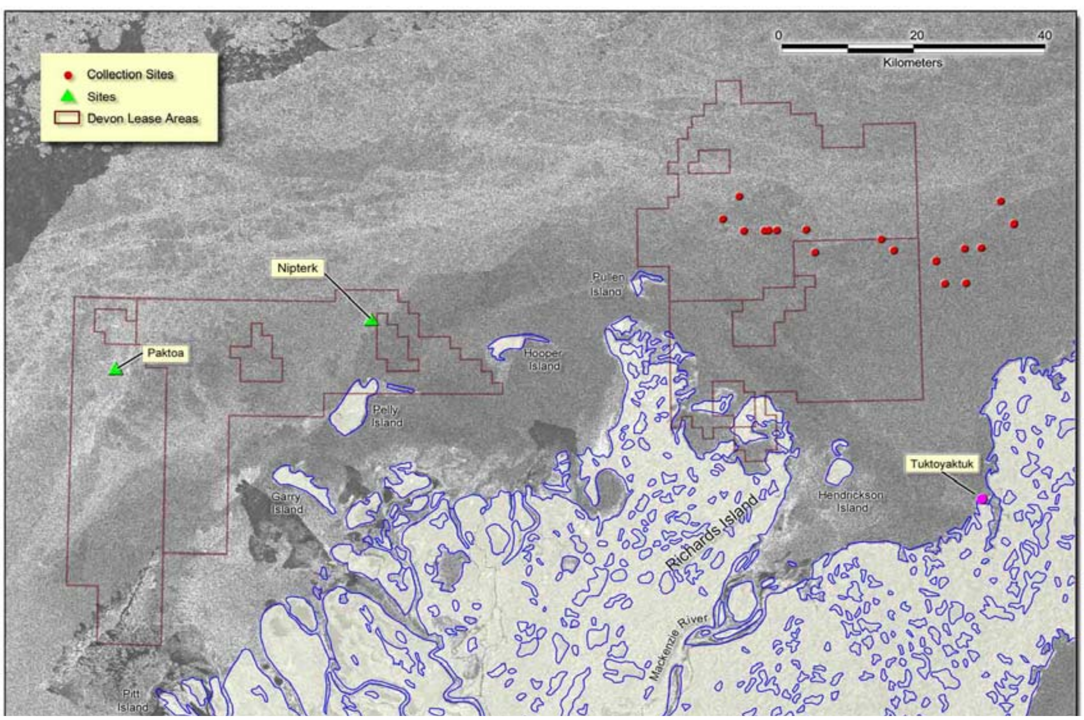


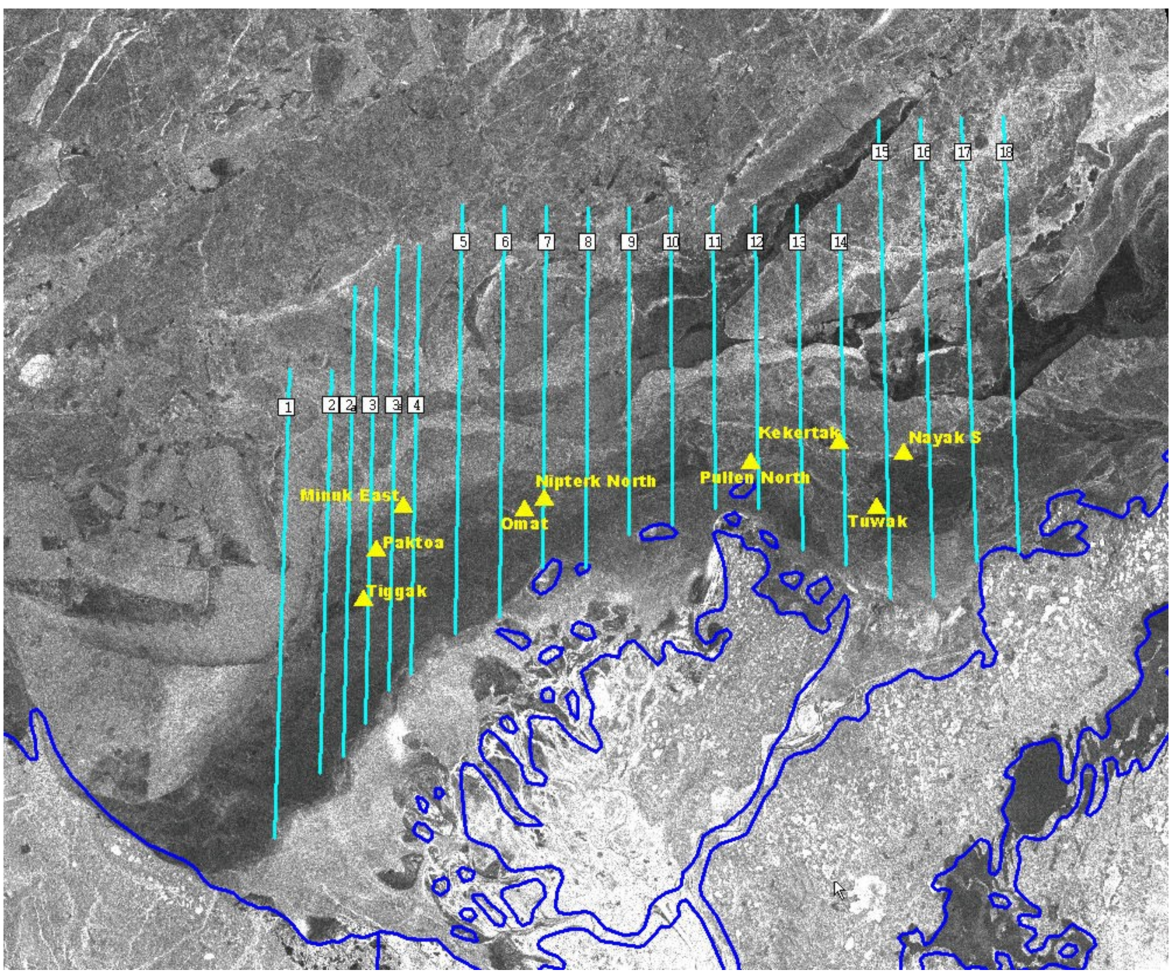
Figure 6 Ringed seal collection sites, May 2005 and May 2006, SE Beaufort Sea





Aerial surveys were flown in June of 2003, 2004, and 2005, and in late May 2006 (Smith and Harwood 2003; 2004; 2005; 2006). Satellite imagery was obtained from the Canada Space Agency to examine ice conditions prior to each survey. The seaward edge of the fast ice was in a similar location in all four years of the study, and all areas of Devon's EL420 blocks were surveyed and were located in the fast ice zone during all surveys. Seaward of the EL, there was an area of open water or pack ice, which varied among the different years of the study and the edges of this were also surveyed when practical (Fig. 7).

Figure 7 Planned aerial survey transect lines for systematic surveys of basking ringed seals, June 2003, 2004, 2005 and late May 2006



METHODS

Surveys of Ringed Seal Breeding Habitat

Our surveys for the subnivean structures of ringed seals were made in a 6 x 8 km plot centered on the Paktoa site (Fig. 1). We searched the area by following the same experienced (7 years old in 2003) female Labrador retriever, and one or two less experienced dogs (photo right, detection dogs ahead of skidoo). The dogs were run on transects of 500 m in width oriented on a quartering head-wind or a cross-wind. Transects were run along different headings depending on wind direction. The dog searched the area upwind, detecting structures sometimes as far as 2 km. When a structure was detected the dog would run to it and begin digging over the breathing hole of the seal. The search was then resumed from the point of departure on the transect line. We searched each transect only one time. We terminated transects when the ice was too rough for travel by snowmobile.

Each structure was marked with a numbered stake or snow block and the location recorded on a handheld GPS and later entered into the Garmin Mapsource computer record. We examined each structure by probing it with a steel rod, sometimes making a small hole in the dome on the lair in order to visually examine its structure. For each structure we recorded (1) total snow depth (cm), (2) structure type: birth lair, resting lair, tiggak lair, breathing hole, tiggak breathing hole (Smith and Stirling 1975); (3) status: active or frozen, (4) predator sign, and (5) habitat type: drift near ice hummock, drift along low pressure ridge, unconsolidated drift, flat ice, refrozen crack, or under an ice slab.

After the field work, the survey area was divided into grid cells 500 m x 500 m, and all seal structures were assigned to the appropriate grid cell using ArcGIS (ESRI 2004). The size of the dog search area in each grid cell was used to calculate the density of seal structures in each year of the study. The different types of structures were grouped as follows: (1) birth and resting lairs, structures used mainly by adult females; (2) tiggak lairs and tiggak holes, structures used mainly by adult males; and (3) breathing holes, which could be used by adult females, or sexually immature seals (Smith and Hammill 1981). The seal structure densities for each grid cell were plotted for each year of the study according to these groupings using ArcGIS (ESRI 2004).

The distance of each subnivean seal structure from the Paktoa site was determined using ArcGIS for each year of the study that we were able to work within the 6 x 8 km block centered at Paktoa – 2003, 2004 and 2006. For 2006, the nearest distance of each subnivean seal structure to the ice road, the research camp, and the airstrip at Paktoa was determined using ArcGIS and plotted as frequency histograms using Lotus Freelance Graphics.

The differences in the actual distance from the Paktoa location of each structure (grouped as birth/resting lairs; tiggak lairs/holes; and breathing holes) for years with no industry activity (2003, 2004) were compared with those for the one year of our study when industry was active (2006), using a Kolmogorov-Smirnov (KS) test (Elliott 1983). Differences in the distance from Paktoa between active and frozen structures, and, between male and female structures, were also examined using a KS test, for each study year.

The proportional representation of the different types of subnivean structures found during the total search effort in area A in 2005, with the other transect searches in 2005 of Areas B and C, were compared using Chi-square.

Capture and Satellite Tagging of Ringed Seals

In 2003 and 2004 we used a single net trap deployed at breathing holes. This trap could only be electronically monitored and activated from a short distance. During the 2005 and 2006 seasons ringed seals were captured in their breathing holes using electronically activated traps that were monitored from our camp (Kelly and Quakenbush 1990; Kelly 1996). Up to ten traps could be set and worked from a distance as far as four km using this equipment. When a seal entered its hole and began to breathe, the sound was transmitted via radio to the camp scanner where it was heard by a researcher standing by to trigger the trap (photo above). Once the seal was caught, it

was removed from the trap within 15 minutes and transported back to camp for processing. No mortalities or injuries to seals were incurred using this method.

Each captured seal was sexed, weighed (American Society of Mammalogists 1967), photographed and the front claw annuli counted for age estimation. Male adult seals were noted as tiggak (rutting) by their odour and dark facial masks. The nipples of adult females were examined for signs that they were lactating. A small sample of skin was taken from the web of the hind flipper of each seal for DNA analysis. After a maximum of 12 h in captivity, satellite tags were applied to the center (2003, 2004, 2006) or lower back (2005) of each seal. The fur was first cleaned with acetone then dried with a hair dryer. The tag was then glued to the pelage using 5-minute epoxy, which was kept warm with the hair dryer until it had set. Seals were released in the same breathing hole where they had been captured (photo right).

We deployed 10 SPOT tags, 1 SDR-16, and 7 SPLASH tags (photo left) manufactured by Wildlife Computers (WC) (www.wildlifecomputers.com) during the four years of the study. The SDR-16 and SPLASH tags had the capability of recording location and diving information, while the SPOT tags provide information on location only. We also deployed three diving and location tags built by the Sea Mammal Research Unit (SMRU), St. Andrews University, Scotland.

Satellite tag instrumentation with diving capabilities measured diving depths to a maximum of 1000 m, with a resolution of 2 m. Each tag consisted of a transmitter, sensors, a strengthened antenna, lithium batteries, circuitry, and a microprocessor, all housed in an epoxy cast package. The processors were programmed prior to deployment to collect and compress the data, and trigger the transmitter at each surfacing up to a maximum of 500 transmissions per day. The tags transmit when the antenna is exposed, either when taking a breath or when hauled out on the sea-ice or in a lair.

Information on the haul-out record (dry or wet readings from the salt water switch), the time spent at the surface, and the status of the sensors and battery performance were collected and transmitted in separate messages for each tag, along with the location. Tags with diving capability (n=9) also recorded time-at-depth, maximum dive-depths and number of dives, per six hour block of time for the WC tags and continuously for the SMRU tags. Tags were not duty cycled (i.e., they were not set to come on or go off at certain times to conserve battery life, as battery capacity was not limiting given our study timing and parameters).

In 2006, seven additional SPOT5 tags from WC, mounted on modified cattle ear tags, were attached to the hind flippers of the first (same) seven seals (photo right). These experimental (location only) tags were deployed by the Alaskan scientists collaborating on this study, who wanted records to extend beyond the moult period when our glued tags would be shed. It was hoped that these tags would transmit well beyond the 2006 spring moult and possibly for up to one year. However, at the time of writing, location data have not been received from those flipper tags since June 2006 (B. Kelly, pers.com.), or the same period corresponding to the tags we deployed in this study.

Data Analysis

Location and diving data (where applicable) were downloaded using SATPAK (Wildlife Computers 2003). The first and last dates that locations were received, and all locations of ARGOS quality 1, 2 and 3 (accurate to 1 km or less) were compiled for each tagged seal. Using the same 500 m x 500 m grid cell system as for the dog search data, the transmitted locations for each seal were assigned to the appropriate grid cell. For each tagged seal, the percent frequency of locations for each grid cell were assigned to five categories (<1% of locations, 1-3%, >3-5%, >5-10%, >10%) and plotted using ArcGIS (ESRI 2004). Grid cells with percentages in the two highest categories (>5% of the locations) were designated as the EOA for that seal.

To examine the size of the EOA for each seal, the number of cells in the EOA was tallied, and compared between 2005 and 2006 using an analysis of variance (SAS 1999), separately for adult males and adult females. For 2006, we compared the size of the EOA of each seal during the time when industry was “active” at the site, with the inactive period which followed when well testing, demobilization and airstrip activities were completed (Table 4) using a Chi-Square goodness-of-fit test.

To examine the relationship of the distances traveled by each seal as it related to the Paktoa location, the frequency distribution of grid cell center point distances (pooled by 500 m intervals) from the Paktoa site (or the Paktoa proxy site in 2005) were plotted for adult male and adult female seals using Lotus Freelance Graphics. For 2005, since we did not actually work in the Paktoa study plot because of extreme rough ice, our analysis is based on calculations of distance from a proxy site centered in the middle of search area A where all the 2005 seals were captured (Fig. 2).

The mean distance from Paktoa, for each of the seals tagged in 2006, for a 19 day period while industry was active and the following 19 days when industry was inactive, were plotted on a frequency histogram and compared using ANOVA and a Duncan’s Multiple Range test (SAS 1999).

Table 4 Construction and drilling activities at the Devon Canada Paktoa site during the period 5 December 2005 to 8 April 2006

Activity	Date
SDC moved to site & set down	late August 2005
Commence drilling	5 December 2005
Airstrip construction commences	8 February 2006
Airstrip operational	16 February to 8 April 2006 (42 Twin Otter loads)
Well testing and abandonment	19 February to 20 March 2006
Ice road construction	Early February
First light truck arrives at SDC on ice road	2 March 2006
Seal Camp to location	13 March 2006 (1 semi load)
First back haul from SDC	14 March 2006 (2 semi loads)
Demobilisation on ice road begins	20 - 31 March 2006 (26 semi loads)
Demobilisation complete	31 March 2006
Seal camp demobilisation	2 April 2006 (1 semi load)
Ice road decommissioned	5 April 2006
Last flight on airstrip	8 April 2006

Collection and Processing of Specimens of Ringed Seals

In each of May 2004, 2005 and 2006, a random sample of ringed seals was collected from within or adjacent to Devon’s Blocks A and B by Inuvialuit harvesters from Tuktoyaktuk, NT (Fig. 6). The following information was taken from each seal: sex, date, location of kill, and the hunter’s assessment of relative age and health. Seals were laid on their backs on a smooth flat surface, and using a steel tape measure, standard length (nose to tail) ($\pm$1 cm) was measured (American Society of

Mammalogists 1967). Body weight was measured to the nearest 0.5 kg using a spring dial scale suspended from a tripod. No corrections were made for blood loss. Other measurements taken by the monitor included blubber thickness at the sternum and at the hip, axillary girth and hip girth. The lower mandible and reproductive tracts were removed from all seals sampled (Smith 1973; Harwood *et al* 2000), as were samples of liver, kidney, muscle and blubber (for contaminants testing, separate study, Dr. Gary Stern, DFO), blood and nasal mucous (for disease testing, separate study, Mr. Ole Nielsen, DFO), skin (for genetic analysis, Dr. Brendan Kelly, UA), and liver and blubber (for PAH level determination and fatty Acid profiling, this study). One complete seal carcass, which was judged sickly (thin) by the collectors, and one neonate pup found dead in a birth lair, were measured and weighed, then shipped whole to our collaborating veterinarian, Dr. Stephen Raverty, Center for Animal Disease, Abbotsford, BC for necropsy.

In the laboratory, the lower jaws were boiled, lower canines extracted, and one cut in cross-section. Age was determined by reading the dentinal annuli of the cross section under transmitted light (Smith 1973). Duplicate readings by the same reader were made for each tooth, with the second reading done separately. If the first two readings did not agree, a third reading was done. A decision of the age was made based on recounts of the dentinal layers, a consideration of the clarity of the dentinal lines, the closure of the pulp cavity and the number of layers in the cementum, if it was readable.

Recent studies have indicated the ages of ringed seals determined from counts of dentinal layers tend to underestimate the age compared to the reading of cementum layers, particularly in seals older than 10 years of age. For seals <10 years of age, a statistically significant correlation has been reported for ages obtained using the two methods (Stewart *et al.* 1996). In our study we used the same ageing method (dentinal), which was used in our 1970’s data set and in the ongoing studies at Holman and Sachs Harbour, to ensure the data sets were comparable (Harwood *et al* 2000).

Following the methods described by Smith (1973), left and right ovaries were sectioned, and the number of follicles >5mm and the size of corpora lutea were measured. We classified a female as mature on the basis of the presence of large follicles or a corpus luteum in her ovary, plus evidence of either a corpus albicans or signs of past parturition based on examination of her uterine cornua. The presence of a large, recently erupted follicle or a corpus luteum was taken as evidence of recent ovulation in adult females.

Stomachs were removed from specimens in the field, ends of the stomach tied off, labelled, frozen and shipped to the laboratory in a frozen state. In the lab, they were thawed and then cut open lengthwise from sphincter to sphincter over a 500 micron sieve. The inside of the stomach was washed thoroughly, making sure all contents and any parasites were removed. Wet weight of the contents was measured, after removing as much water as possible from the material. Different items in the stomach were separated into weighing dishes, according to the following five groups: (1) all identifiable invertebrates, (2) all identifiable fish, (3) fish remains (parts of fish that are not immediately attributable to a given species such as scales, eggs, bones, tissue attached to bones), (4) otoliths, and (5) unidentifiable material (digested material that could not be attributed to anything specifically). Wet weights were obtained for each grouping. Invertebrates and fish that were identifiable were enumerated and identified to lowest taxonomic group possible by North/South Consultants Ltd., Winnipeg, MB.

Data on seals collected by the harvesters in 2004, 2005 and 2006 formed our basic data set. All data were entered on to a Microsoft Excel spreadsheet, and statistical analyses conducted using SAS (1999) on a PC according to Sokal and Rohlf (1981) and Elliott (1983).

Condition indices were calculated according to the method described by Harwood *et al* (2000) and Hammill *et al* (1995). Body weight was related to standard length according to the formula: weight = 10^{a} length^{b} (Innes *et al* 1981, cited in Hammill *et al* 1995). Our index of condition, referred to here as the body-mass index (BMI), was obtained using the relationship: BMI = weight (kg) x 10 000/standard length $(\text{cm})^{exp}$, where the exponent was the parameter b from a nonlinear regression of weight against length (2.76 for adult females, 1.92 for adult males) (Harwood *et al* 2000). Mean BMI was calculated and tabulated for each year of our study, for adult males and adult females separately.

Analysis of variance (SAS 1999) was used to examine differences in seal body condition (BMI) among seals collected in 2004, 2005 and 2006, and a Duncan's Multiple Range Test was used to reveal which years were different. These tests were done separately for adult males and adult females, and homogeneity of variances was examined using an F test.

Aerial Surveys for Ringed Seals

A systematic aerial survey of seals hauled out on the sea ice offshore of the Mackenzie Delta, was conducted from 13-17 June 2003; 1-4 June 2004; 5 June 2005; and 28 -30 May 2006, along all or part of 18 pre-established north-south transect lines (Fig. 7). The size of the surveyed area (mean = 727 km^2, range 567 km^2 - 925 km^2), and total transect distance flown in each year (mean = 939 km, range 826 - 1161 km) varied in the different years of our study depending on the location of the ice edge.

A strip transect method was used, with a planned survey speed of 200 km/h, survey altitude of 152 m, and strip width of 400 m per side (Kingsley 1986). Windows were marked using an inclinometer to delineate the inner and outer edges of the transect, which was offset from the flight path by 50 m to account for the area of reduced visibility directly under the aircraft. The north- south transect lines were spaced at 15' longitude, and covered all of Devon's western and eastern blocks, and extended to or beyond the edge of the fast ice seaward of those blocks.

Two experienced observers conducted the survey, and made tape recorded observations of ice, weather, and all marine mammals sighted. The same primary observers conducted the survey on all flights in all years of the study, from the same left and right rear seats, which were equipped with bubble windows. Secondary observers were also present on the flights in 2004 and 2005, and their observations designated as off-transect (e.g. not included in the basic density calculations).

Audiotapes were later transcribed to standardized data forms. Surveys were conducted in the afternoon and evening on each survey day, from approximately 1300 h to 2100 h. Sighting locations were determined using elapsed time, aircraft speed and the start and end coordinates for each transect from the aircraft's Global Navigation System (GNS). Data were entered into Microsoft Excel. Radar satellite imagery for the corresponding date of each survey, or as close as possible to the survey date, were obtained from the Canada Space Agency and analyzed for each survey period.

The survey study area was divided into essentially square grid cells, after the method described in Harwood (1989). Each grid cell was 9.3 km (5' latitude) x 9.7 km (15' longitude at 70^{o}N), and had an approximate surface area of 90.3 km^2. Sampling units were the 9.3 km transect segments within each grid cell. Sightings were assigned to the appropriate grid cell. Two strata were used, WEST (transects 1-9 inclusive) and EAST (transects 10-18 inclusive). Sightings were assigned to the appropriate grid cell. All marine mammals sighted during the surveys were plotted over the radar satellite ice imagery for the corresponding survey period.

To examine trends in abundance for each species, estimates of ringed seal density were calculated for each year using the transect segment in each grid cell as the sampling unit. Mean grid cell density was calculated as the number of seals sighted on-transect/km^2 surveyed, and regional density and variances using these grid cell values for each stratum and the overall survey area. To examine the relationship between ringed seal density and distance from the edge of the fast ice, a regression was conducted for each year with observed ringed seal density in each cell as the dependant variable (y) and the distance of the center point of each cell from the nearest location of the 1 June ice edge (in that year) as the independent variable (x).

The 2003, 2004, 2005 surveys were conducted before industry activity commenced at the Paktoa site, while the 2006 survey was conducted when all operations at Paktoa were complete (Table 4). To compare the distribution of seals observed in the surveys prior to and after the industry activity at Paktoa, ArcGIS was used to determine the distance of the center point of each grid cell to the Paktoa site. To examine the relationship between ringed seal density and distance from the Paktoa site, observed ringed seal density in each cell (y) was regressed against the distance of the center point of each cell from the Paktoa location (x), for the 2004, 2005 and 2006 surveys for the WEST stratum, which included the Paktoa site. Data from 2003 could not be included in this analysis since the Paktoa site was ice free by the time of the survey, which was conducted two weeks later than in the other years, under only fair survey conditions, and with coverage that was interrupted in space and time due to weather (fog, warmer conditions).

RESULTS

Ringed Seal Structures

The type and status of subnivean seal structures found during these surveys, are summarized in Table 5, and plotted on Fig. 8 (birth and resting lairs), Fig. 9 (tiggak lairs and breathing holes) and Fig. 10 (breathing holes). Impassable ice conditions precluded surveying parts of the 6 x 8 km study area surrounding Paktoa in each year, and prevented us from surveying any of it in 2005. The proportion of the study area that could be surveyed ranged from 62-73% (Table 5). In 2005, three smaller areas located 6-12 km to the SW of Paktoa were surveyed. Two of the three (B + C) were surveyed using the 500 m wide transect design, and had 62% coverage (Fig 2).

The density of seal structures (all types combined) ranged from a low of 1.02 structures/km^2 in 2004, to a high of 2.17 structures/km^2 in 2003 and 2.13 structures/km^2 in 2006 (Table 5). The density of seal structures (all types of seal structures considered together) was statistically different only for two years in our series, with 2004 being the lowest and 2006 the highest (T=1.96321, df=733, p=0.05).

Although the density of birth lairs separately was lower in 2006 (0.11/km^2) than in the other years of our study (0.17 to 0.35 /km^2) (Table 5), the density of birth and resting lairs (all complexes used by adult females) was not statistically different among the years of the study (T=0.54, p>F=0.6575). The same was true for the density of breathing holes (F=0.95, p>F=0.4171), which was not statistically different among the years of the study. The density of tiggak structures (used by adult males) was statistically different, being greater in 2006, than in 2003 and 2004 (T=1.96321, p<0.05). Visual examination of the plots of the distribution of seal structures found during the dog searches in all years, revealed no obvious trends or patterns of clumping, avoidance or attraction in any of the seal structure groupings with regard to the Paktoa site (Figs. 8-10). Rather, the location of seal structures was closely linked to surface topography of the ice.

Table 5. Type and status of subnivean seal structures detected during dog searches on 500 m wide transects in the Paktoa area 2003-2006

Year	Days of fast ice prior to survey	km^2 surveyed	Total structures n	Total structure density per km^2	Active birth lair density per km^2	Number of lairs						Number of Breathing Holes				Unknown structures
						Birth		Resting		Tiggak		Non-tiggak		Tiggak		
						active	*frozen*	*active*	*frozen*	*active*	*frozen*	*active*	*frozen*	*active*	*frozen*	
2003	90	31.30	68	2.17	0.35	11	4	13	6	8	4	11	4	7	0	0
2004	84	40.20	41	1.02	0.17	7	1	3	0	5	0	6	5	6	1	7
2005*	75	15.04	26	1.73	0.27	4	3	3	1	2	0	6	2	2	0	3
2006	23	34.80	74	2.13	0.11	4	0	5	0	15	0	20	6	10	0	14

*Area B+C only

Figure 8 Birth and resting lairs (adult female structures) located by search dogs during sea ice surveys in the Paktoa study area, spring 2003, 2004, 2005 and 2006

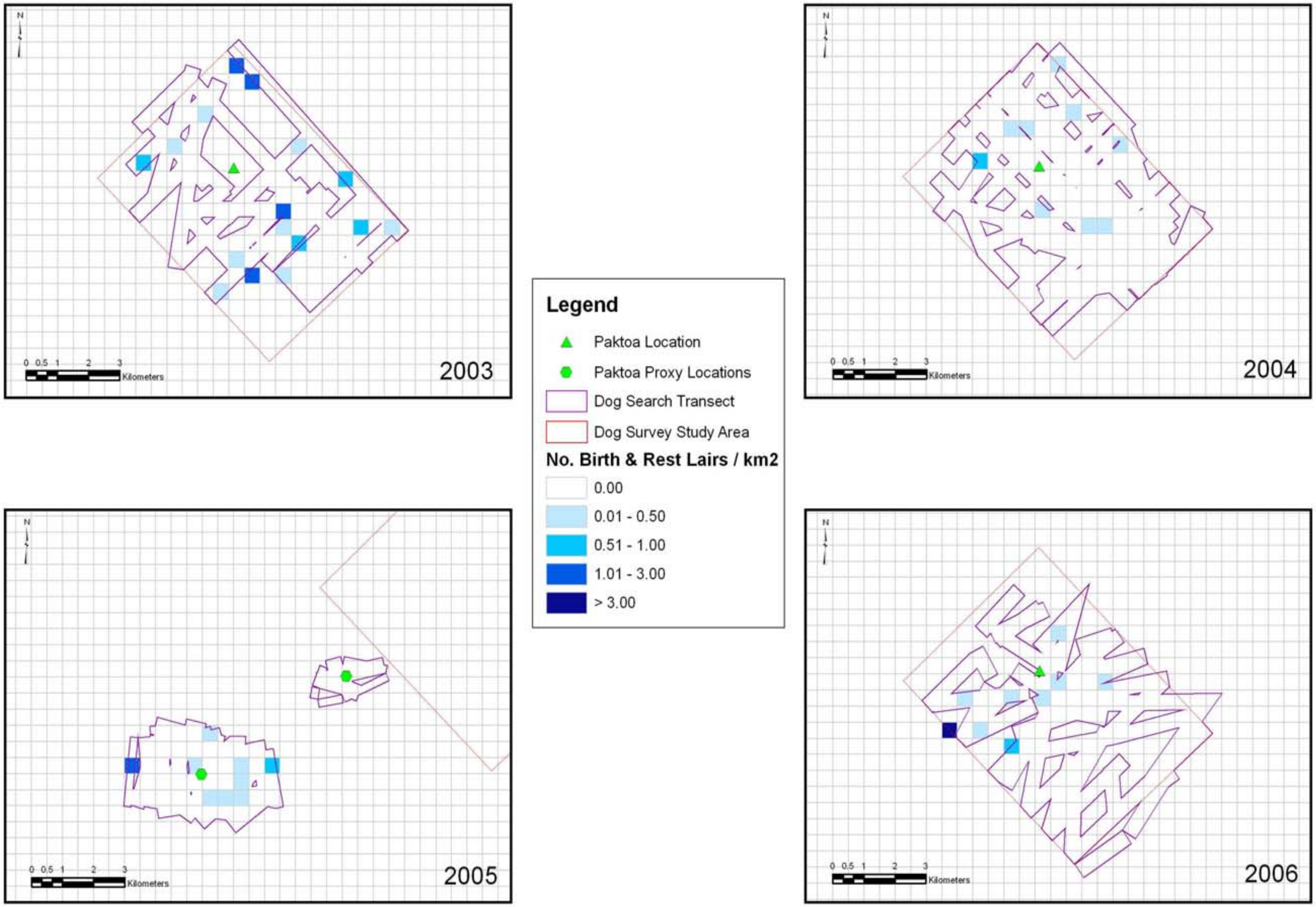


Figure 9 Tiggak lairs and tiggak holes (adult male structures) found during dog search surveys of the sea ice at Paktoa, 2003, 2004, 2005 and 2006

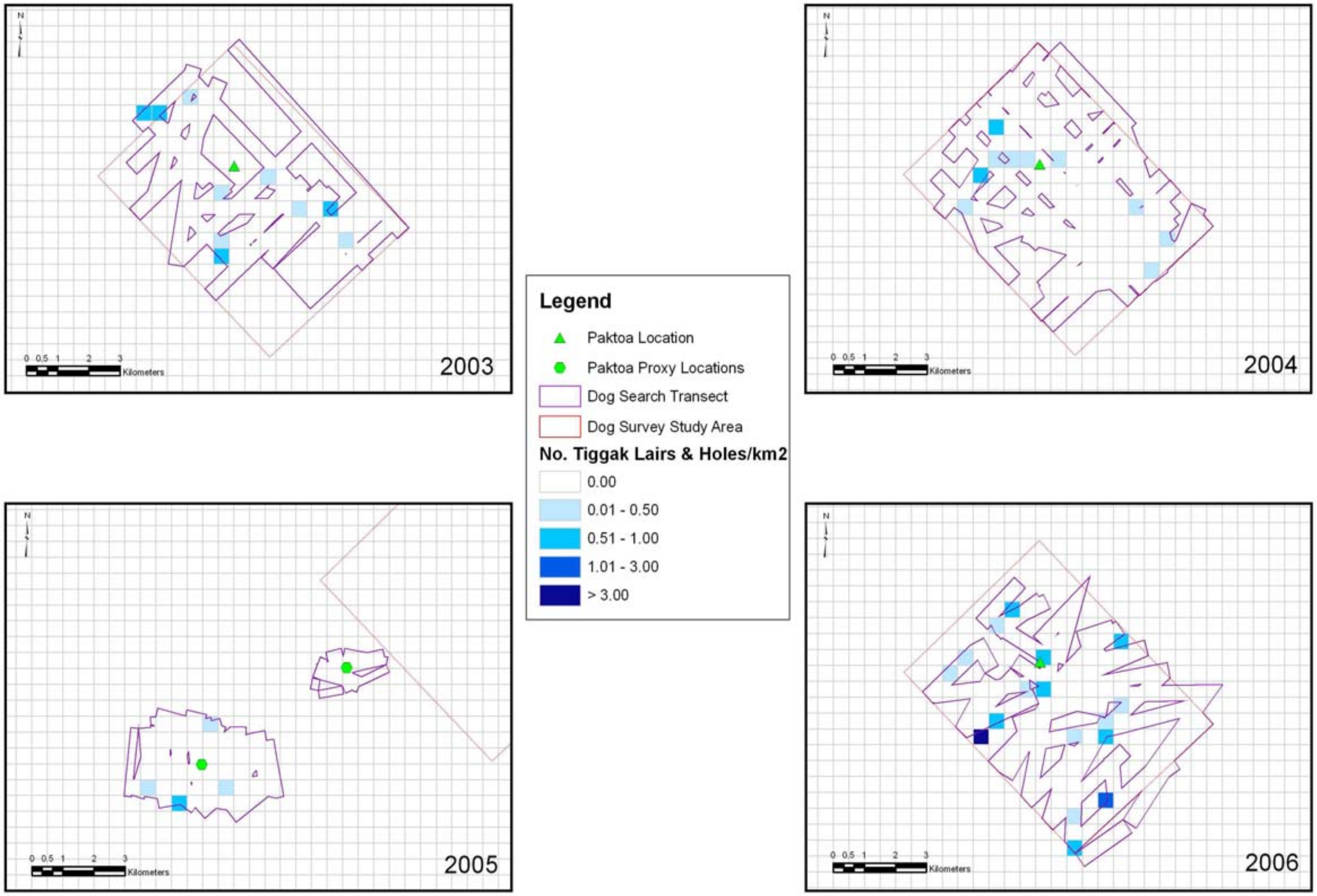


Figure 10 Breathing holes located during dog searches in the Paktoa area, spring 2003, 2004, 2005 and 2006

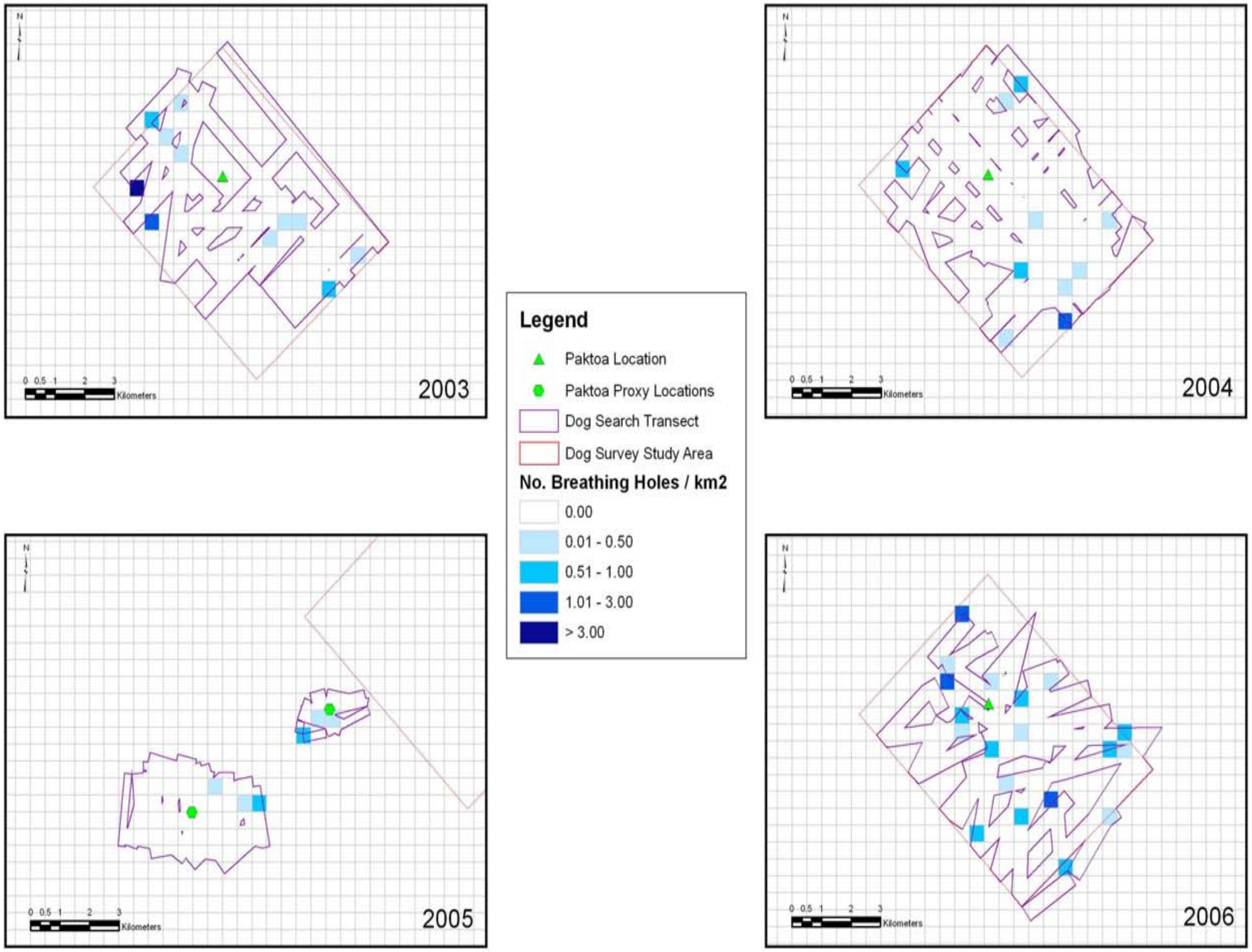


Table 6. Habitat in which different types of seal structures were found in all four years of the study, 2003-2006

Type of seal structure	Consolidated drift near ice hummock Year Total & Percentage 03	04	05	06	T	%	Consolidated drift in small pressure ridge Year Total & Percentage 03	04	05	06	T	%	Unconsolidated drift Year Total & Percentage 03	04	05	06	T	%
Birth lairs	8	6	10	4	28	0.74	7	2	0	0	9	0.24	0	0	1	0	1	0.03
Resting lairs	16	4	8	5	33	0.94	1	1	0	0	2	0.06	0	0	0	0	0	0.00
Tiggak lairs	9	4	4	12	29	0.78	3	1	0	2	6	0.16	0	0	0	0	0	0.00
Breathing holes	1	1	4	10	16	0.26	1	0	2	1	4	0.06	0	3	1	1	5	0.08
Tiggak breathing holes	0	0	0	4	4	0.17	0	0	1	0	1	0.04	0	0	1	0	1	0.04
Total per habitat area					110						22						7	
Overall mean percentage						0.56						0.11						0.04

Type of seal structure	Flat ice area Year Total & Percentage 03	04	05	06	T	%	Refrozen crack in ice Year Total & Percentage 03	04	05	06	T	%	Under ice slab Year Total & Percentage 03	04	05	06	T	%	Stucture type total
Birth lairs	0	0	0	0	0	0.00	0	0	0	0	0	0.00	0	0	0	0	0	0.00	38
Resting lairs	0	0	0	0	0	0.00	0	0	0	0	0	0.00	0	0	0	0	0	0.00	35
Tiggak lairs	0	0	0	0	0	0.00	0	0	0	0	0	0.00	0	1	0	1	2	0.05	37
Breathing holes	11	2	5	7	25	0.40	0	4	1	2	7	0.11	0	0	1	4	5	0.08	62
Tiggak breathing holes	5	0	2	3	10	0.42	0	0	1	0	1	0.04	2	0	2	3	7	0.29	24
Total per habitat area					35						8						14		196
Overall mean percentage						0.18						0.04						0.07	

Table 7. Average snow depths as measured at birth lairs, resting lairs and tiggak lairs for each year of the study 2003-2006

Study year	**Snowfall Inuvik NT* Oct-April**	**Mean snow depths at birth lairs**	**Mean snow depths at resting lairs**	**Mean snow depths at tiggak lairs**	**Mean all structures pooled**
2003	183.2 cm	57.7,S.D.=7.21,n=6	47.2,S.D.=10.1,n=6	67.6,S.D.=16.9,n=5	56.9,S.D.=13.9,n=17
2004	314.2 cm	93.1, S.D.=15.5,n=8	85.3,S.D.=16.2,n=3	64.6,S.D.=13.2,n=5	82.7, S.D.=18.2,n=16**
2005	172.4 cm	67.1,S.D.=16.6,n=7	46.9,S.D.=11.2,n=7	72.8,S.D.=35.2,n=4	60.5,S.D.=22.3,n=18
2006	na	62.0,S.D.=21.4,n=4	54.8,S.D.=9.83,n=5	51.6,S.D.=13.8,n=14	54.1,S.D.=14.6,n=23
Mean all years pooled		72.3,S.D.=17.9,n=25**	54.3,S.D.=17.0,n=21	59.8,S.D.=19.5,n=28	

* closest weather site available, approx. 150 km to the SE of Paktoa
** statistically signficiant p>0.05

The seal structures were found in five different habitat types (Fig. 11; Table 6). Most birth lairs (74%) were built in consolidated snow drifts formed near ice hummocks (singular features made of ice blocks surrounded by relatively flat ice), or in the drifts (24%) along low pressure ridges (formed by the edges of ice floes pushing against each other during the freeze-up period). Resting lairs and tiggak lairs showed the same trend, with 94% and 78% being found in consolidated drifts near ice hummocks, respectively. Breathing holes of both sexes were found in all five habitat types, but predominately in snow covered flat ice areas or along refrozen cracks in the ice (Fig. 11). Breathing holes were also found under ice slabs in small ice rubble (particularly in 2005) or in areas of unconsolidated drifts (Table 6). There is great annual variation in the surface features of the ice resulting in the differences we witnessed in the distribution of subnivean structures within our study area in each of the four years of our surveys (Figs. 8-10).

Mean snow depth at the lairs (all types combined) was least in 2006 (mean 54.1 cm) and greatest in 2004 (82.7 cm) (Table 7). ANOVA revealed the differences were statistically significant (F=9.52, df=73, p>F=0.0001), with the year 2004 having greater snow depths at seal lairs than 2003, 2005 and 2006 (Table 7; Duncan's Multiple Range test). This year of greatest snow depths at lairs corresponded well with snowfall data available from Inuvik, NT (www.climate.weatheroffice.ec.gc.ca), which is located 150 km to the southeast of our study area. Snowfalls in 2004 were higher than that in the other years of our study (Table 7).

Total snow cover was significantly different (F=5.40, df=2, p>F=0.0067) between lair types. Snow depths over birth lairs tended to be greater (mean 72.2 cm, n=25) than that over resting lairs (mean 54.3 cm, n=21) or over tiggak lairs (59.8 cm, n=28), and this difference was statistically significant (Duncan's Multiple Range Test, p<0.05).

The number of naturally abandoned structures (those with no predator sign) was similar in all years of our study (21 to 26 percent), except the year 2006, when it was only 10 percent (Table 8). Predation attempts were largely aimed at birth lairs. Polar bears made attempts or kills at 6 and 12 % of seal structures in 2003 and 2004, respectively, but no attempts or kills were found in 2005 and 2006 (Table 9). Arctic fox, *Alopex lagopus*, predation attempts or kills were highest in 2005 and lowest in 2006. In 2004, the study was completed by mid March, which appears to be well ahead of the arrival of foxes in the area.

Table 8. Naturally abandoned (frozen breathing hole; no predator sign) seal structures found during 2003-2006

Year	Total					% frozen over
	active	**frozen**	**unknown**	**structures**	**known**	**(abandoned)**
2003	50	18	0	68	68	26.47
2004	27	7	7	41	34	20.59
2005	15	5	3	23	20	25.00
2006	54	6	14	74	60	10.00

Year	fox attempt	total structures	% structures	polar bear attempt	total structures	% structures
2003	7	68	10.29	4	68	5.88
2004	0	41	0.00	5	41	12.20
2005	5	23	21.74	0	23	0.00
2006	2	74	2.70	0	74	0.00

Table 9. Predator sign (urine, scats, digs, kills) at ringed seal structures during the years 2003-2005

In 2005, Area A (Fig. 2) comprising 5.03 km^2 was searched repeatedly during the period from 22 March to 4 April to facilitate our seal trapping efforts. This may be considered a total search of the area, similar to the experiment of Hammill and Smith (1990), which sought to determine the actual density of seal structures in study plots of 2 to 4 km^2. In our study, the 2005 density was 4.57 structures/km^2, which is 2.64 times the density (1.73/km^2) found in the transect searches in 2005 and 2.60 times the mean transect densities in all years of the dog searches. In 2005 the proportional representation of the different types of subnivean structures found during the total search effort in area A, and the transect searches in areas B+C, were not significantly different (Chi Square = 6.90, df = 5, p>.10) (Table 10).

Area	km^2 searched	Density per km^2	Total structures	Lairs						Breathing holes				
				Birth		Resting		Tiggak		Non Tiggak		Tiggak		Unknown
				Active	Frozen	Active	Frozen	Active	Frozen	Active	Frozen	Active	Frozen	
A	5.03	4.57	23	4	0	4	0	2	0	7	0	5	0	1
B + C	15.04	1.73	26	4	3	3	1	2	0	6	2	2	0	3

Table 10. Comparison of densities of subnivean structures found during total search efforts (Area A), and 500 m wide transect searches of areas (B+C) in 2005

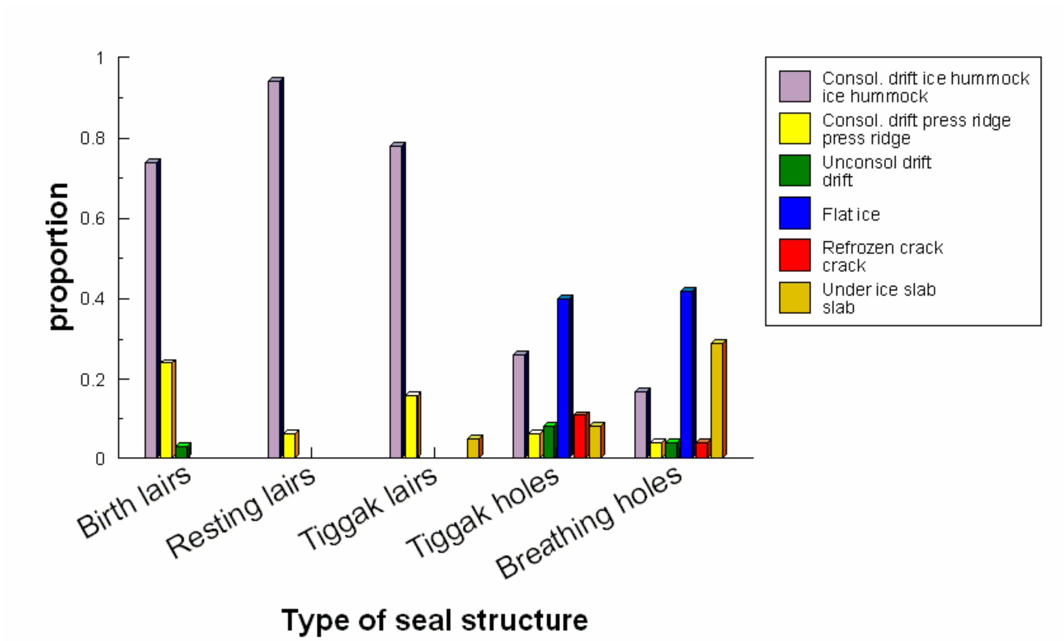


Figure 11 Types of sea ice habitats where ringed seal structures were found during dog searches, spring 2003-2006

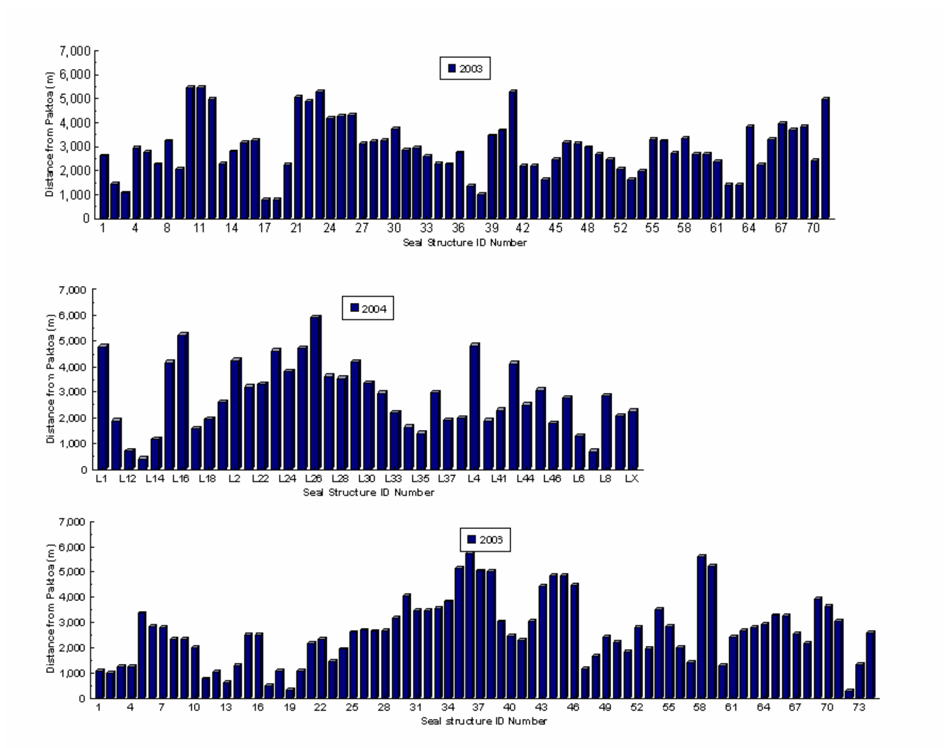


Figure 12 Frequency distribution of distances (m) from Paktoa for individual subnivean ringed seal structures, spring 2003, 2004 and 2006

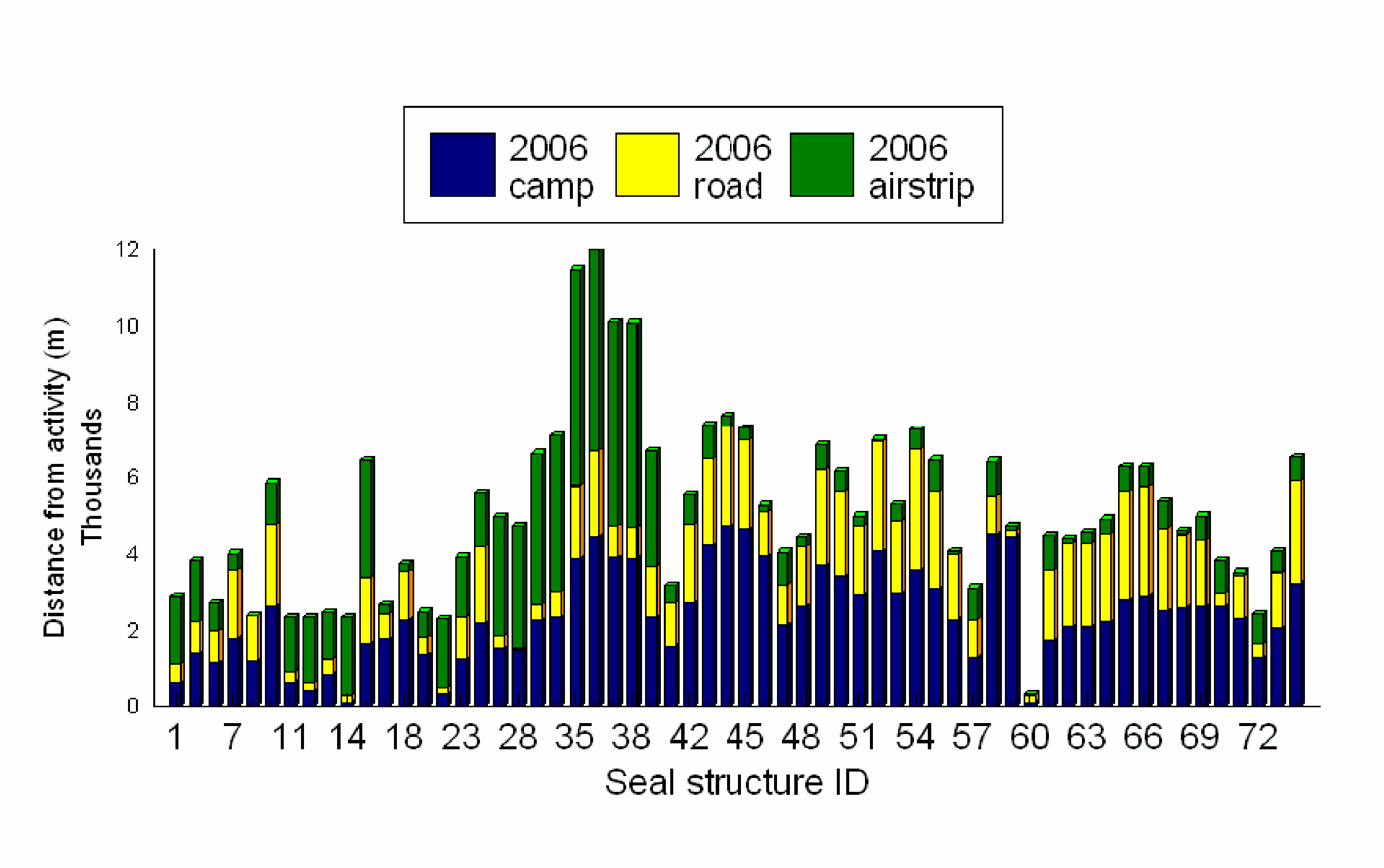


Figure 13 Distance of seal structures (m) from sites of industry's ice road and airstrip, and the seal research camp, spring 2006

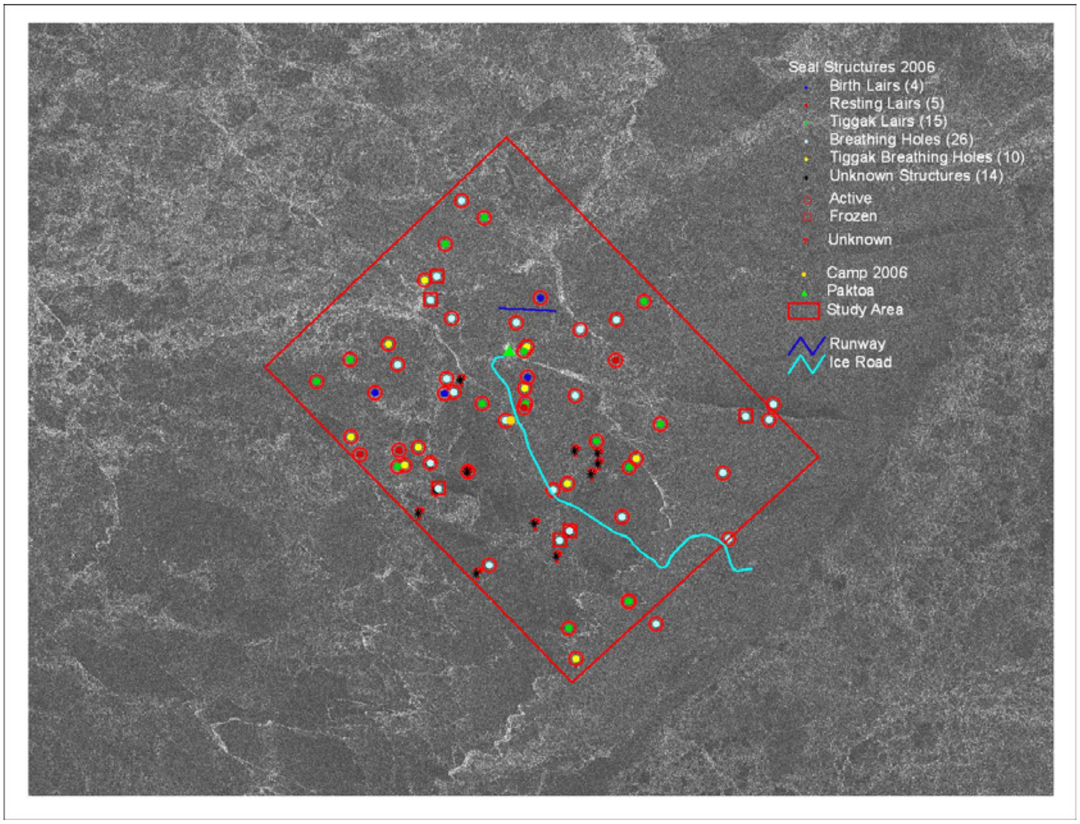


Figure 14 Location of seal structures found by detection dogs, and sites of industry activity in spring 2006

Table 11. Comparison of distances of seal structures from Paktoa 2003, 2004, 2006

Mean distance in meters from Paktoa (n in brackets)									
Study Year	Comparison of structure types			Comparison of active vs frozen structures			Comparison of female vs male str		
	Female structures (birth and resting)	Tiggak structures (lairs and holes)	Other structures (breathing holes)	Active	Frozen		Female	Male	
2003	2886 (34)	3078 (19)	2968 (15)	3117 (50)	2515 (18)	KS=0.125490, p>KS = 0.2345	2886 (34)	3078 (19)	KS=0.103120 p>KS
2004	1978 (11)	2278 (12)	3557 (11)	2391 (27)	3380 (7)	KS=0.198963, p>KS 0.1355	1978 (11)	2278 (12)	KS=0.124882 p>KS
2006	1886 (9)	2704 (25)	2766 (26)	2569 (54)	2964 (6)	KS=0.09444, p>KS = 0.6582	1886 (9)	2704 (25)	KS=0.162745, p>KS
	KS=0.220091 n=54 p>kS >0.05	KS=0.188097 n=56 p>KS >0.05	KS=0.186647 n=52 p>KS>0.05						

There were no discernable patterns of distribution with regards to the distribution of seal structures in relation to the Paktoa site in any year (Fig. 12). No significant differences in the distance of any of the different types of seal structures from the Paktoa site were found during the years 2003, 2004 and 2006 (Table 11). Neither was any significant differences found when the distances of active and abandoned structures were compared for any of the years, or differences between structures of males and females (Table 11).

For 2006, the mean, minimum and maximum distances of seal structure types from the ice road, the airstrip and our research camp were calculated (Table 12) and observations plotted along with the location of these activities (Fig. 13). Visual examination of the plots revealed no obvious trends or patterns of avoidance or attraction of seal structures with regard to the ice road, the airstrip or our research camp location (Fig 13, 14.). The closest seal structure to any site of activity was a breathing hole within 48 m of the ice road, a birth/resting lair within 187 m of the ice road, and a tiggak lair/hole within 231 m of the ice road (Fig. 14). In 2006, the shortest distance of any seal structure from the Paktoa site itself was 611 m for a birth/resting lair, 280 m for tiggak lair/hole, and 489 m for a breathing hole (Table 12).

Birth and resting lairs (adult female structures)					
	N	Mean distance (m)	SD	Minimum distance (m)	Maximum distance (m)
Distance to Paktoa	9	1887	890	611	3283
Distance to ice road	9	1469	890	187	2854
Distance to runway	9	2104	1096	217	3639
Distance to our camp	9	1722	832	332	2782
Tiggak (adult male) structures					
	N	Mean distance (m)	SD	Minimum distance (m)	Maximum distance (m)
Distance to Paktoa	25	2705	1435	280	5722
Distance to ice road	25	1594	917	231	3171
Distance to runway	25	2854	1523	678	6276
Distance to our camp	25	2492	1141	401	4454
Breathing Holes					
	N	Mean distance (m)	SD	Minimum distance (m)	Maximum distance (m)
Distance to Paktoa	26	2767	1492	489	5626
Distance to ice road	26	1258	816	48	2894
Distance to runway	26	2786	1556	255	5917
Distance to our camp	26	2527	1337	97	4730

Table 12. Mean distance of birth and resting lairs, tiggak lairs and holes, and breathing holes from industry activity in the Paktoa study area, spring 2006

Tagging and Tracking of Ringed Seals

During the four years of our study, 20 ringed seals were live-captured, tagged with satellite-linked transmitters, and released. Biological information for the tagged seals, along with tag type, tagging date and tag performance are summarized in Table 13. Our sample consisted of 5 adult females, 12 adult males and 3 sub adults; all but two of the satellite-linked tags, and all of the Rototags (numbered passive tags attached through the web of the hind flipper), were deployed in 2005 (n=8) and 2006 (n=11) (Table 14). Adult females and adult males from the 2005 and 2006 efforts formed the basic data set for comparison of pre-industry and industry activity exposures; these seals were tagged between 23 March and 3 April in their respective years. All but two of our tagged animals in those years (seal # 1 and seal # 5 with only three and four days of transmissions) continued to transmit until late May or early June, for an average of 56 days (range 27 to 81 days) when the tags were shed during the annual moult. The total number of locations received was 4682, of which 2541 (54.3%) which were used were of quality 1, 2 or 3 (1= accuracy <1 km;, 2 =accuracy <350 m; 3 =accuracy <150 m). The proportion of quality 1, 2 and 3 locations averaged 56.2% for the tagged females, 52.9 % for the tagged males (Table 13). Most of the seals shed their tags in late May or early June (75%), although signals were lost from some tags in late April and early May.

All five of the adult females, tagged in 2005 or 2006, were assessed to be pregnant at the time of tagging. This was based on their age from claw bands, their size and their live weight. No direct test was used to determine if the seals were pregnant. Parturition usually occurs during late March and early April, so it is likely that these females were tagged just prior to giving birth since they were not lactating.

Each location of quality 1, 2, or 3 that was received from each seal was assigned to a grid cell, and the proportion of locations from each grid cell was plotted for each seal by year, sex and relative age (Figs. 15 to 21). Capture location, and first and last transmitted locations are shown on those figures, as is the location of the 1 March ice edge in the given year.

All but one of our adult females, captured in 2005 and 2006, remained in the vicinity of the location where they were tagged for 6-8 weeks following release (Figs. 15 and 16). Tags ceased to transmit from these seals in late May and early June, commensurate with the time that the tags would be shed during the annual moult. The one exception was seal #15, an adult female (Fig. 16-A), which left the Paktoa area soon after tagging on 22 March 2006, and followed a north-westerly track, apparently toward the edge of the fast ice. From there she continued to the west toward Herschel Island, where the last signal was received on 21 May 2006. This pattern was similar to one that had been seen in a single adult male tagged in late April 2004 (Fig. 20).

Table 13. Summary of ringed seals tagged at Paktoa and tag performance 2003-2006

Seal #	Field ID #	Year	Type of satellite tag	tag provides location da	tag provides diving data	DFO PTT #	Alaska PTT #	Flipper tag #	Tagging date	Date of last signal	Days of locations	Proportion of quality 1,2,3	Sex	Relative age	Claw age	Nose/tail length cm	Girth cm	Weight kg	BMI
1	PK-03-01	2003	SDR16	x	x	23526	na	na	Apr-22	Apr-25	3	60	M	subadult	6++	101	102	48	68
2	PK-04-01	2004	SPOT4	x		23526	na	na	Apr-27	Jun-05	39	24	M	adult	8++	135	nr	75	61
3	PK-05-1	2005	SPLASH	x	x	57085	na	C001	Mar-23	May-26	63	80	F	adult	6++	109	105	55	131
4	PK-05-2	2005	SPOT	x		23527	na	C002	Mar-30	May-24	55	49	M	subadult	4++	103	92	37	51
5	PK-05-3	2005	SMRU	x	x	21212	na	C003	Mar-30	Apr-03	4	47	M	adult	6++	117	119	69	74
6	PK-05-4	2005	SMRU	x	x	5092	na	C004	Mar-30	May-25	56	65	M	adult	6++	120	116	69	70
7	PK-05-5	2005	SPOT 4	x		5056	na	C005	Mar-31	May-31	61	45	M	adult	4++	104	111	57	76
8	PK-05-6	2005	SMRU/SPOT	x	x/	11747/23529	na	C006	Mar-31	May-14	44	40	M	adult	6++	127	115	71	64
9	PK-05-7	2005	SPOT	x		23528	na	C007	Apr-01	May-20	49	44	F	subadult	3-4	91	89	34	133
10	PK-05-8	2005	SPLASH	x	x	57084	na	C008	Apr-03	May-08	35	58	F	adult	5++	119	112	67	125
11	PK-06-01	2006	SPLASH	x	x	23527	57997	11	Mar-20	Jun-09	81	72	M	adult	6++	105	107	54	71
12	PK-06-02	2006	SPLASH	x	x	23529	57982	12	Mar-20	May-29	70	69	M	adult	7++	114	119	57	64
13	PK-06-03	2006	SPOT5	x		23526	57983	13	Mar-20	Apr-29	40	40	M	adult	5++	108	112	55	68
14	PK-06-04	2006	SPOT5	x		5092	57984	14	Mar-21	May-28	68	63	M	adult	5++	124	121	66	63
15	PK-06-05	2006	SPLASH	x	x	57085	57988	15	Mar-22	May-21	60	43	F	adult	6++	117	119	75	147
16	PK-06-06	2006	SPLASH	x	x	23528	57993	16	Mar-23	Jun-04	72	44	F	adult	6++	117	116	58	113
17	PK-06-07	2006	SPLASH	x	x	57084	57980	17	Mar-24	May-23	59	69	F	adult	5++	119	112	64	119
18	PK-06-08	2006	SPOT5	x		21212	na	18	Mar-26	May-17	51	55	M	adult	6++	126	117	65	60
19	PK-06-09	2006	SPOT5	x		11747	na	19	Mar-29	Apr-26	27	52	M	adult	7++	124	114	59	56
20	PK-06-10	2006	SPOT5	x		5056	na	20	Mar-29	Jun-07	69	60	M	adult	6++	121	119	75	75

Table 14. Summary of age and sex categories of ringed seals tagged with satellite-linked transmitters 2003-2006

	2003	**2004**	**2005**	**2006**	**Totals**
adult female	0	0	2	3	5
adult male	0	1	4	7	12
subadult	1	0	2	0	3
Total	1	1	8	10	20

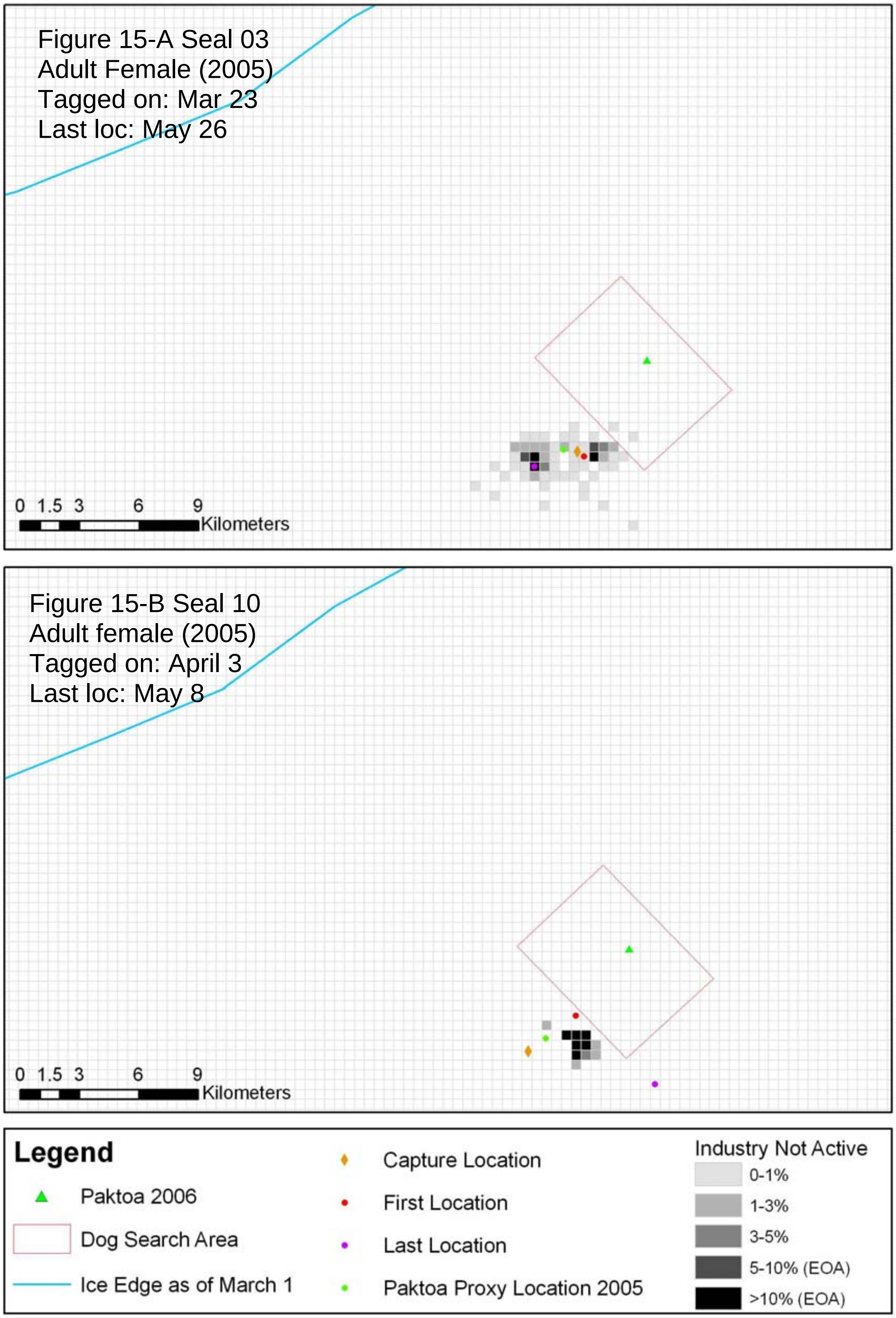


Figure 15 Movement of satellite tagged adult female ringed seals, spring 2005

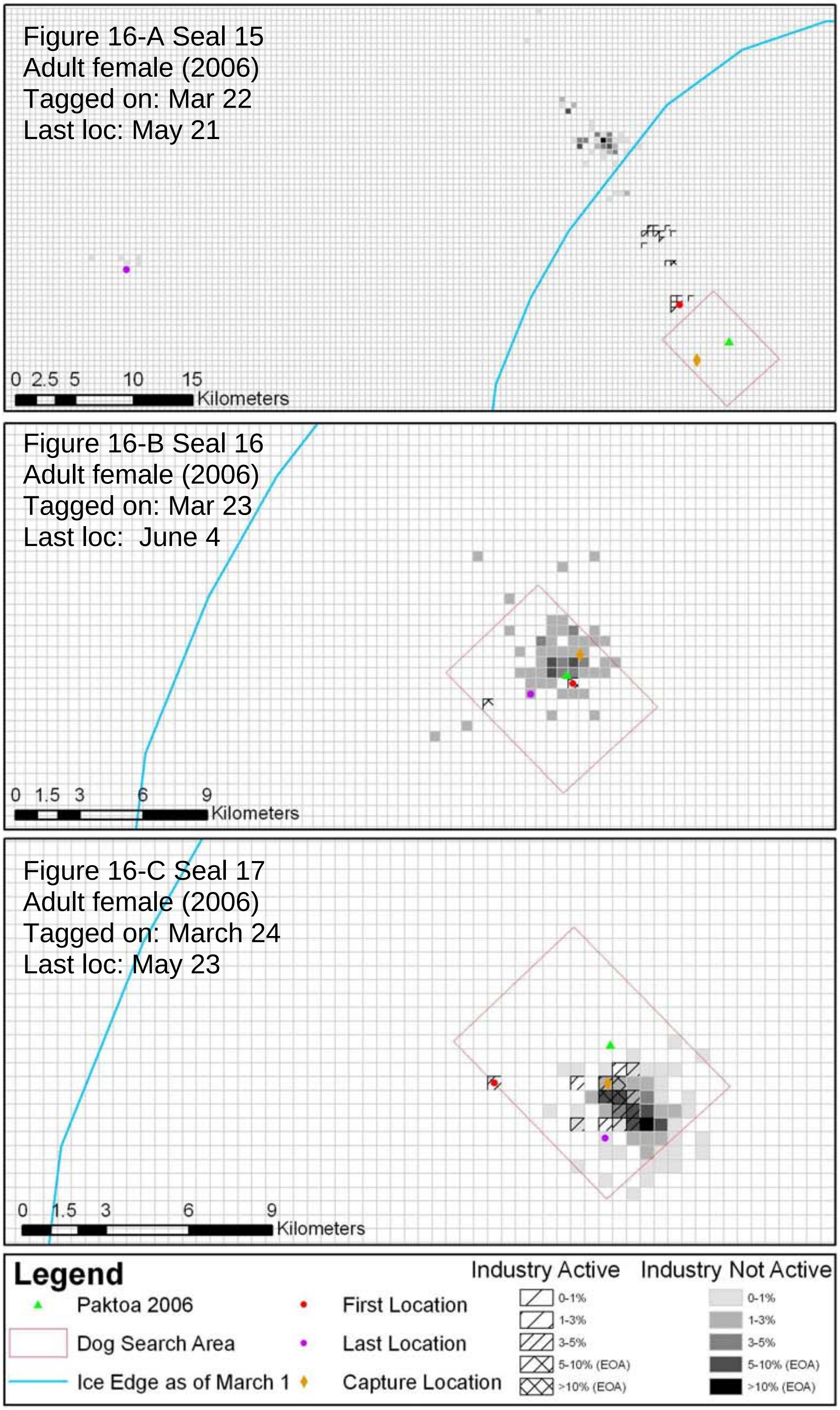


Figure 16 Movements of adult female ringed seals tagged at the Paktoa study site in spring 2006

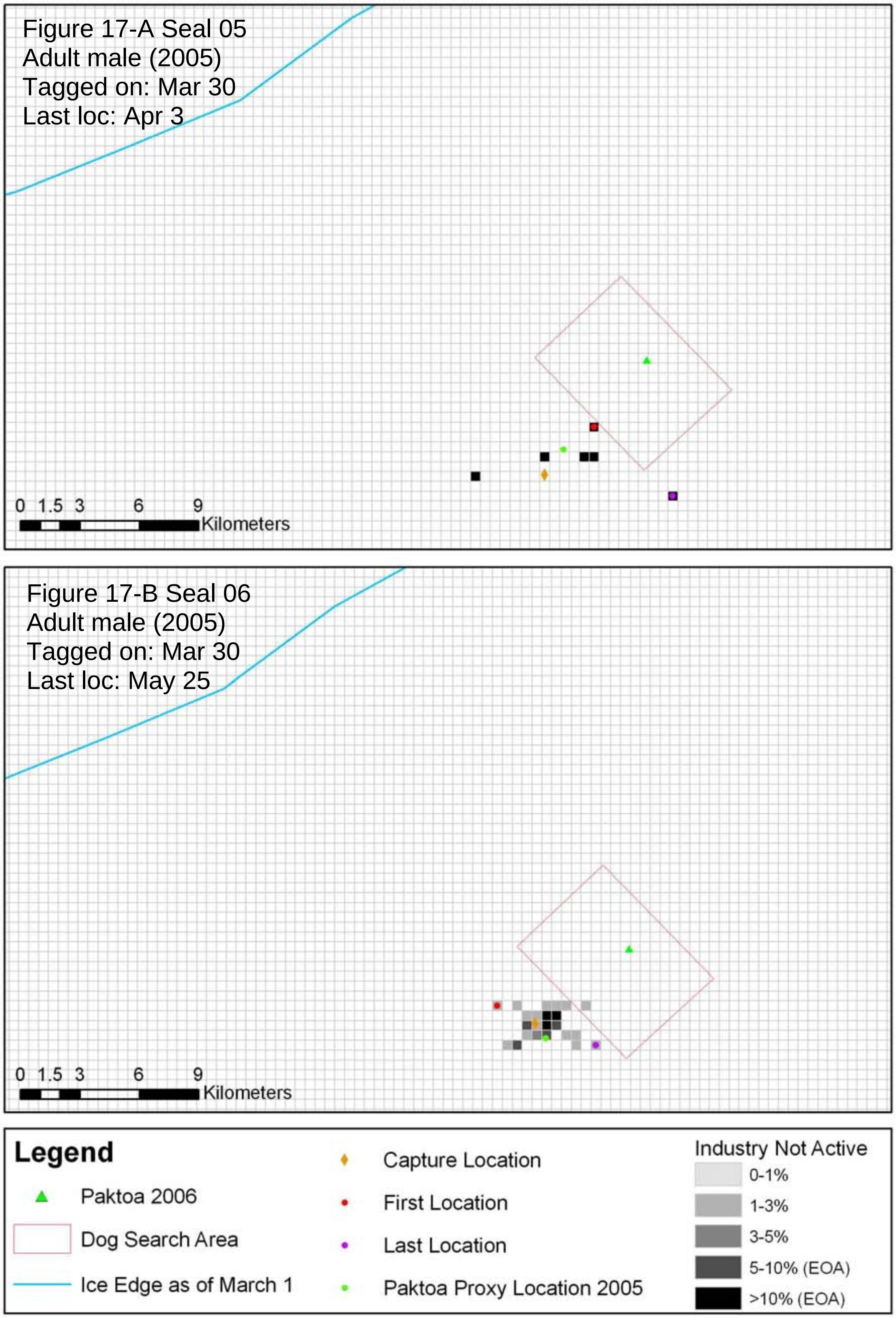


Figure 17 Movement of adult male ringed seals tagged in spring 2005

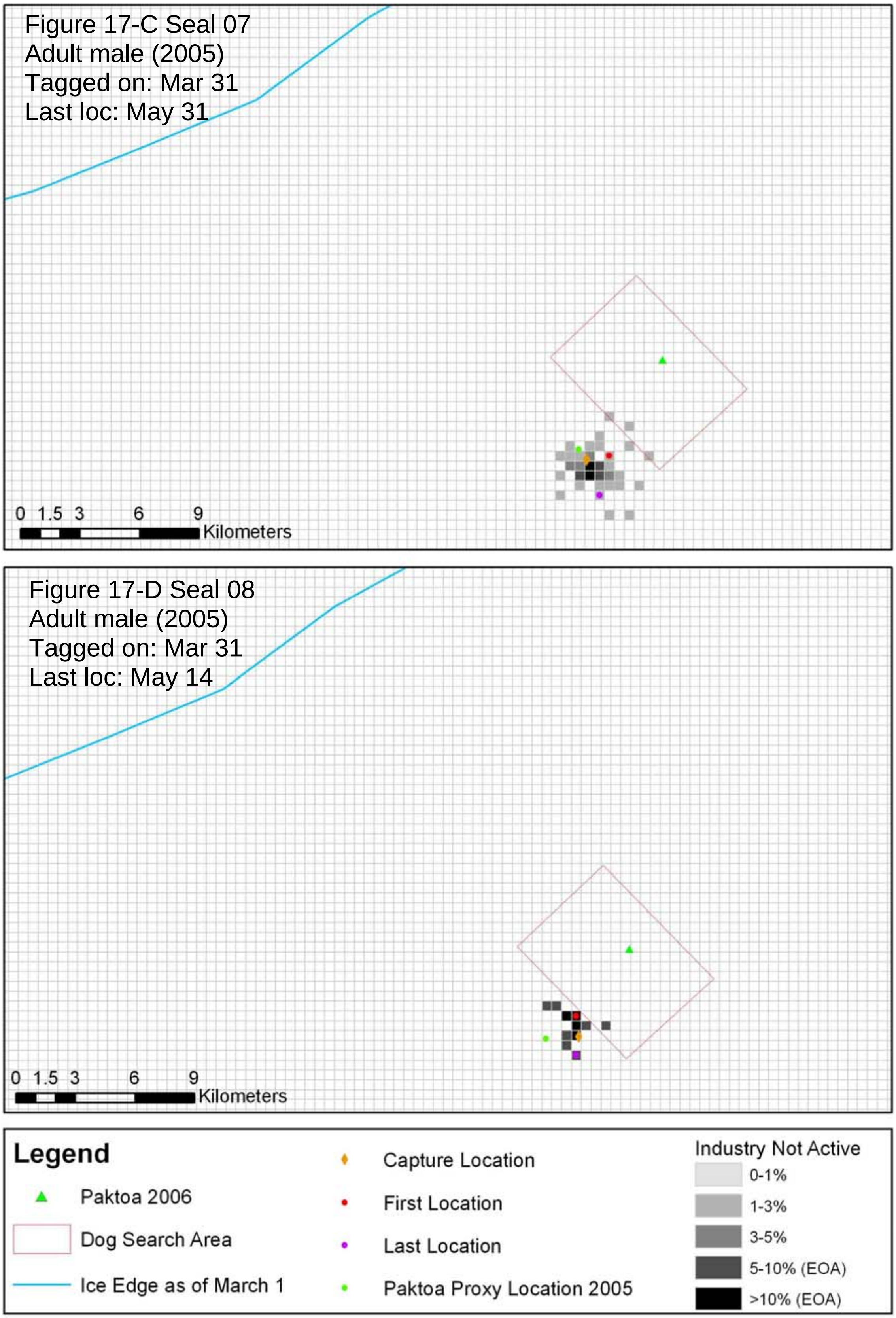


Figure 17 (cont'd) Adult Males 2005

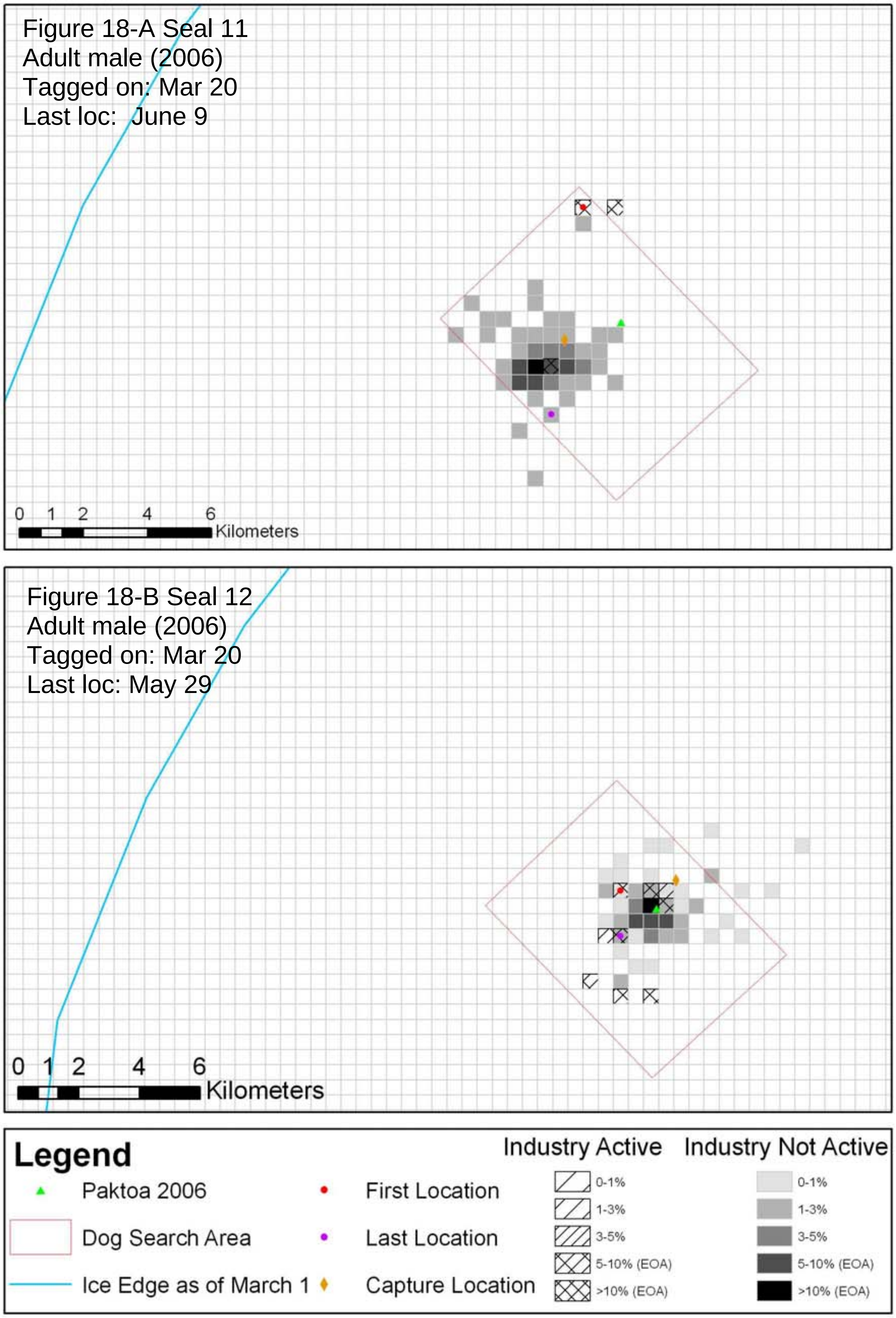


Figure 18 Movement of adult male ringed seals tagged in spring 2006

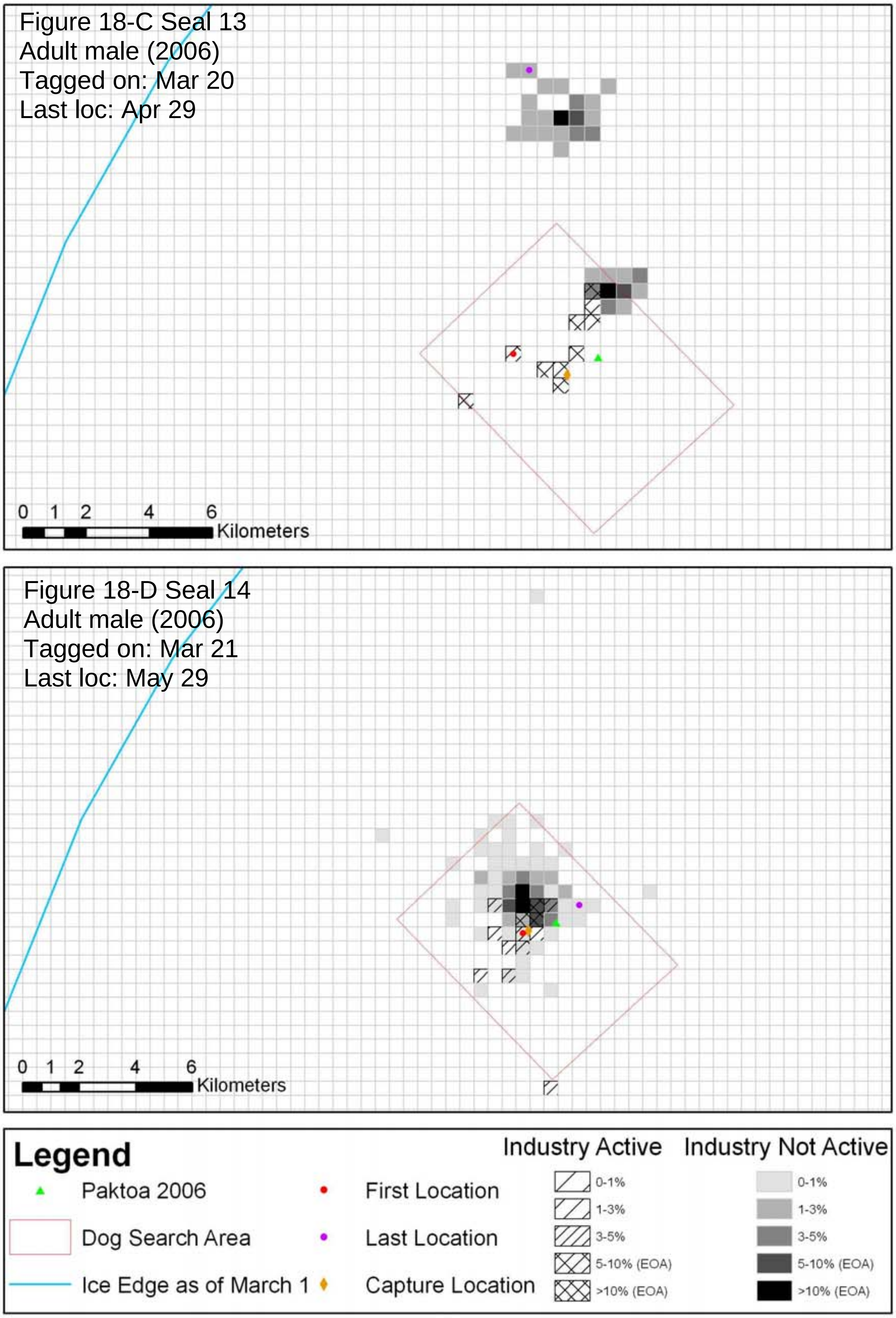


Figure 18 (cont'd): Adult Males 2006

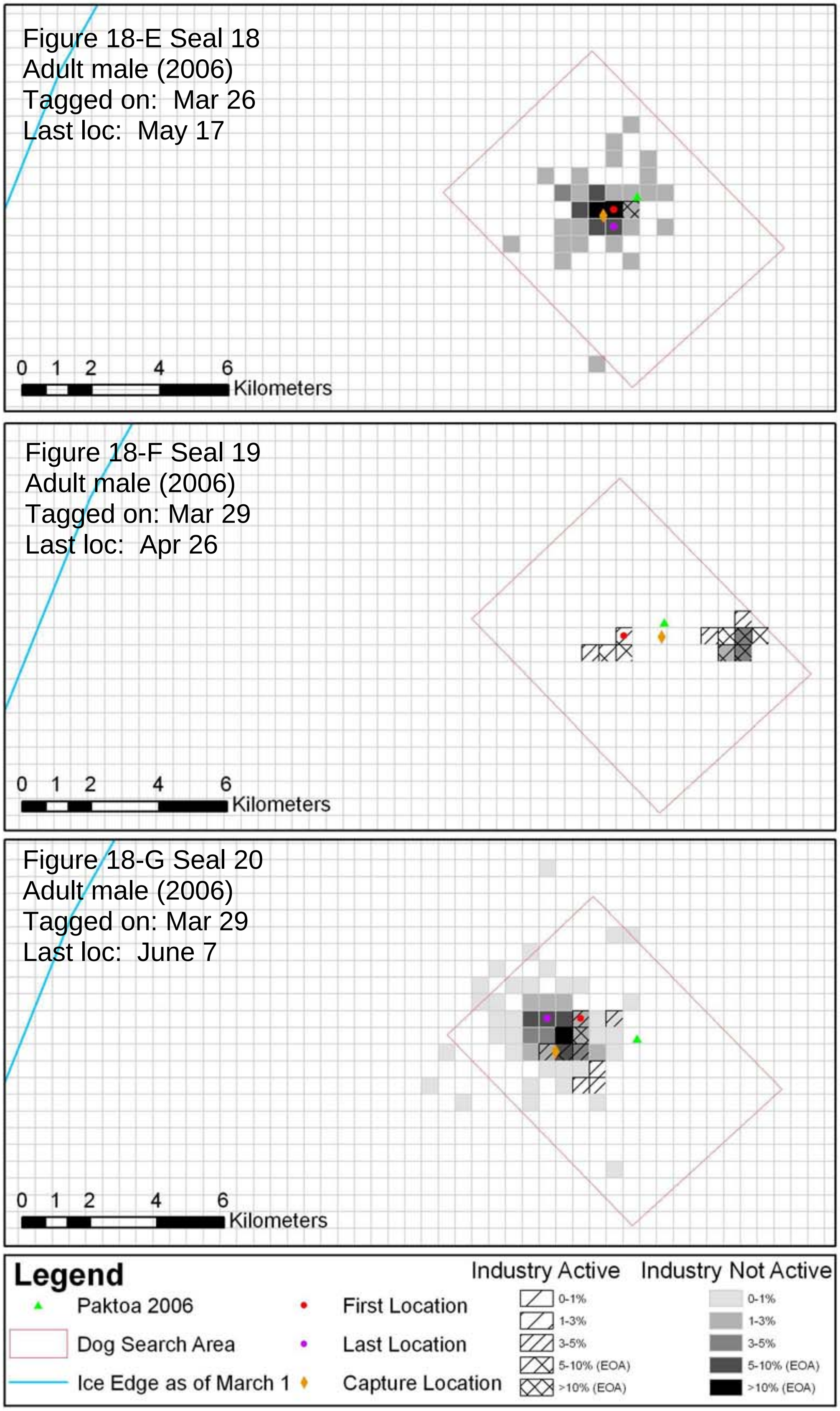


Figure 18 (cont'd): Adult Males 2006

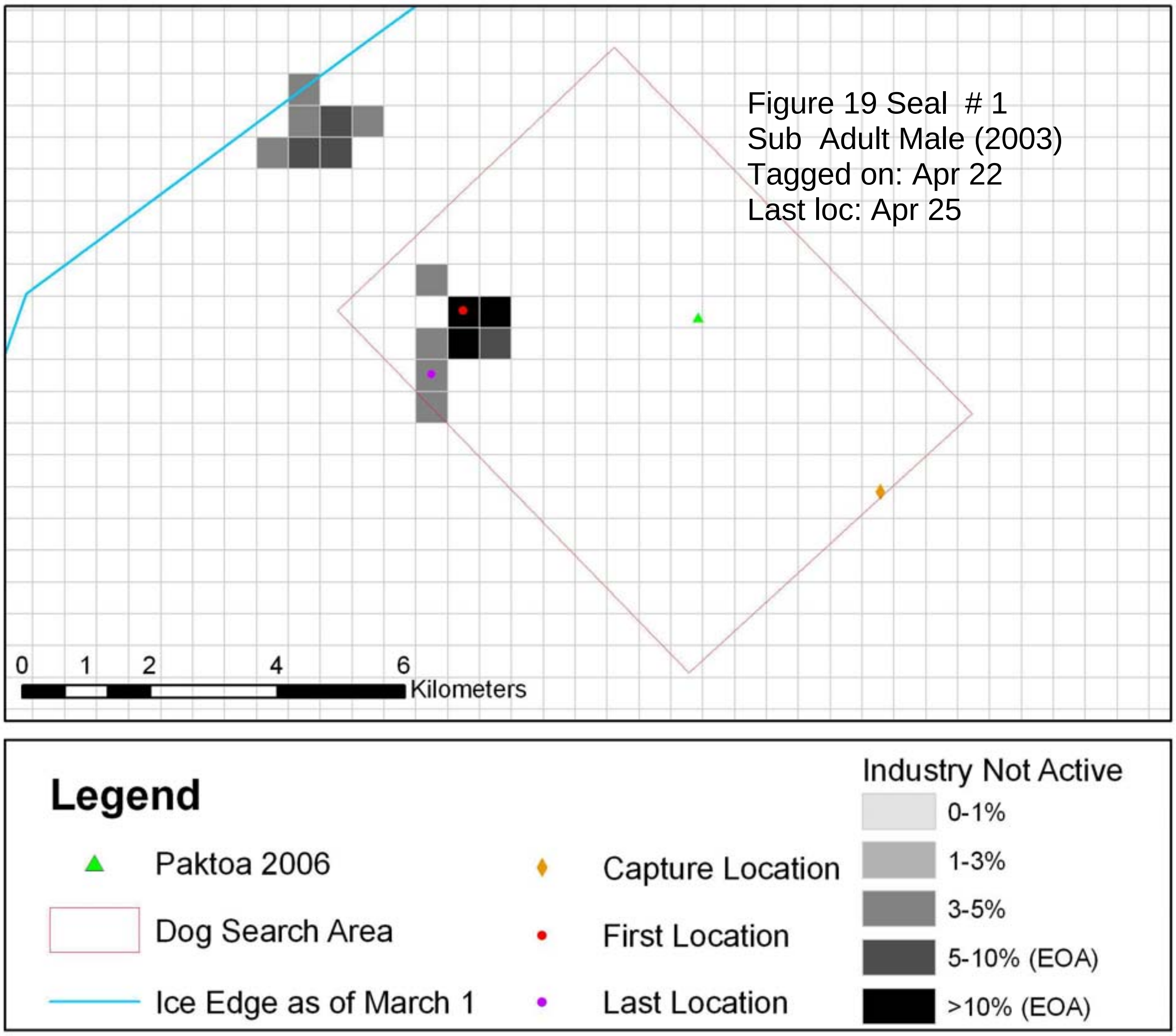


Figure 19 Movements of sub adult male ringed seal tagged in spring 2003

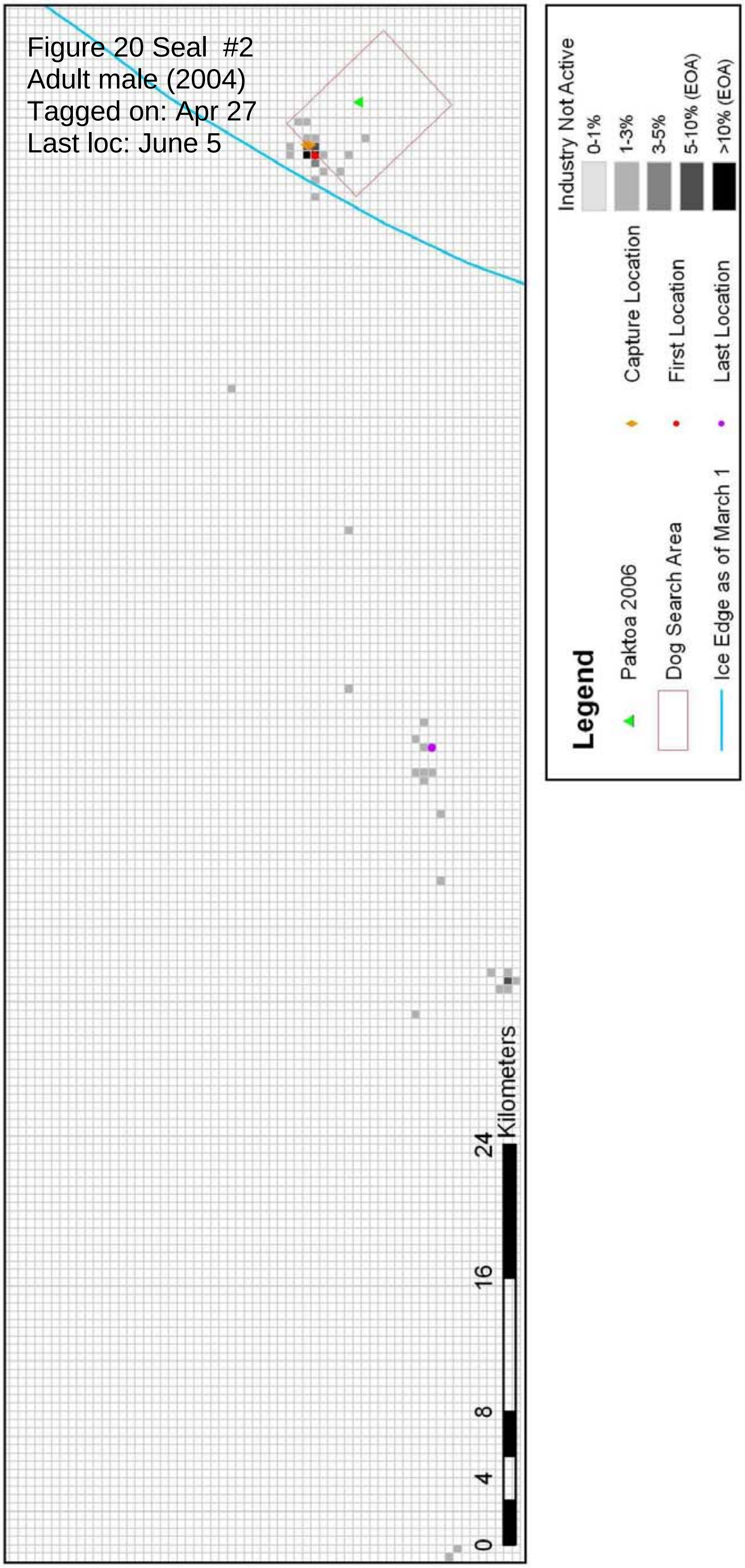


Figure 20 Movement of adult male ringed seal tagged in spring 2004

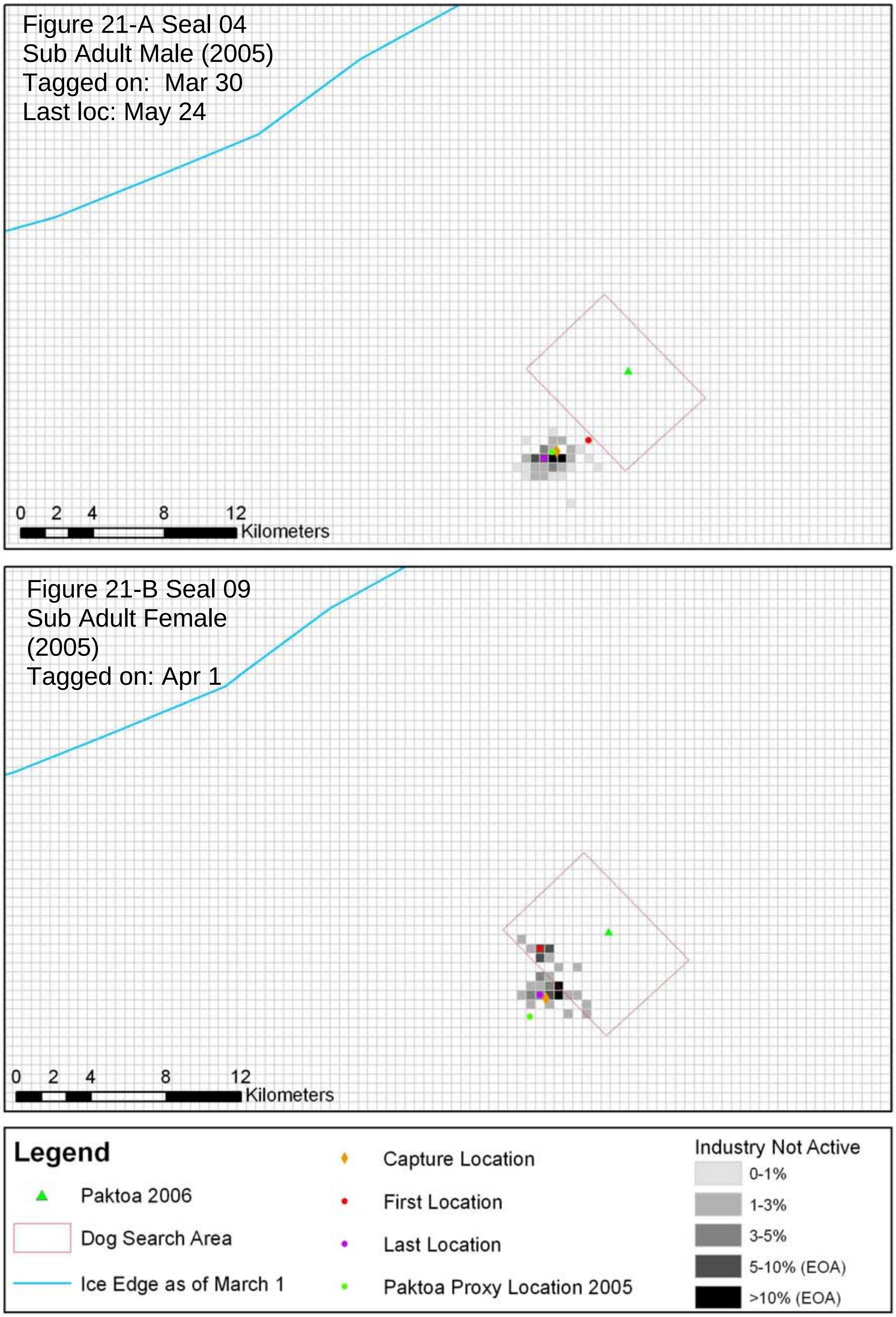


Figure 21 Movements of Sub-Adult ringed seals tagged in 2005

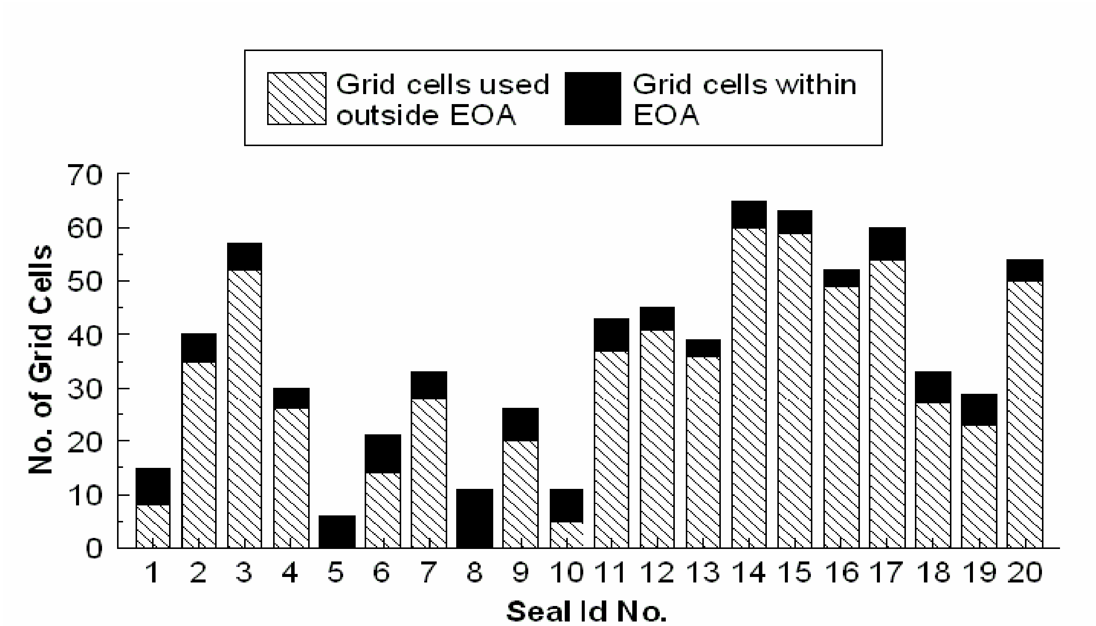


Figure 22 Number of grid cells used by tagged seals within (solid) and beyond (hatched) their EOA's for each tagged seal near Paktoa in spring 2003 (seal #1), 2004 (seal #2), 2005 (seals #3-#10) and 2006 (seals #11-#20).

Most adult males tagged in 2005 and 2006, and two sub-adults (both sexes) tagged in 2005, showed a similar pattern to the females, staying relatively close to the capture location following tagging and until the tags were shed in late May and early June (Figs. 17, 18, 20). One exception to this was seal #13 (Fig. 18-f), a relatively small tiggak male that moved to the north and northwest following tagging, and eventually toward the ice edge, as had been the case for a sub adult male tagged in 2003 (Fig. 19) and one adult female tagged in 2006.

The number of grid cells used by each seal during the transmission period ranged from 6-65 (15 km^2-163 km^2), averaging 36.7 cells, SD 17.7 (91.7 $\pm$ 44.2 km^2; Table 15). The frequency of transmissions from each grid cell was calculated, and all grid cells in which >5% of the transmitted locations occurred were designated as the EOA for that seal (Fig. 22). The size of the EOA ranged from 3 - 11 grid cells (7.5 km^2 - 27.5 km^2), averaging 5.5 cells (SD 1.7) (13.75 km^2) overall. The EOA's averaged 5.0 cells for females and 5.6 cells for males, and these and were not significantly different (Fig. 20) (T=2.11991, DF=16, p>0.05). Differences in the size of the EOA's among seals tagged in 2005 vs 2006 were also not significantly different (Mean 2005=6.25 cells, n=8; mean 2006 = 4.7 cells, n=10; T=2.11991, df=16, p>0.05).

In looking at the overall movements of seals outside of their EOA's, the total number of grid cells that were used by males and females was not statistically different (F=1.35, df=17, p>F=0.2629) between the sexes. However, the total number of grid cells used by both sexes was significantly different between years (F=12.15, df=17, p>F=0.0031). Seals used fewer grid cells overall in 2005 (mean = 24.6 cells) than in 2006 (mean= 48.3 cells) (Fig. 22).

Table 15. Essential operating areas (EOAs) of seals tagged near Paktoa and comparison of EOAs during active and inactive industry periods 2003-2006

Seal #	Year	Sex	Age class	Tagging date	Days with locations	Grid cell use during Overall deployment		Grid cell use during industry year (2006)			
								Industry active 20 March-8 April 2006		Industry not active 9-28 April 2006	
						Overall (no. of cells)	EOA (no. of cells)	total used	EOA	total used	EOA
1	2003	M	subadult	Apr-22	3	15	7				
2	2004	M	adult	Apr-27	39	40	5				
3	2005	F	adult	Mar-23	63	57	5				
4	2005	M	subadult	Mar-30	55	30	4				
5	2005	M	adult	Mar-30	4	6	6				
6	2005	M	adult	Mar-30	56	23	7				
7	2005	M	adult	Mar-31	61	33	5				
8	2005	M	adult	Mar-31	44	11	11				
9	2005	F	subadult	Apr-01	49	26	6				
10	2005	F	adult	Apr-03	35	11	6				
11	2006	M	adult	Mar-20	81	43	6	3	3	0	0
12	2006	M	adult	Mar-20	70	45	4	12	10	6	6
13	2006	M	adult	Mar-20	40	39	3	16	7	27	5
14	2006	M	adult	Mar-21	68	65	5	15	6	6	5
15	2006	F	adult	Mar-22	60	63	4	24	4	14	6
16	2006	F	adult	Mar-23	72	52	3	2	2	0	0
17	2006	F	adult	Mar-24	59	60	6	20	5	17	5
18	2006	M	adult	Mar-26	51	33	6	3	3	9	9
19	2006	M	adult	Mar-29	27	29	6	16	6	16	6
20	2006	M	adult	Mar-29	69	54	4	11	4	8	3
				Mean	50.3	36.8	5.5	12.2	5.0	10.3	4.5

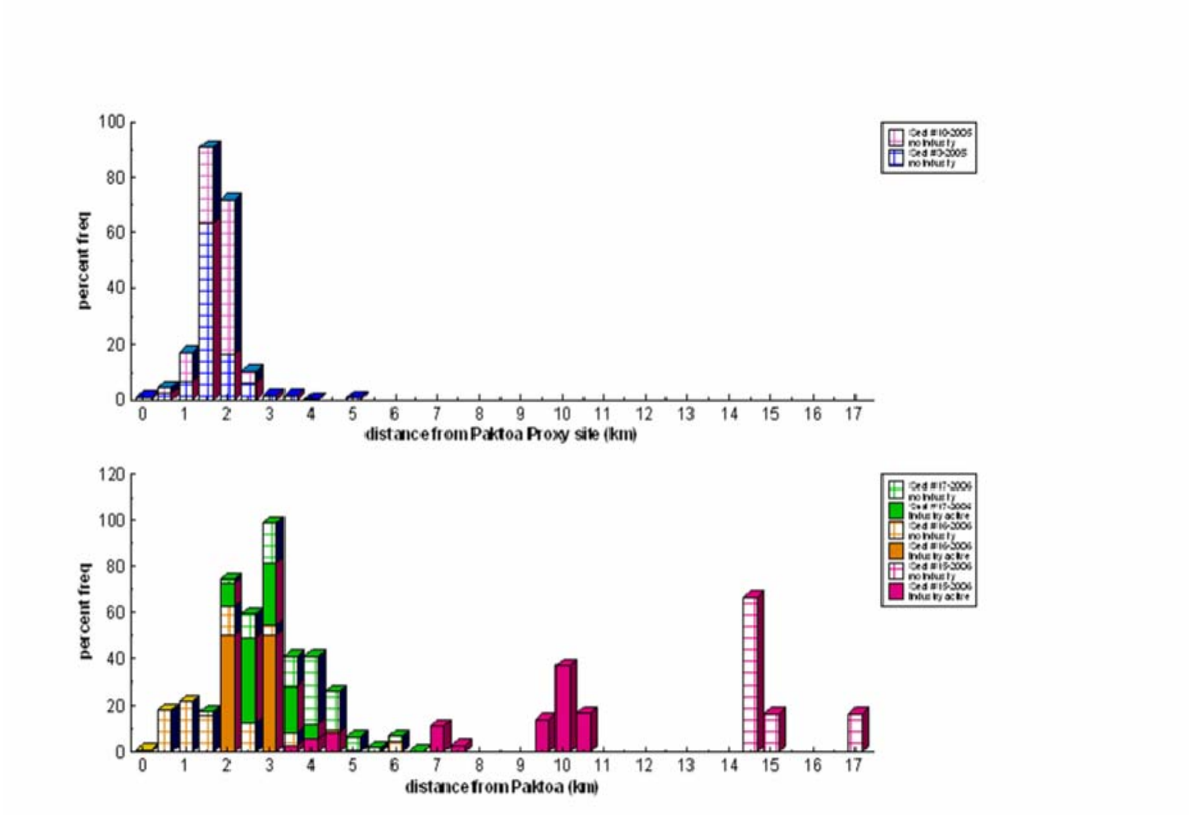


Figure 23 Distances of adult female seals tagged in spring 2005 and spring 2006 from the Paktoa proxy site (2005) and the Paktoa site (2006)

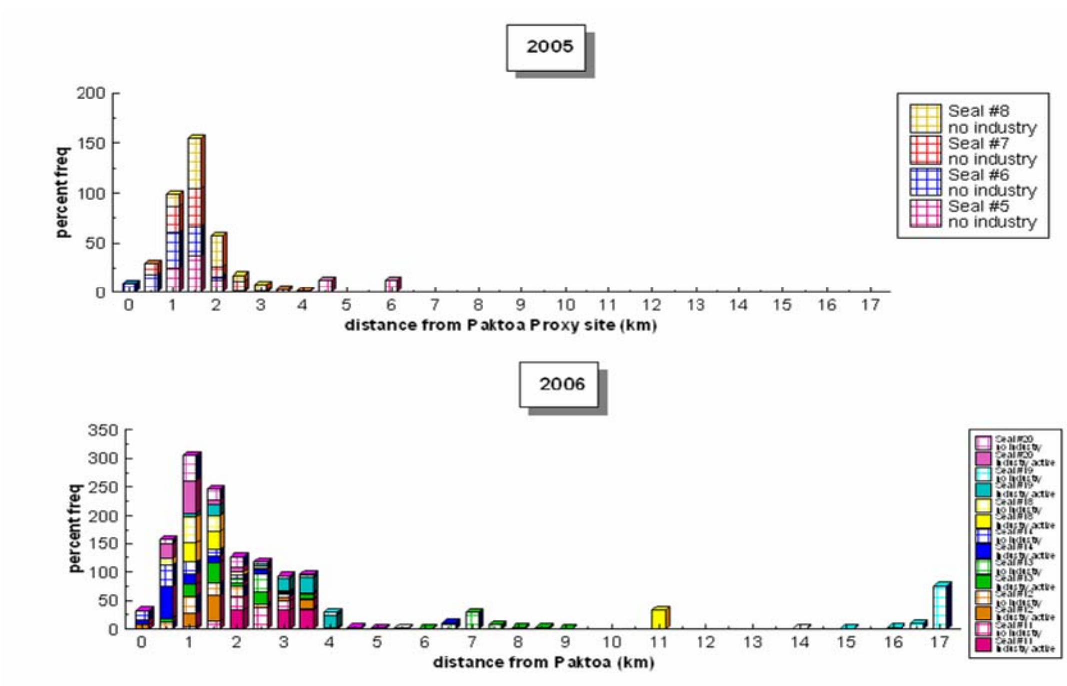


Figure 24 Distances of adult male ringed seals tagged in spring 2005 and spring 2006 from the Paktoa proxy site (2005) and the Paktoa site (2006**)**

Industry vs Non-Industry Comparisons

The distance from Paktoa (or Paktoa proxy in 2005) of all high quality locations received from adult female and male ringed seals tagged in 2005 and 2006 are shown on Figs. 23 and 24, respectively. The industry active period was shorter than the industry inactive period during the time that the tags were deployed. For this reason, subsequent analyses are based on only that portion of the industry inactive period (19 days) that corresponded in length to the industry active period (19 days). For 2006 alone, the size of the EOA of adult seals was compared for equivalent time for these two 19 day periods. There were no significant differences in the size of the EOA's overall for seals tagged in 2006, when comparing the active industry period (mean EOA size = 5.0 cells) to the inactive industry period (mean EOA size = 4.5 cells) (Chi-square = 8.33, df = 7, $0.10>p<0.25$) (Table 16). In contrast, the total number of all grid cells used by tagged seals in 2006 was statistically different between the 19 days industry was active, and the 19 days which followed (Chi-square 29.65, df = 7, $p<0.001$). We believe that the use of a larger area after industry activities were done was a reflection of their normal seasonal activity pattern, as was seen in 2003, 2004 and 2005 when no industry was present. Ringed seals are known to move further afield later in the season, as their activities change from breeding territory defence, through the time of lactation and care of their increasingly mobile neonates, to then begin using haul-out sites during the moult (Smith 1973, 1987).The mean distance from Paktoa of the locations of tagged seals in 2006 was calculated for the 19 days of industry activity that overlapped with our tag deployment (March 20-April 8, 2006) and for the 19 days immediately following when there was no industry activity at the Paktoa site (Fig. 25, Table 16).

Overall, the mean distances for both males and females were closer to Paktoa during the first 19 days (industry activity) than for the 19 days following. The mean distance from Paktoa was 2.9 km (SD 4.0 km) for adult males during the 19 day industry period and 8.1 km (SD 7km) during the 19 day industry inactive period which followed ($F=74.56$, $p>F<0.0001$, df=380). For adult females, the mean distance of received locations during the industry active period was 6.0 km (SD 4.3km) and 9.5 km (SD 7.7 km) during the 19 days which followed ($F=12.45$, $p>F=0.0006$, df=151). Interpretation of these data is complicated somewhat by individual variation but mostly by the relatively short duration of the industry exposure period that we were able to test. In addition, three of our tagged seals (seal #'s 13, 15, 19) initiated a typical pattern of migrating to the ice edge during the latter 19 day period, to distances of 9-19 km from Paktoa. While the data are variable, there were no clear patterns of avoidance of the Paktoa site during the period of industry activity that we were able to examine.

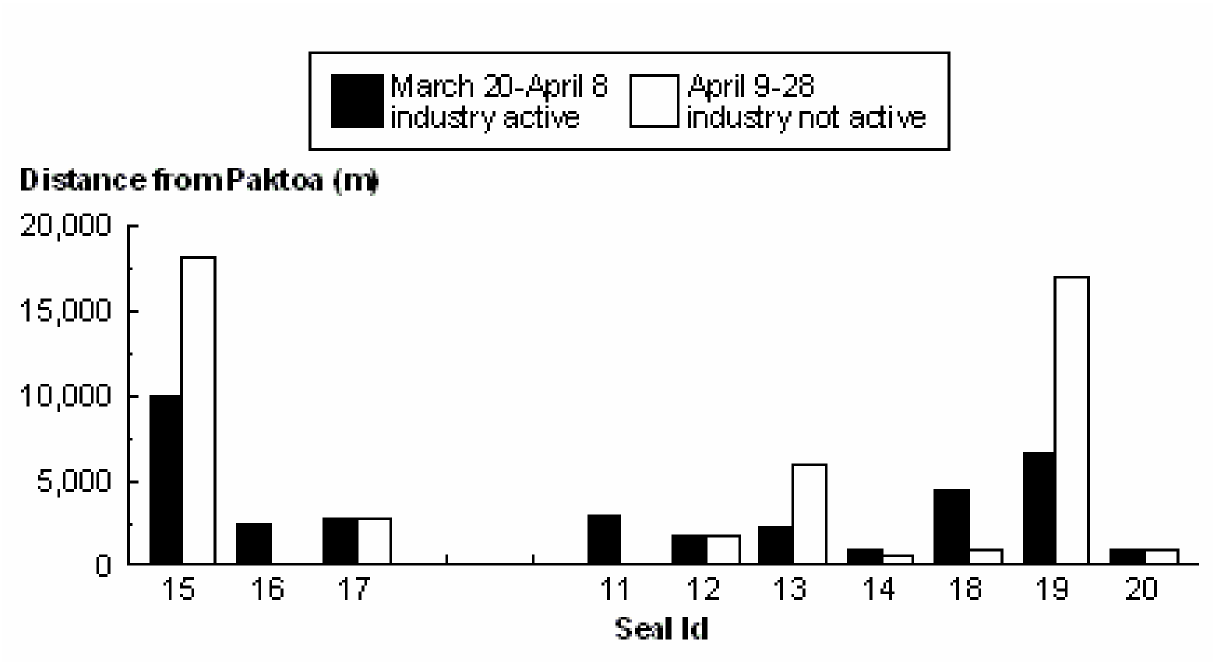


Figure 25 Distance of ringed seals tagged in 2006 from the Paktoa site during the 19d that industry was active at the site, and during the 19d immediately following that industry was not active at the site

Seal #	Sex (all adults)	Distance from Paktoa (m) during a 19 day active industry period: Locations n	Mean	S.D.	Minimum	Maximum	Distance from Paktoa (m) during a 19 day inactive industry period: Locations n	Mean	S.D.	Minimum	Maximum
11	male	3	2863	730	2027	3371	0				
12	male	13	1679	964	210	3482	7	1699	485	998	2237
13	male	37	2187	720	662	3430	65	5940	2290	1983	8806
14	male	36	936	1076	210	6401	26	522	316	210	1128
18	male	3	4504	5767	998	11160	16	864	298	320	1596
19	male	45	6549	6225	813	17830	76	17041	458	14886	18962
20	male	31	988	385	210	1855	24	977	308	457	1939
males overall[1]		168	2880	4054			214	8149	7045		
15	female	43	10001	3660	3722	18483	25	18272	514	16931	19164
16	female	2	2398	875	1780	3017	0				
17	female	50	2771	564	1373	4199	33	2839	456	2109	4172
females overall[2]		95	6035	4393			58	9491	7724		

[1] F=74.56, p>F<0.0001 for males pooled during industry active vs industry inactive periods
[2] F=12.45, p>F=0.0006 for females pooled during industry active vs industry inactive periods

Table 16. Distances of tagged seals from Paktoa during the 2006 active and inactive periods of industrial operations

Biological Sampling

In total, 68 ringed seals were collected from the sea ice, 38 females and 30 males (Table 17). Most (66/68) of these seals were adults (mean age 14.9 yr for females; mean age 14.6 yr for males), and 2 were sub-adults (aged 5 and 6 yr). There were no pups taken by harvesters in this collection. Seals were shot while basking by their breathing holes in the fast ice at locations shown on Fig. 6 in 2005 and 2006. Harvesters worked in the same general area for the 2004 collection, but specific kill locations were not available due to difficulties with the operation of the hand held GPS.

Overall, females had thicker blubber than males (females pooled mean = 5.1 cm, SD = 0.37 cm; males pooled mean 4.1 cm, SD 0.14 cm; Fig. 26). Blubber thickness (at the hip) of adult females was not significantly different among the years 2004, 2005 and 2006 for adult females ($F=1.49$, $p>F=0.2337$, $df=31$) or for adult males ($F=0.93$, $p>F=0.4643$, $df=24$) (Table 17).

The mean BMI's were significantly different among years ($F=4.75$, $p>F=0.0047$, $df=32$) for adult females, with the differences being attributed to higher mean values from the 2006 sample (Duncan's Multiple range test, $p=0.05$, $df=28$). Mean BMI was also significantly different among years for the adult males ($F=5.47$, $p>F=0.0042$, $df=23$), with the differences attributed to higher BMI's in 2005 and 2006, compared with 2004 (Duncan's Multiple range test, $p<0.05$, $df=19$) (Fig. 27). The ovulation rate of the adult females was similar and stable during the three years of this study, ranging from 78-83% between 2004 and 2006 (Fig. 28).

Of the 22 ringed seals collected in 2005, all had stomach contents while only 55% of the seals collected in 2006 had food in their stomachs. In both samples, most of the seals had only traces of invertebrates and/or fish in their stomachs (Table 18), although one seal in each year had a full stomach having just finished a meal. These large meals consisted of primarily isopods, with one other seal in 2005 having had a recent meal of mysids. Of those stomachs with identifiable contents (n=17 in 2005; 17 in 2006), 59% had invertebrates only, 36% had both invertebrates and fish remains, and 6% had only fish remains. Invertebrates were represented by eight taxonomic groups, with isopods (78.1%) and amphipods (9.1%) predominating (Table 18).

	Devon lease areas (Tuktoyaktuk) ringed seal collection								
						Adult females		Adult Males	
Sample year	Collection period	Sample size	Mean age of sample (range)	% females in sample	Ovulation rate (%)	Mean BMI**	Mean blubber thickness at hip (cm)	Mean BMI**	Mean blubber thickness at hip (cm)
2004	May 28-31,	13	14.5 (9-21)	61.5	83.0	94.1	4.9	46.6*	4.0
2005	May 6-17, :	22	16.8 (6-26+)	59.1	80.0	92.5	5.0	54.4	4.3
2006	May 12-19,	33	13.4 (5-21+)	51.5	78.0	114.6*	5.6	57.7	4.1

* Statistically different from other years in sample p>0.05 (Duncan's Multiple Range test)
** BMI - exponent 2.76 for females; 1.92 for males as per Harwood *et al* 2000

Table 17 Sample size and sex ratio of seals collected from the south-eastern Beaufort Sea 2004-2006

Sample year	n	no. with contents	no. with identifiable contents	Wet weight (g) mean	Wet weight (g) min	Wet weight (g) max	Invertebrates only %	Fish & Invertebrates %	Fish only %
2005	22	22	17	28.7	0.358	196.1	41.2	47.6	11.7
2006	32	18	17	30	0.002	307.2	76.0	24.0	0.0
							58.6	**35.8**	**5.85**

Sample year	n	Percent occurrence of invertebrate classes							
		Isopoda	Mysidacea	Amphipoda	Nematoda	Arthropoda	Mollusca	Cumacea	Ostracoda
2005	22	74.0	18.1	3.5	3.5	0.4	0.0	0.4	0.4
2006	32	82.2	0.0	8.1	7.6	1.0	1.0	0.0	0.0
		78.1	**9.05**	**5.8**	**5.55**	**0.7**	**0.5**	**0.2**	**0.2**

Table 18 Summary of stomach contents of ringed seals collected from the sea ice off Tuktoyaktuk in May 2005 and 2006

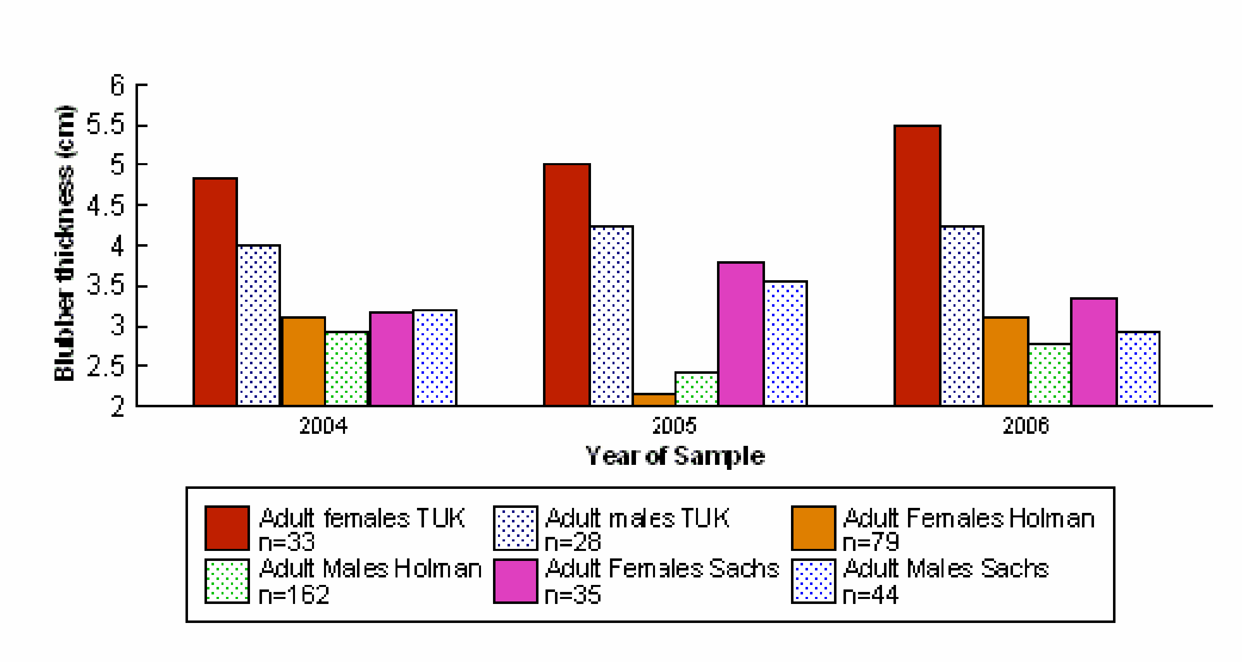


Figure 26 Mean blubber thickness at hip of ringed seals collected offshore of Tuktoyaktuk May 2004-2006, and in subsistence harvests at Sachs Harbour and Holman during the corresponding years but different seasons

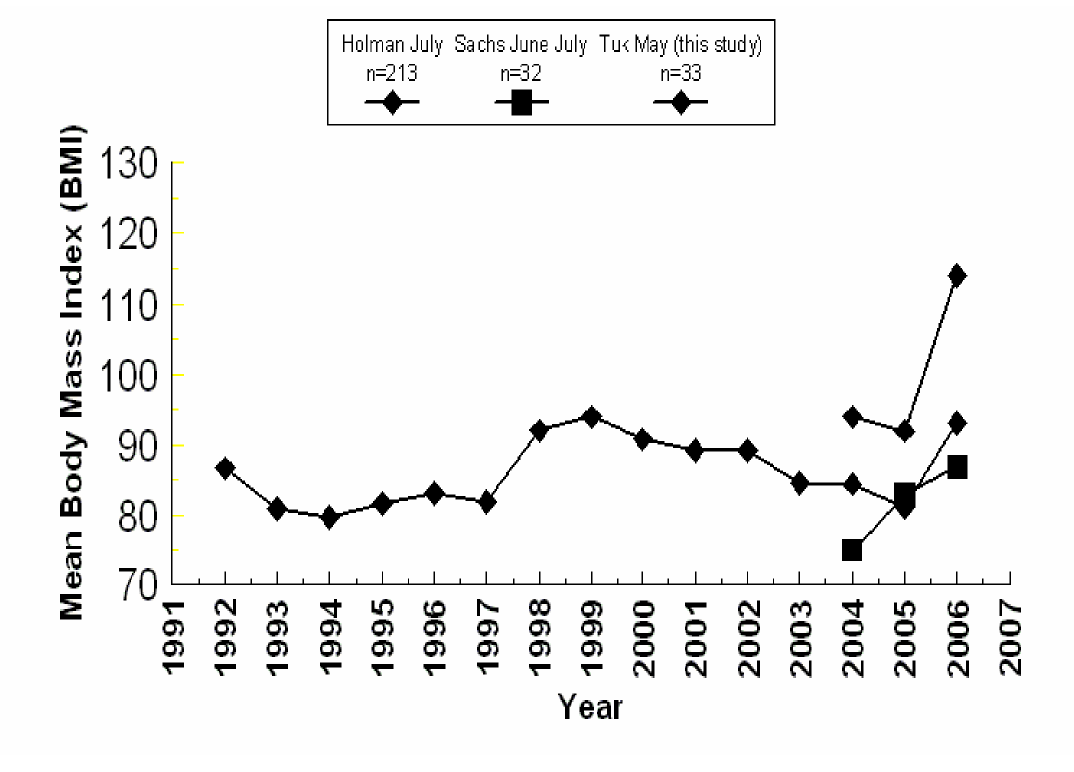


Figure 27 Mean body mass index of adult (age 7-20 yr) female ringed seals captured and released at Paktoa (2005-2006), collected offshore of Tuktoyaktuk (2004-2006)(this study), and from the subsistence harvests at Holman (1992-2006) and Sachs Harbour (2004-2006)

One newborn ringed seal pup was recovered 19 March 2006 from a birth lair at N69°38.951 W136°29.045 during the dog search and tagging work. A necropsy revealed that within the right frontal region of the skull, there were two small punctures and a short percutaneous laceration. The multiple bone fractures and acute haemorrhage are consistent with blunt force trauma, possibly inflicted by a predator or another seal. There was no digging, urine, scats or sign of tracks of predators found outside or in the lair. There were no other apparent, gross internal or external lesions. The pup had been born alive since it had ingested milk and the small intestine and colon contained a small amount of meconium (Laboratory report, Dr. Haulena, Case number 06/01977, BC Animal Health Center, Abbotsford, BC). It is probable that the pup was killed by an adult male ringed seal.

One seal, collected in 2006 (sample no. 2006-Tuk-06), was judged to be abnormally thin by the harvesters, and the carcass and tissues were examined by our collaborating veterinarian. Clinical and laboratory work did not reveal any pathogens or lesions in the tissues or carcass, and the underlying cause for the apparent poor condition of this animal (Case No. 06/02315, S. Raverty, pers. Comm.) is unknown.

Liver and fat samples from 30 of the seals collected in this study were sent to Mote Marine Laboratories for PAH analyses (Wetzel 2007). Results revealed that only three samples had detectable amounts of PAHs. They were ringed seal samples Tuk-05-01, Tuk-05-02 and Tuk-05-03. Although 37 PAHs were monitored, only the parent compound of naphthalene was detected in these three samples. As these were the first three seals sampled, the possibility that they were cross contaminated in the field cannot be ruled out. All other samples had no detectable levels of any PAHs (Wetzel 2007).

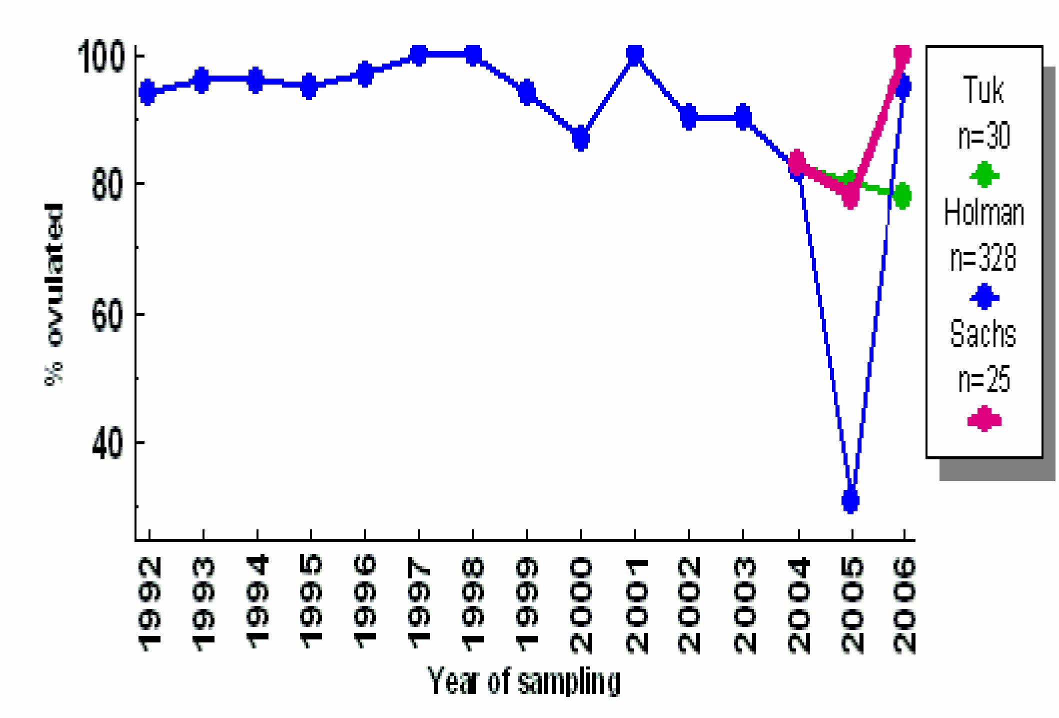


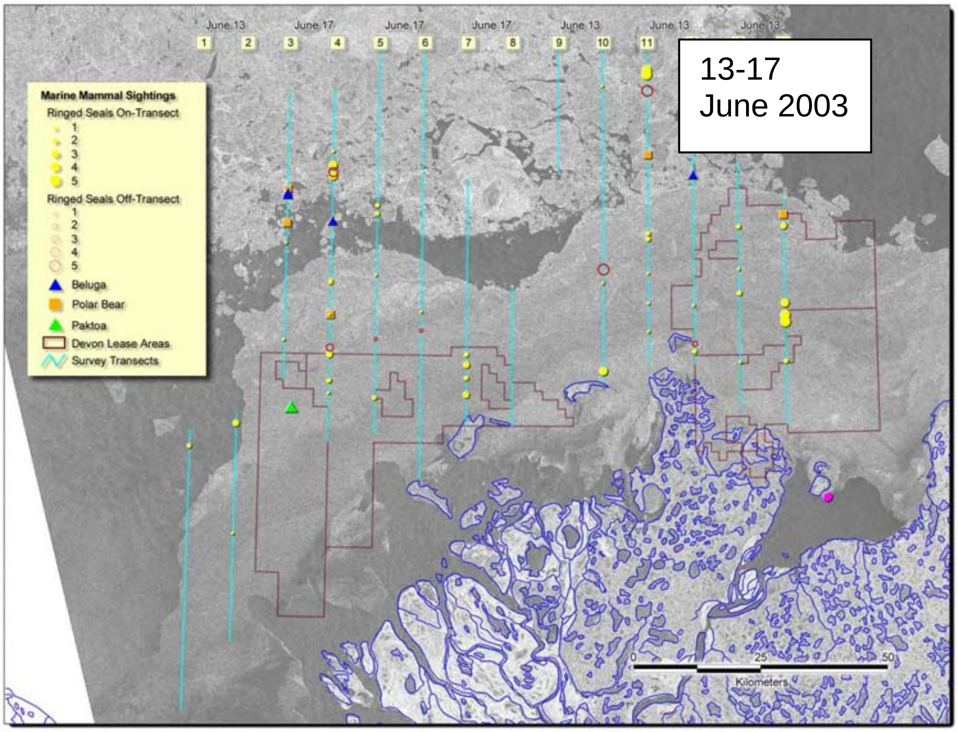
Figure 28 Proportion of mature adult female ringed seals that ovulated, Tuk (2004-2006) collection, and Sachs Harbour (2004-2006) and Holman (1992-2006) subsistence-harvested samples

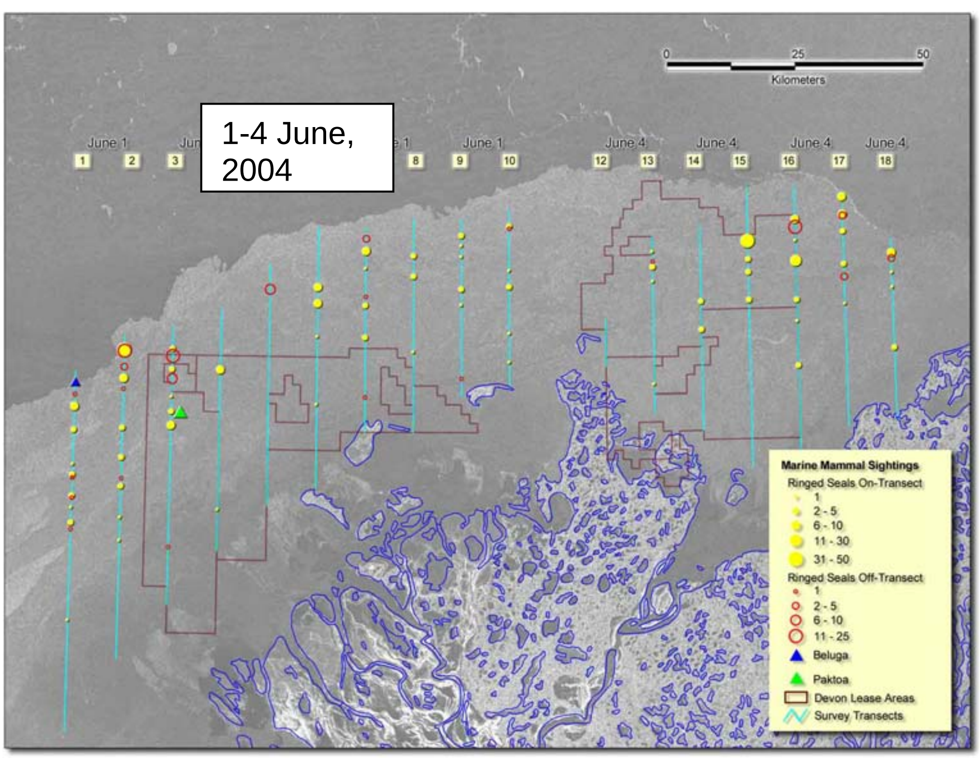
Aerial Surveys

In total, 3760 linear km were flown on-transect over the four years of the study, with primary observers counting a total of 909 ringed seals in 473 groups (on-transect), as well as seven bearded seals, 10 polar bears, one bowhead whale and 15 beluga whales. In addition, the remains of five seals killed by polar bears, nine collapsed ringed seal lairs (2004 and 2006 only), and 79 sets of polar bear tracks were also seen during the surveys (Table 19) (Fig. 29).

Conditions during the 2004, 2005 and 2006 surveys were excellent, as all flights were conducted during periods of clear skies, moderate to light winds, and excellent

Figure 29 The distribution of ringed seals and other marine mammals sighted during systematic aerial surveys for basking ringed seals in the SE Beaufort Sea/Devon License areas, late spring 2003-2006





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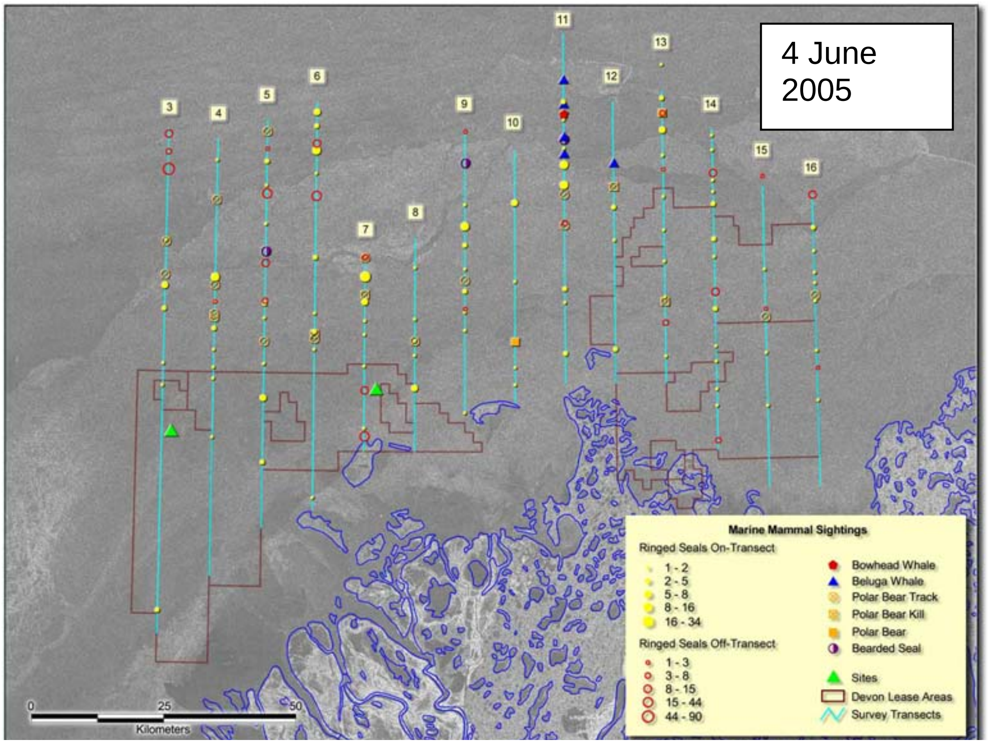

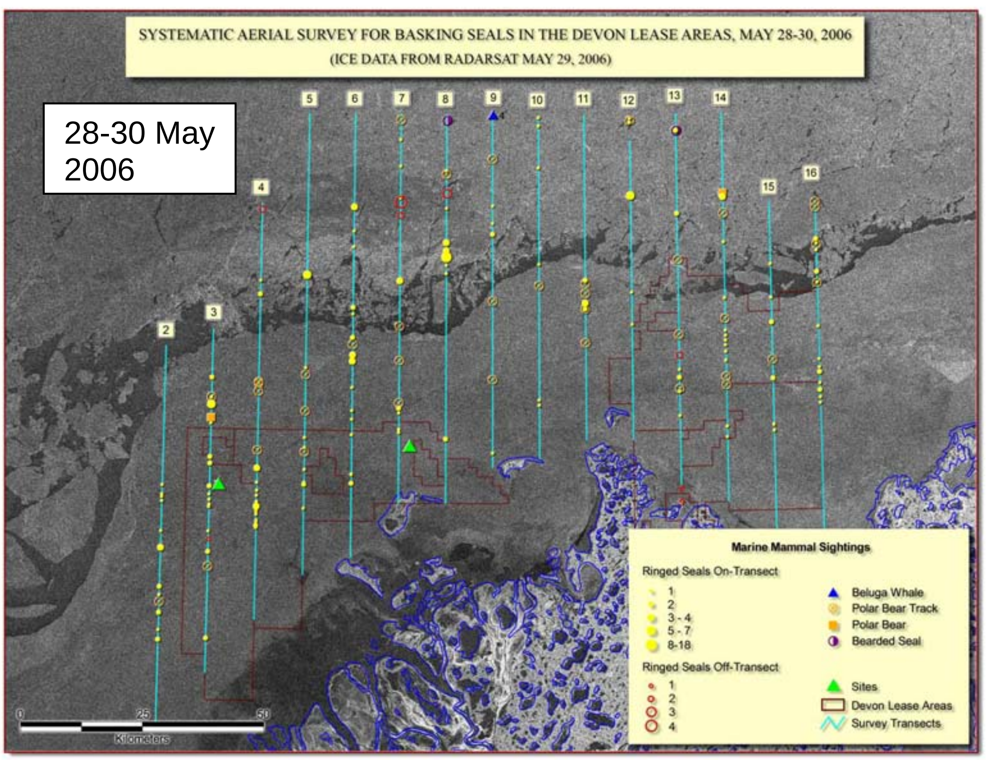

visibility. These surveys were also completed without interruptions in temporal or spatial survey coverage (Table 19). Survey conditions and circumstances in 2003 were less favourable, owing to low cloud ceilings, localized fog, high winds, and intermittent visibility. In addition, the 2003 survey was flown 1-2 weeks later in the season than surveys in 2004, 2005 and 2006. During the 2003 survey itself, the only two flying days possible were separated temporally by four days, and this introduced a further bias due to temporal gaps in coverage, which was not a problem in the other survey years. For these reasons, a quantitative comparison of the 2003 results to the other years in terms of assessing effects was not valid. For most analyses we have focussed on the results from 2004, 2005 and 2006, although the 2003 results do provide a view as to the distribution of seals only days before the ice had completely disappeared.

Ringed seals were the most numerous marine mammal sighted during the surveys, with densities that ranged from a low of 13.0/100 km^2 in 2003, to a high of 42.4 /100 km^2 in 2004 (Table 19). The density of seals in the overall survey area was not statistically different between the 2004, 2005 and 2006 surveys (ANOVA, F=2.46, df=335, p>F>0.0871; Duncan's Multiple Range test, p>0.05).

Seals were widely distributed throughout the survey area over water depths >2m, and were observed basking at their breathing holes or along the edges of cracks (Fig. 29). The proportion of those grid cells surveyed in which seals were spotted ranged from 31% in 2003 to 64% in 2005, and overall averaged 48%. Seals were observed mainly as individuals (66.2%) or in pairs (17.6% of groups), with only 24 groups (5.1% of total groups seen) consisting of more than 5 seals. Group sizes (groups larger than 5 seals pooled) did not differ statistically among years (Chi-square = 18.5, df=15, p=0.2386).

There was a clear relationship between distance from the ice edge and ringed seal density in all years but 2003 (F=0.09, df=97,p>F=0.7600), with densities declining at increasing distance from the ice edge in 2004 (F=11.18, df=97, p>F=0.0012) and in 2005 (F=6.77, df=104, p>F=0.0106) (Fig. 30; Table 20). The same trend was apparent in 2006, although the relationship was not statistically significant (F=2.67, df=132, p>F=0.1045).

Table 19 Summary of ringed seal and other marine mammals sightings during aerial surveys for basking seals, 2003-2006

	Ringed Seals												
	2003			2004			2005			2006			TOTAL
	west	east	overall	west	east	overall	west	east	overall	west	east	overall	all years
No. grid cells surveyed	61	37	98	56	42	98	56	49	105	75	58	133	434
Km^2 surveyed	316	250	566	380	277	657	389	336	725	528	397	925	2873
No. ringed seals on transect	36	38	74	181	126	307	183	108	291	162	75	237	909
Ringed seal density (no. /100 km^2)	11.9	14.8	13.0	43.6	40.7	42.4	44.4	29.9	37.6	29.2	18.4	24.4	

	Other Marine Mammals (no. sighted)												
	2003			2004			2005			2006			TOTAL
	west	east	overall	west	east	overall	west	east	overall	west	east	overall	all years
Bearded Seal	1	1	2	0	0	0	2	1	3	1	1	2	7
Polar Bear	4	2	6	0	0	0	0	2	2	1	1	2	10
Polar Bear tracks	15	3	18	7	2	9	12	4	16	18	18	36	79
Seal killed by Polar bear	1	0	1	0	0	0	2	2	4	0	0	0	5
Beluga	5	1	6	0	0	0	0	9	9	0	0	0	15
Bowhead	0	0	0	0	0	0	0	1	1	0	0	0	1

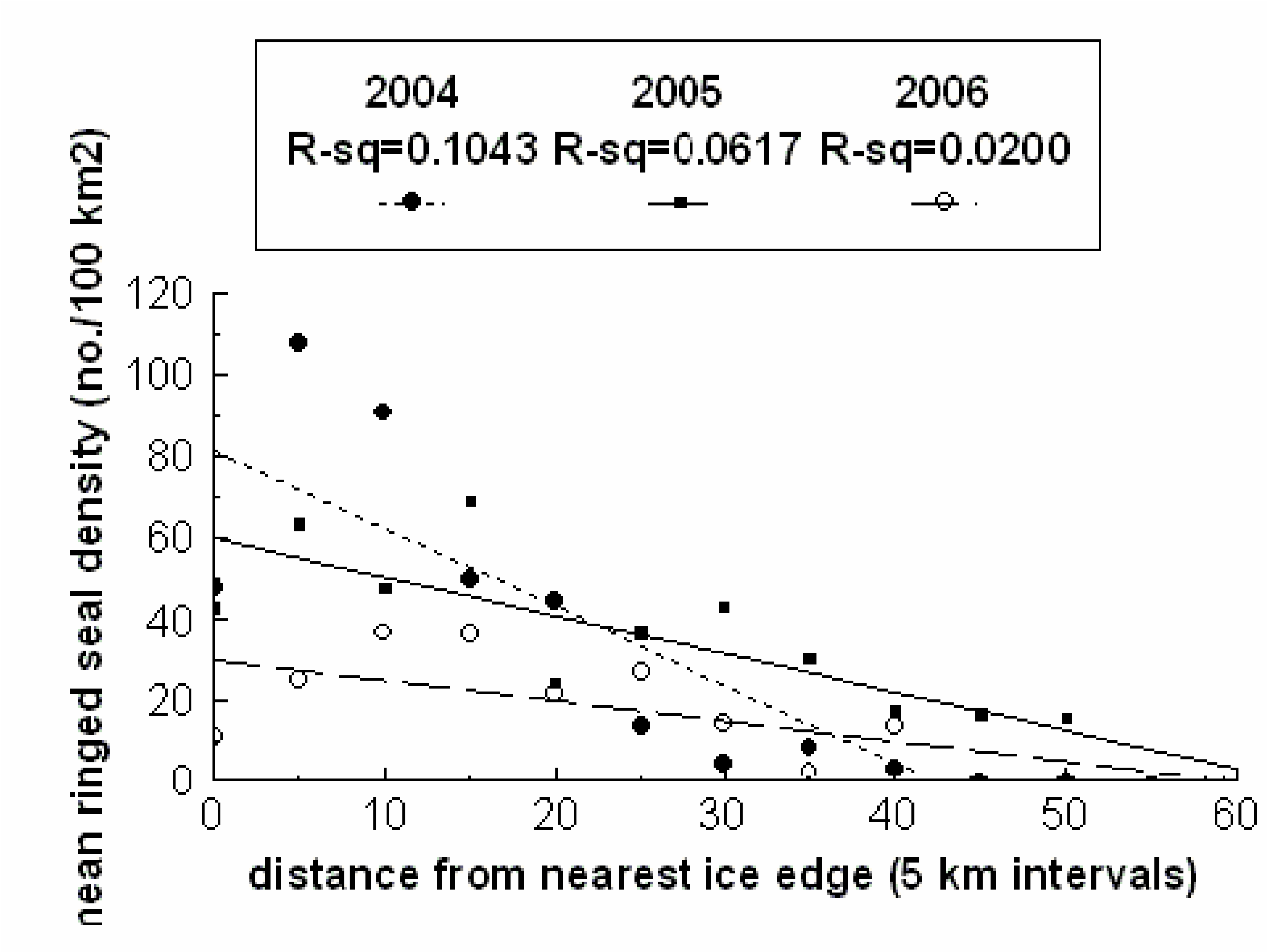

Figure 30 Distance from nearest ice edge and mean ringed seal density during aerial surveys flown in late spring 2004, 2005, 2006

For the WEST stratum, seal densities appeared to increase with increasing distances from Paktoa in 2004 and 2005, although there was no industry activity at the site at the time. This was the case in 2004 (F=5.17, df=55, p>F=0.0270, R-square 0.0874) and 2005 (F=4.70, df=55, p>F=0.0345, R-square 0.0801) (Table 20). There was no significant statistical relationship between basking seal densities and distance from the Paktoa site in 2006 (F=1.90, df=74, p>F=0.1728, R-square=0.0253).

	2003				2004				2005				2006			
	mean	**SD**	**min**	**max**	**mean**	**SD**	**min**	**max**	**mean**	**SD**	**min**	**max**	**mean**	**SD**	**min**	**max**
Distance from Paktoa (km)																
overall	63.3	35.2	10.5	111.0	70.3	48.0	3.2	148.1	69.1	36.3	6.1	132.0	70.0	40.8	3.2	135.1
west	29.0	13.1	10.5	53.4	30.8	18.3	3.2	66.8	40.2	18.0	6.1	71.9	37.0	22.4	3.2	80.6
east	93.4	13.6	68.0	111.0	115.2	26.1	68.0	148.1	102.7	18.7	68.0	132.0	108.2	16.2	69.2	135.1
Distance from ice edge*(km)																
overall	16.7	8.5	3.1	34.0	16.1	10.8	0.2	39.3	21.8	13.4	0.4	50.3	16.3	9.6	0.2	37.7
west	12.6	7.1	3.1	23.8	17.6	10.9	2.1	39.3	23.2	14.5	1.6	50.3	17.4	9.1	1.9	35.9
east	20.3	8.2	6.9	34.0	14.4	10.7	0.2	38.9	20.1	12.2	0.4	45.4	15.1	10.1	0.2	37.7

* km from ice edge on 1 June of that year

Table 20 Summary of distances of cells with basking seals from Paktoa and from the ice edge, 2003-2006

Year of study	Date of survey	Ringed seal density (seals/km^2) Western blocks	Eastern blocks	Overall density	Survey conditions
1974 [1]	June 19-20	44.6	65.9	50.8	
1975 [1]	June 12-16	5.9	2.2	4.8	
1976 [1]	June 17-21	16.8	22.8	18.5	
1977 [1]	June 13-14	5.8	1.3	4.5	
1978 [1]	June 13-16	22.8	18.2	21.4	
1979 [1]	June 16-18	8.6	7.6	8.3	
2003 [4]	June 13 & 17	11.9	14.8	13.0	fair[2]
2004	June 1-4	43.6	40.7	42.4	excellent[3]
2005	June 4	44.4	29.9	37.6	excellent[3]
2006	May 28-30	29.2	18.4	24.4	excellent[3]

[1] data for 1974-1979 provided by Canadian Wildlife Service for their corresponding areas (lines 16, 18, 20, 21, 24-27, 31, 34, 35) flown in 1974-1979 (complete data set published in Kingsley et al. 1982).

[2] fair - low ceilings, cool temps, moderate winds

[3] excellent - light or calm winds; clear skies; no fog or cloud obstruction; relatively warm tem

[4] ice melting quickly at time of survey

Table 21 Comparison of ringed seal densities from systematic aerial surveys between 1974-1979 and 2003-2006

DISCUSSION

Subnivean Ringed Seal Structures

The Paktoa study area site of the 2006 hydrocarbon exploration drilling activity is located where the fast ice platform is subject to great variability within and between years. During the four years of our study we have witnessed great variability in the dates of ice freeze-up and break-up as well as a highly variable surface topography of the sea ice surface.

There is no indication that the presence of industrial activities in 2006 had any measurable effect on either the distribution or overall densities of the ringed seal structures. It is important to note that our understanding of the natural and highly variable factors impinging on the winter sea ice breeding habitat is still very limited. From our short study it is, however, obvious that ringed seals can adapt to vastly changing sea ice conditions.

The surface topography, itself difficult to characterize even in a small 48 km^2 study plot, is of obvious importance in the distribution and density of ringed seal structures. This combined with the accumulation of snow, depending in turn on precipitation and the date of ice consolidation, are the two most influential factors on the distribution of the subnivean structures.

The higher number of birth lairs in 2003 is likely explained by greater availability of drifts formed along low pressure ridges. This allowed a better opportunity for individual pregnant seals to construct more than one birth lair. These have been previously described as birth lair complexes, which are usually found in areas of stable sea ice such as in bays, or along complex coastlines (Smith and Stirling 1975, 1978; Smith 1987). The year 2003 also had the greatest number of days of stable sea ice (90, Table 3) prior to the surveys. This, combined with the later date of the surveys (from 10 April), which coincides with the peak of the birthing season, usually around 15 April at this latitude (Smith 1987), largely accounts for the higher birth lair densities in 2003.

The 2004 survey was conducted much earlier, from 28 February to 14 March. This timing was prior to, or during the very the beginning, of the birth period. Although the ice platform had been stable for 84 days prior to the detection dog surveys that year, the timing of the study would almost certainly account for the lower overall densities of birth lairs compared with 2003.

The year 2005 was exceptional in the roughness of the sea ice caused by a severe storm in early January. In the small areas we were able to survey using the transect approach, we found comparable densities of seal structure and birth lairs to the other years. Both the date of freeze-up (75 days before the survey) and the survey period (22 March to 4 April) were appropriate for the construction and presence of seal structures including potential birth lairs. Surprisingly the densities obtained from the transect surveys did not appear to be inflated by the lack of smoother, presumably more favourable ice, in the greater area.

The high density of 4.57 seal structures/km², found in the repeated searches of area A in 2005, are similar to those of Hammill and Smith (1990), which they determined to be in the range of 4.8 to 7.9/km² in Barrow Strait. They calculated that their estimates were within 10% of the actual seal structure density. Our estimate from this one area of repeated searches is 2.6 times those we obtained from the single coverage of the 500m transect dog surveys in all the years of our study. We might use this correction factor, with some caution, to estimate the actual density of seal structures in our study area. It is possible that it might be positively biased because of the limited amount of stable ice during the year 2005 although transect densities obtained in the immediate vicinity were not different than in the other years.

Although the density of total seal structures was similar to other years in 2006, there was a noticeably lower density of birth lairs. Both the early date of the surveys (ending March 30) and the short (23 days) tenure of the stable ice platform were major influencing factors. Breeding seals had occupied the area as evidenced by the high number of rutting male (tiggak) structures, which we found in the 2006 study plot. Since birth lairs (prior to pupping) are largely defined by their relatively larger size, which in turn relates to their age, we might have under reported their presence because they would have been classified by us as resting lairs. Our interpretation is that breeding females were fully present in 2006 (see also section on seals captured), but that the late date of ice stabilization had delayed the creation of suitable habitat (deep drifts of sufficiently hardened snow) in which they could make their birth lairs.

Also of note in 2006 is the much lower rate (10%) of naturally abandoned seal structures compared to the other years of the survey (24-26%). This also relates directly to the short tenure of stable ice platform in 2006 and is supported by the fact that the fast ice season was delayed. Other studies (Williams *et al* 2000) have shown that seals abandon structures throughout the winter; thus a greater number of such naturally abandoned structures are seen in winters with earlier freeze-up dates.

Evidence of polar bear predation was not high in any year of our study, and to our knowledge, bears did not come close to our immediate camp area. In 2005, we found no bear sign at all and only one track was seen west of our area. The rough ice might have kept bears from traveling through the area both because it was energetically costly and because their prey was difficult to hunt in these ice conditions.

Researchers working seaward of the rubble field reported polar bears were numerous at the edge of the fast ice in that year (I. Stirling, pers. Comm.). Factors such as the proximity of open water and flat ice adjacent to our study area such as occurred in 2003 and 2004 might make it more likely for bears to travel through our study area, which was the case, although still in low numbers. In 2006 the floe edge was 18-20 km to the north. Personnel aboard the SDC had sighted some animals during the freeze-up in late January when there was still open water near the rig.

Arctic foxes, potential predators of ringed seal pups in their lairs (Smith 1976), were found to be present in all but the year 2004, when the surveys were completed earlier (mid March) than in the other years. It was observed in 2005 and 2006 that Arctic foxes did not move into our offshore location before 1 April, which was a few weeks ahead of the peak timing of ringed seal pupping in this region (Smith 1987).

Satellite Tagging and Tracking

We were successful in the live capture, tagging and release of 20 ringed seals during the course of this study. All but three of the seals tagged were breeding adults, which corroborates the dog search findings that the study area was being used by mature animals and that Paktoa is located in a ringed seal breeding area. The time of year that they were tagged and monitored represents a short but critical period in their annual cycle, encompassing the pupping, breeding, and lactation periods, and the time that both males and females defend territories.

All of the seals that were captured were in excellent body condition, and all of the females were likely pregnant. The data return from the tags themselves was remarkable, with 56% of the locations received being accurate to within 1 km or less. This is in contrast to the proportion of locations with the same accuracy from our open water work (Harwood and Smith 2003), during which only 10.4-21.2% (average 16.1%) of the locations received were of this high quality. The greater return of high quality receptions during the ice work is believed to be the result of seals spending time hauled up on the sea ice/in their lairs, and thus affording longer transmission times to the satellites and less corruption of signals than can occur during a brief surfacing period when an animal is swimming in the open water. In all, 75% of our tags lasted from deployment through to being shed because of the spring moult. Our Inuvialuit technicians became skilled at the setting of traps, capture and handling of seals and the deployment of satellite tags. Capture equipment purchased as part of this project is available for future work.

In general, most of the tagged seals remained relatively close to the areas where they were tagged and we found that the size of the EOA's were small but relatively consistent among sexes and years. We also found that the size of the EOA's did not change whether or not industry was present, at least within the parameters of our study. The average size of the EOA's (14 km^2), reflects the typical patterns of seals establishing and maintaining relatively small territories (Kelly and Quakenbush 1990). The territories of males are mutually exclusive (Smith and Hammill 1981). The recapture of two tagged seals at the same or a neighbouring breathing hole or lair at which they were captured, demonstrated the tendency of the seals to stay within their established territories. The one male tiggak seal that was tagged in 2004 was resighted at the same hole by our Inuvialuit technicians, with the tag in place and visible, two days after tagging.

Seals moved beyond their EOA's, in all likelihood for foraging, and there were differences in the extent of their movements between 2005 and 2006. Seals moved further afield in 2006 than in 2005. We believe this may be related to, at least in part, the presence of the extensive surrounding rough ice fields which in 2005 might have either reduced their access to breathing holes or cracks used during their travel to foraging areas. However, a few of the seals tagged in 2005 did move into the rubble ice after they had been released (Smith and Harwood 2005), where they maintained breathing holes or lairs. Unfortunately we were unable to travel to these locations with our search dogs to examine the habitat they were using. Polar bears had difficulty in hunting seals occupying such sites in that same season (I. Stirling, pers.com.).

Only four of our tagged seals ventured any great distance from the vicinity of the tagging area, and did so during the latter parts of the tag deployment period. All of these animals moved in the same general direction and to the ice edge, and exhibited similar behaviour. This observation tallies with the results from the aerial survey, which showed how seals concentrate near the ice edge as spring progresses and once the basking begins (Fig. 29). There was no evidence that the tagged seals were avoiding the Paktoa site during the period of industry activity at the site.

Seal Collections

The seal collections done in May 2003, 2004 and 2005 revealed that the ringed seals adjacent to the Paktoa study area were actively feeding, were in good body condition, and showed a normal and consistent pattern of ovulation during all three years of the sampling. Seals handled at the tagging operations at the Paktoa site in all years showed the same trend, and were found to be in excellent body condition as were their counterparts collected in May 2005 and 2006.

This is interesting for a number of reasons, particularly relating to the year 2005. The seals were operating in that year within and adjacent to an extensive rubble field which appeared to restrict their foraging movements as evidenced by the satellite telemetry data. In contrast to the ringed seals, polar bears in the SE Beaufort at this same time were reportedly in poor condition (I. Stirling, pers.com.), possibly owing to difficulties accessing or hunting seals within this rubble field.

Although seasonal differences in the time of collection preclude a direct comparison of seal body condition indices between the seal collection from this study (collected in May) with those collected from the Uluhaktok area (collected in June/July), there are trends in each respective data set which are instructive. While body condition and blubber thickness of seals taken within or adjacent to the Devon license areas remained relatively consistent in all three years studied, this was not the case in the corresponding years in Uluhaktok (Fig. 26, 27, 28). There, significant downturns in 2003-2005 were documented in mean seal fatness, BMI's, ovulation rates and pup production, which showed a modest recovery in 2006 (Harwood, unpublished data). This pattern was not evident in 2005 in our Devon license area samples, despite the fact the ice conditions were extreme in that year. This underscores the variability to which the seals are exposed, and to which they can adapt. It also suggests that the habitat, albeit variable, offshore of the Mackenzie Delta does provides good feeding opportunities for seals.

Food can be contaminated by environmental PAH's that are present in air (by deposition), soil (by transfer) or water (by deposition and transfer), and during processing and cooking. The natural and anthropogenic sources of PAH's in the environment are numerous and include natural seeps, processing of coal, crude oil, petroleum, natural gas, production of aluminum, iron and steel, heating in power plants and homes (oil, gas, charcoal-fired stoves, wood stoves), burning of refuse, wood fires, and motor vehicle exhausts (Wetzel 2007).

Overall, the body burdens of PAH contamination in this study were very low and the only PAH's found in the tissues was from the highly soluble naphthalene (Wetzel 2007). The highest levels were found in only 10% of our test subjects' blubber, and even those levels may have been due to cross contamination and were less than the levels found to produce some effects on rats (USEPA 1998). Therefore, it appears that there is likely no PAH risk associated with the consumption of the marine mammal blubber based upon the samples taken and analyzed during this study.

Aerial Surveys

Survey conditions in 2004, 2005 and 2006 were excellent and similar among the different years of the survey. These surveys were conducted over 1-2 days with no interruptions in spatial or temporal coverage. The evidence of collapsed lairs in 2004 and 2006 suggest that those surveys were particularly well timed, being in late May or early June, as this is the time when most seals are expected to be hauled up, visible and not concealed in their lairs (Kelly et al 2005).

Surveys flown in 2003 in mid June were conducted too late in the season. Interestingly, the survey dates in 2003 were originally selected to correspond to the survey dates flown in 1974-1979 for basking seals in this region (Stirling *et al* 1982) (Table 21). Thirty years later, it appears that earlier break up has led to basking periods for seals of 1-2 weeks earlier in the season than was the case during surveys flown in the 1970's (Stirling *et al* 1982).

The density of basking seals on-transect were not different among 2004-2006, with 2003 being the only year when densities were lower and this likely related to the later timing of the survey. Seals were widely distributed throughout the survey area, seen on most transects, usually in pairs or small groups. The density of basking seals revealed by these basking surveys was 10 fold less than the density of seals seen in dense offshore feeding aggregations in the open water period (Harwood and Stirling 1992).

Throughout the study area, we found a positive relationship with the density of basking seals and proximity to the ice edge. In contrast, there was no apparent relationship between the Paktoa site and the density of ringed seals in the WEST stratum, in any year including the 2006 year when industry was active. Polar bears and polar bear tracks were numerous and observed in all surveys, and were usually sighted in the same general areas where seals were seen. Evidence of seals killed by polar bears was also observed by aerial observers once during the 2003 survey, and four times during the 2005 survey. Beluga whales and one bowhead whale, seasonal migrants to the Beaufort, were seen in open water in leads at the end of some transects, presumably having just arrived from their spring migration from the Bering /Chukchi Seas (Harwood and Smith 2002).

Bearded seals were sighted during the aerial surveys in all but 2004. Too few were sighted (9 in total) to make comparisons or analyses in regard to their distribution or potential effects of industry on them. It appears from the aerial survey results that bearded seals are not present and likely not breeding to any significant extent in the 6 x 8 km study block. Bearded seals are known to be very patchy in their distribution and are found late in the ice melt season along ice edges or in areas of pack ice concentration. It is not clear if they are in those areas all winter or if they move in during some seasonal migration. It is known that they are able to maintain breathing holes in fast ice areas and occupy those sites throughout the winter and during the spring as breeding locations (Cleator and Smith 1984, Cleator *et al* 1989). Invariably those same areas often contain significant food resources for them, such as sessile holothuroideans (sea cucumbers) or hyperbenthic prey such as decapods and isopods (Smith 1981). We found no evidence from the fast ice searches with detection dogs that bearded seals were present to any significant extent in the Paktoa area.

CONCLUSIONS

Areas of land fast ice in the near shore Beaufort Sea support ringed seals during the winter and through the spring pupping, mating, lactation and basking periods. The ice conditions in this area are highly variable and in some years especially challenging, but ringed seals in this area appear well adapted to survive, reproduce and thrive in this habitat.

1) ***The seal captures and biological collections as well as the analysis of the specimens in 2004, 2005 and 2006 revealed the seals in the near shore Beaufort Sea as having adequate fat reserves, normal reproductive rates and to be in good body condition.***

2) ***There were no detectable differences in the densities, distribution or status of subnivean seal structures between the pre-industry years (2003-2005) and those of 2006 when the SDC was in operation at Paktoa.***

3) ***In 2006 there were no obvious differences in the distances from the SDC, ice road, airstrip or our research camp for any of the ringed seal structures of any type, nor was there any indication of increased natural abandonment of lairs or holes compared to other years.***

4) ***The behaviour of tagged seals as shown by their location and movements also showed no significant changes when industry was present, although our study period was necessarily short owing to the difficulty of capturing and tagging seals during mid-winter. Adult seals remained close to the structures at which they were trapped and appeared to maintain their breeding territories (Smith and Hammill 1991, Kelly and Quakenbush 1990) as we would have expected in an undisturbed and pristine environment.***

5) ***Comparisons of the detailed movements of tagged seals in 2006 when industry was either active or shortly after operations had ceased also showed no discernable differences. They remained in their territories as would be expected at that time of the year, and the size of their EOA's did not vary despite different ice quality in 2005 and 2006 or the presence or absence of industry activities in 2006.***

6) ***Similarly, the aerial survey data also did not reveal differences in seal density during the basking period, between industry and non-industry study years. Hauled-up ringed seals were widely distributed during the aerial surveys, at densities that were similar among years, and similar to densities found in this area at the same time of year in the 1970's (Stirling et al 1982; Table 21).***

7) ***Collectively, the dog searches of the breeding habitat, the behavioural data from the satellite tagged seals, the aerial survey results and the data on body condition from the biological collections all support the conclusion that a single season of drilling a test well at Paktoa did not have a detectable influence on ringed seals near the drilling site.***

We caution that the short period of industrial activity (19 days) during which we monitored the behaviour of ten tagged ringed seals is not a robust sample upon which to make firm conclusions. We cannot definitely state with our present knowledge that the lack of abandonment of subnivean structures, or lack of movement away by tagged seals from the proximity of industrial activities indicates that there would be no adverse effect, particularly if future industrial activities become permanent and with significantly larger footprints and duration. The conclusions of this study should be verified and expanded through future studies during multi-year industry and drilling operations.

DESIGN RECOMMENDATIONS FOR FUTURE STUDIES OF THE RINGED SEAL IN SEA ICE HABITATS

The variable nature of the sea ice surface topography at a particular study site, combined with the annual differences of dates of freeze-up and break-up, and precipitation are the proximate factors controlling the distribution and densities of seal structures. Added to this is what appears to be a fairly constant seasonal effect related to the time of births and amount of time required to nurture a pup to weaning (Smith 1973, 1987: Hammill *et al* 1991). Taking this into account, points to the necessity of conducting seal breeding habitat surveys, at the same time each year, in order to obtain comparable results.

The most difficult aspect of studying the effect of industrial impacts is the design of the study area around the industrial exploration or development site. Intuitively, the design is based on attempting to measure disturbance as it relates to the distance from the industrial presence (Moulton *et al* 2003, Williams *et al* 2006). The size of the study area must be large enough because of the variable nature of the seal habitat, but small enough to be surveyed thoroughly. Our experience in the present study suggests that a 48 km^2 study plot (6 km x 8 km) can be covered once with survey dogs along transects of 500m in width during a 10 day survey period. This is adequate to get a comparative index of seal structure abundance and status around the industrial site.

Added to this is the need to survey a sub-area around the source of disturbance in order to set traps and tag seals for behavioural observations. This sub-area should be approximately half the size of the whole study area. In years with relatively stable ice conditions, free of mid winter storms, this should an adequate area to allow the capture and tagging of a sample of ten seals for satellite tracking. Additionally the intense and repetitive surveying of the seal tagging area, using a repeatable systematic transect search pattern (Hammill and Smith 1990), will yield an estimate of the actual seal density needed for both the analysis of seal behaviour in their breeding territories, as well as providing a correction factor to calculate actual densities for the larger study plot, or for the broader scale regional dog surveys. Our experience, with transect searches, intensive searches and trapping, indicates that a 20-25 day period is required to complete such a study in a 6 km x 8 km study area. Given that the mean seal pupping date is 15 April for this area (Smith 1987), studies should be planned to take place from approximately 25 March to 20 April to ensure the breeding season is covered.

Once a seal has been captured the maximum amount of information on its health status, reproductive condition, age and feeding strategies should be obtained by techniques that are minimally invasive in order to avoid any undue stress, which might compromise the normal behaviour once it has been released. Blood, fat and DNA samples as well as the standard morphometric measurements are all useful samples to those ends (Geraci and Smith 1975; Coltman et al 1998; Iverson et al 2003).

Should the study design include the recapture of tagged animals, which we have in this study seen to be feasible, labeled water could be injected in order to obtain direct measurements of the energy budgets of the seals during their breeding season (Fedak 2004; Lydersen et al 1992). This could be related to body condition of seals collected in the greater area and define the specific importance of the area as a feeding site.

NEW STUDIES FOR CONSIDERATION

There has been renewed interest in Arctic offshore industrial exploration and development in recent years. At this point, the level of activity at the few permanent drilling sites in Alaska and exploratory seismic or drilling projects in Canada has been low and the footprint of industry in the offshore relatively small or temporary. We can realistically anticipate that industrial activities of many kinds will increase in the future and from what we have learned during this project, make some practical comments about the limitations of our present conclusions and recommend means of improving future studies as they become necessary. We also realize that some of these studies are not directly related to the oil and gas industry, but would provide important baseline information for the future.

Because of highly variable sea ice conditions in the offshore areas where hydrocarbon exploration is slated to take place in the Beaufort Sea, the evaluation of the short and long term impacts of industrial activities on the ice inhabiting fauna is extremely difficult. Ringed seals, the subject of the present study, are the species of pinniped most closely adapted to living and breeding in areas covered by annual sea ice. The present study is one of the first to look in detail at ringed seals in a zone of fast ice that varies greatly in persistence, extent and quality of habitat from year to year and sometimes also in the same winter. It appears from our four year study that breeding ringed seals can adapt quickly to highly variable ice conditions, remain in good condition and breed successfully. During 2005, with its January storm causing extensive highly fractured ice fields with high pressure ridges and deep ice keels, we found ringed seals in good condition and breeding in the few areas of flat ice in which we were able to conduct our research. We do not, however, know how much good breeding habitat was lost that year or how this might have affected the overall recruitment of the ringed seal populations inhabiting the SE Beaufort Sea. We do not in fact know the extent to which ringed seals were able to use the extremely rough ice areas, Indications from the seals which we tagged in the flatter ice areas bounded by the large area of rubble ice led us to believe that breeding seals did not use those areas very much, making only the occasional foray into the rubble field. Some seals did live in this rough ice and it was observed that polar bears hunting in the heavily fractured ice zones were having low success in killing ringed seals, which were sheltered in lairs located under ice slabs. Bears appeared to not be feeding successfully in the spring of 2005 and were observed to be in poor body condition (I. Stirling CWS pers.com.).

More work with helicopter supported dog surveys, possibly in concert with polar bear surveys, and continuing studies using captured and tagged seals in such areas, would help us to further investigate how and if ringed seals use the rubble ice fields to any significant extent.

There is an increasing probability that this type of habitat will be more frequently seen in the future because of the trend of increasing storm events linked to climate change (Comiso 2006) and the importance of these areas to both seals and polar bears should be critically evaluated.

Much larger scale survey coverage combining breeding habitat surveys on the sea ice in areas chosen from remote ice imagery would be needed for an assessment of the annual recruitment to the ringed seal population. With an adequate sample size, extrapolations could then be made from remotely acquired ice imagery to obtain an annual index of ringed seal breeding success. Future studies aimed at monitoring ringed seal productivity on a regional scale should incorporate such a sampling design.

Prior to that, studies correlating the different sea ice habitat features, obtained from remote imagery (Barber and Richard 1992; Nichols 1999) to seal structure densities obtained from detection dog surveys would be needed as ground truthing.

There is also a requirement for standardization in the description of the habitat features in which seal structures are found, in areas of industry activity in particular. The characteristics of fast ice that represents desirable habitat for ringed seals are related to the thickness and strength of snow cover and to structures created via ice failure under stress (cracks, rafts, ridges, on various scales). Snow, drifts, rafts and ridges are features with scales of 1 to 10 m. At this scale these features are very challenging to measure and map over large areas via remote sensing.

The use of conventional aerial stereo photography is one possibility, provided that solar illumination is appropriate to provide surface contrast via shadows. New techniques that utilize airborne scanning lidar would be ideal, but costs are high. There is some potential in high resolution space borne optical scanning such as Quick Bird, (1 m resolution), with similar constraints regarding illumination and cloud obscuration. The resolution of existing airborne and space-born microwave sensors is inadequate.

Satellite tags deployed on seals provide a direct view of the animal's real- time behaviour and location. Only a small amount of information exists on the behaviour, feeding and mating strategies of ringed seals in their under- ice breeding habitat (Smith and Hammill 1991, Kelly and Quakenbush 1990, Wartzok *et al* 1992, Kelly and Wartzok 1996, Furgal *et al* 1996), and this study has provided important new insights into their activities in the offshore fast ice habitats. As found in this study, early studies attempting to assess the impact of industrial activities on ringed seal densities using aerial surveys failed to show significant impacts (Burns and Kelly 1982, Burns and Frost 1988) and recent aerial surveys have produced the same results (Moulton *et al* 2002). Studies, using detection dogs and tagged seals of the effect of disturbances from seismic surveys have shown a significant effect when seismic lines were within 150 m (Burns and Kelly 1982). It was however difficult to separate the effect of natural abandonment and the effect of the researchers themselves from the actual effect of the seismic surveys on the abandonment of seal structures. Later studies looking at the rate of structure abandonment with distance from a drilling island, showed that holes and lairs were abandoned and sometimes reoccupied throughout the winter and overall that no clear industrial effect could be discerned (Williams *et al* 2002; Williams *et al* 2006). Consistent with the findings of our study, seals studied in proximity to offshore industrial activities to date have not appeared to move away or react noticeably to either construction or drilling related noise, or the presence of vehicles on ice roads (Blackwell *et al* 2004).

Many impact studies produce ambiguous results because the reactions of the target species are either difficult to observe or their normal behaviour is poorly understood (Sutherland 1996). In order to get a finer resolution on such reactions for the ringed seal when it is hidden from view in its breeding habitat, we would need more accurate location or activity data than is possible with the conventional Argos satellite system. As we found in this study, breeding territories are mutually exclusive and not large (Smith and Hammill 1981, Smith 1987) and the satellite data used in our study has a resolution of <1 km.

> *In the future, ground augmented GPS tags (Telonics 1996) or electronic identity sensors placed in the seal structures, might provide the accuracy and additional data needed for more thorough investigation of impacts on the movements or territorial behaviour of ringed seals. Archival tags, cameras or remote transmitting devices attached to satellite tagged seals which could; 1) record the level of the disturbing stimulus (noise) at the animals location (Burgess et al 1998); 2) detect changes in the activity (e.g., heart rate) of the animal during different behaviours in the presence of a stressor (MacArthur et al 1983, Woakes et al 2006) will ultimately be the too*ls *with which to measure the reaction of seals to any source of possible disturbance.*

Such studies have been quite revealing and have pointed to the fact that wild animals usually react strongly to stimuli that either mimic or resemble direct threats from their natural predators. A number of studies have shown that they react very little to vehicles or industrial noise and often only in specific situations when their potential to evade the source is perceived to be blocked (MacArthur *et al* 1983, Sutherland 1996). Such studies, which directly asses the level of disturbance and the specific circumstances in which animals react to perceived threats, are immediately pertinent and will lead to practical approaches to effective mitigation of adverse impacts. These will be of increasing importance in the future when the cumulative effect of increasing industrial developments inevitably will impinge on formerly pristine environments such as the Arctic.

There is also mounting evidence that ringed seals are philopatric to specific fast ice areas (Smith and Hammill 1981; B. Kelly, University of Alaska pers. com.), which leads to the implication that local sub-populations of ringed seals might in fact exist and could be compromised by human impacts on their traditional fast ice breeding territories. This underscores the importance of further site-specific studies of the detailed behaviour of ringed seals, which are possibly returning residents of fast ice areas, when those habitats become subjected to various anthropogenic influences.

> *Further studies are needed to elucidate the extent and importance of philopatry in ringed seals. This could be addressed using genetic samples of shed shin and hair collected in the subnivean lairs and the re-sampling of those areas over several years. This would yield information on the identity of the individual seals and their faithfulness to their breeding sites. Combined with this, there should be the tagging of an adequate number of breeding adults with flipper tags that stay on for a full year or more. Added to this would be the capture and tagging of juvenile seals in the autumn as they move west out of the Eastern Beaufort (Smith et al 1973) on their annual migration towards the Chukchi and Bering seas (Smith 1987).*

Annual migratory movement towards the west is a well documented event in the life cycle of the ringed seal in this large region (Smith 1987, Harwood and Smith 2002), and has important implications in the management of those populations.

In addition to the ringed and few bearded seals present in the study area, their predators the arctic foxes and polar bears use this habitat. It appears that arctic foxes move out from the mainland into the areas where ringed seals are present around the end of March, which coincides with the beginning of ringed seal births. Arctic foxes in some areas have been shown to be important predators of ringed seal pups in their birth lairs and in peak years of fox abundance they kill as many as 60% of all pups born in an area (Smith 1976). Arctic foxes have a keen olfactory sense and are known to be attracted and to investigate camps and industrial sites that might provide them with an opportunity to feed. In some areas foxes have become nuisances and health risks because they are infected with rabies and special efforts have had to be taken to avoid attracting them and to reduce their numbers (Ballard *et al* 2001). The potential for attracting foxes and increasing their predation of ringed seal pups in the area adjacent to an industrial project has not yet been studied, but should be considered as a possible impact. The attraction of bears to the area is a concern both from a human safety perspective (Clark 2003)

> *It also relates to the possible increase of arctic fox and polar bear predation on breeding ringed seals. This aspect of increased predation has been little studied around offshore industrial sites (Stirling 1988) and should be further investigated.*

It appears that in the ice zone in which Paktoa was located, bears would be most frequently present during the period of early fast ice formation, which as we have seen, is highly variable in its timing. Years when the ice edge is closest to Paktoa, or when there is an area of smooth ice running from Paktoa to the floe edge, would be when the highest number of bears would be in the area. In such conditions bears travel and hunt the deformed ice zone at the edge of the keel anchored fast ice and the smooth newly formed fast ice. In two of the four years of our study, this feature was located at the northern boundary of our 6 km x 8 km study plot.

The possibility of spills of industrial contaminants or oil is always present during the construction or operation of offshore industrial projects (Christensen 1994, Anderson and Labelle 2000). The proximity of ringed seal lairs and breathing holes to the SDC (as close as 270 m in this study) indicates that even minor undetected leakages could have a direct effect on some of the seals in the vicinity of the drilling rig.

> *Some thought should be put towards formulating a plan for the periodic monitoring of water quality at reasonable distances around the industrial sites before, during and after termination of industrial activities in the ice covered period.*
>
> *Seals captured during impact studies close to offshore industrial projects or collected by Inuit hunters should also be sampled for both surface and systemic petroleum pollutants (Geraci and Smith 1976, Engelhardt et al 1977; Engelhardt 1983; Wetzel 2007). Special handling will be required when obtaining these samples to avoid compromising them with extraneous contaminants.*

MITIGATIVE MEASURES AND MONITORING

We have not detected any significant direct impacts of one season's drilling in the offshore fast ice on seals during this study. However, it is possible given our recently acquired knowledge of the density, distribution and habitat features related to the subnivean structures of ringed seals in this ringed seal breeding habitat, to make some practical recommendations for mitigation of possible direct industrial impacts in the future that could be associated with larger, longer or multiple operations. This relates specifically to any construction of roads, airstrips or clearing of snow covered areas around drilling rigs, which could destroy drifts or pressure ridges containing structures that are part of the ringed seal breeding territories. We now know that such structures can be created quite close to ice roads (Williams *et al* 2006) or to the drilling rigs, as we have seen in this study. These structures appear to be built initially by rutting adult males from mid February to early March prior to the arrival of adult females. The period from 15 February to the end of the suckling of pups around the 20 May would thus appear to be the most critical for breeding ringed seals, and it is also the time when industry can access the fast ice habitats and most readily operate equipment. Industry should therefore try to carry out any construction activities on the sea ice before 15 Feb if at all possible. We recognize that in years when the ice forms late such as in 2006, or years when there have been winter storms, such as in 2005, there will be delays in the timing of construction activities. Features which are attractive to seals such as ice hummocks and pressure ridges, that happen to be contained within an industrial area could be in short supply and be critical to the local breeding ringed seal stock.

1) These habitat features should be avoided if possible. If unavoidable, this could be done effectively by clearing the area using detection dogs and marking a buffer zone around the structures with stakes, prior to 15 Feb. Detection dog surveys along the proposed roads or construction sites prior to the removal of the snow could also be used to create a 150 m buffer zone around the important habitat features such as pressure ridges or stable ice with suitable ice hummocks containing seal structures.

It is almost impossible to avoid attracting predators. Subtle olfactory cues can be perceived at great distance by both arctic foxes and polar bears and smells other than food or waste will solicit their investigative response. Other than the usual precautions such as not burning garbage, and bagging and sealing waste and refuse in order to avoid having them actually feeding on it, little can be done effectively to avoid attracting bears and foxes to the area.

2) The most effective way to reduce the possible increased predation on seals by both bears and foxes and at the same time deal with the hazard of bears, is to patrol the area around industrial sites on a daily basis and in a repeatable and systematic manner.

This would provide the basis for a quantitative comparison of the conditions from one year to the next. Trained Inuvialuit wildlife monitors could be hired for this task. These monitors could also be trained for the job of collecting detailed information on the frequency and location of predator tracks, to characterize and describe the habitat and seal structures where they find digs and kills. They could also be trained in the collection of water samples and preservation of any biological remains (scats and carcasses) that they may encounter. The water samples, specimens and an annual report from these monitors could be provided by industry to the appropriate authorities (Fisheries and Oceans Canada or Canadian Wildlife Service) at the end of each season of operations.

Despite a small sample size, and challenging logistics associated with the collection of seals from the sea ice in May, the collections done as part of this study were valuable in assessing the health and status of the local seal population, and as a backdrop against which to interpret the results of the other more empirical aspects of this study. The finding that seals near to the Paktoa study area were in excellent body condition, and that reproduction was occurring at a normal rate despite variable ice conditions and the presence of industry, are significant findings of this study. When combined and interpreted with broader and longer data sets from other sampling programs in the Beaufort/Amundsen Gulf region (e.g. Kingsley and Byers 1998; Stirling *et al* 1982), we will be better prepared to evaluate the biological consequences and significance of perturbations on local seal populations.

3) To this end, continued seal sampling/collections by Inuvialuit hunters is viewed as a community-supported and particularly important way of monitoring the status of the seal populations and assessing present or future effects on seal fitness and reproduction. Future and continued sampling to build on the data base of seal condition and reproduction offshore of the Mackenzie Delta will well serve regulators, industry and the Inuvialuit in the coming years.

Aerial surveys conducted as part of this study provide a regional perspective, and are most suited to examine the long term, broad-scale trends in the use of the offshore Beaufort Sea by basking seals at the only time when the seals are visible on the ice surface. The method has limited usefulness in the assessment of site-specific impacts of industry on local seal populations. Results from aerial surveys are subject to variability in observation conditions which cannot be easily accounted for, and cannot be controlled. If repeated at intervals, and repeated using methods as consistent as possible with existing data bases (e.g. Table 21), they are useful in examining broad changes in the use of these habitats by seals over the long term (e.g. decades*).*

4) To support long-term monitoring, it is necessary to repeat the aerial surveys at 5-10 year intervals, to continue to build on this data base that has been developed over the past four decades on the use of the Beaufort Sea/Mackenzie Delta area by seals. This is an opportunity that should not be missed given the potential for increased industry activity, cumulative effects, and the combined and probable strong influence of climate change on the sea ice regime over the long term.

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