AERIAL SURVEY OF MINKE WHALES OFF EAST ANTARCTICA: REPORT ON 2009/10 SURVEY

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Abstract

A full-scale, double-platform aerial survey for Antarctic minke whales (*Balaenoptera bonaerensis*) was conducted in East Antarctica in the 2009/10 austral summer. The survey targeted polynyas within pack-ice between 93º and 113ºE between mid-December, 2009 and early February, 2010. The aim of the aerial survey was to collaborate with a concurrent IWC-SOWER voyage surveying north of the ice edge, and to collect environmental information to study the distribution of minke whales within pack-ice environments. The 2009/10 aerial survey was conducted in three phases: first phase repeated a survey design from the previous summer period, based in and around Vincennes Bay; the second phase moved survey effort over to the Shackleton Ice Shelf and the Davis Sea; and the final phase repeated the Vincennes Bay survey, but also extended transects around 40 nm north of the sea ice boundary. In total, 4,923 nm of effort was achieved, covering around 55,559 nm^2 of survey area. Across the entire survey period there were 24 on-effort sightings (34 individuals) of minke whales; 5 sightings (5 individuals) of 'like' minke whales; and 5 sightings (5 individuals) of minke whales observed off-effort. Other species sighted were killer whales, southern right whales, sperm whales, southern bottlenose whales and a number of sightings of unknown species.

Although no direct overlap in space and time was achieved between the aerial survey and the IWC-SOWER voyage, there was around 11,900 nm^2 overlap where both programmes surveyed within 14 days of each other.

Introduction

Progressing from a successful small-scale (or pilot) aerial survey focussing on Antarctic minke whales (*Balaenoptera bonaerensis*) in east Antarctica during the 2008/09 summer season (Kelly *et al.* (2009); SC/61/IA3)[1], another aerial survey, extended across a broader range of longitude (approximately 20º), was undertaken in the 2009/10 summer season. Including a a series of survey test flights flown near Casey station in the summer of 2007/08 (Kelly *et al.* (2008); SC/60/IA4), this was the third summer season in a row that aerial surveys for minke whales in east Antarctica were attempted/completed.

The aims of this large-scale aerial survey were the same as those reported for previous years (i.e., Hedley *et al.* (2007); SC/59/IA2). Debates concerning conventional line transect estimation methods aside, the Scientific Committee of the IWC has noted an apparent decline the abundance estimates for Antarctic minke whale between the second and third circumpolar IDCR/SOWER ship-based surveys. One theory, reported in Branch (2006; SC/58/IA4), suggests that changes in the ice edge boundary each year, and changes in the number of minke whales present in the pack-ice beyond this boundary, could be responsible for the differences in abundance estimates of whales in open water. In other words, could there be more minke whales within pack-ice (and open areas within pack-ice), where the research ships can't search? The aerial survey programme aims to estimate relative abundance of minke whales in pack-ice and also in adjacent open water to test this hypothesis. Our survey programme also aimed to collect environmental data along side whale distribution data in order to study pack-ice habitat relationships. In the 2009/10 summer season, the aerial survey programme was also able to collaborate with the IWC-SOWER voyage that was operating in open water to the north of the aerial survey study area.

[1] This small-scale aerial survey (using fixed-wing aircraft), involved a total on-effort length of 2,970 nm, covering an area of 17,668 nm^2, yielding sightings of approximately 76 individual Antarctic minke whales (another 27 individuals were of unknown species) (see Kelly *et al*. (2009; SC/61/IA3) for more details).

General study area

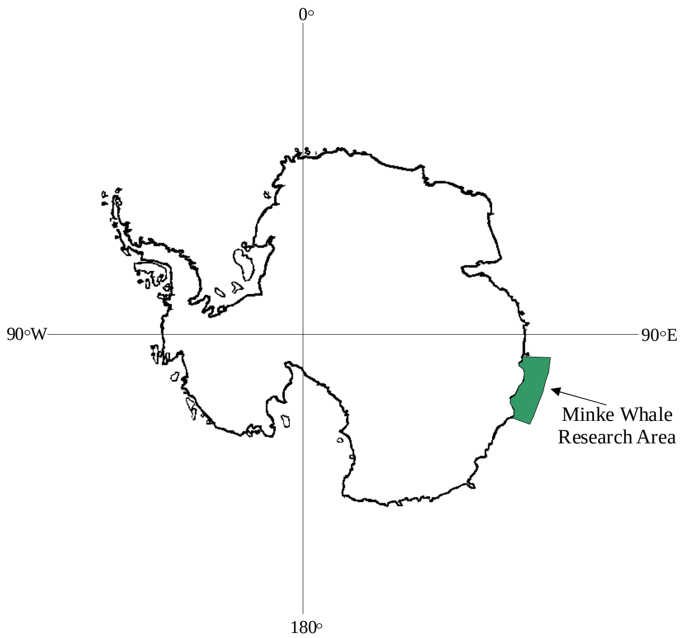

Figure 1 Aerial survey research area for 2009/10 summer season.

A number of factors, both operational/logistical and environmental, influenced the decision as to where to extend the 2009/10 survey area from that covered in the 2008/09 summer season. Operationally, the aerial survey was confined to operating from skiways with fuel depots. Within areas of coastline adjacent to the 2008/09 survey extent, this limited survey bases to two locations: Casey station (66° 16.32'S 110° 31.65'E) and a summer camp maintained by the Australian Antarctic Division at Bunger Hills (66° 10'S 100° 53'E), around 450 km west of Casey. So, in the 2009/10 summer the aerial survey programme targeted reliable polynya features between 93° and 113°E, see Figure 1.

In addition to two dominant polynya features—Vincennes Bay (66° 24'S 110° 18'E) and the Cape Poinsette polynya (65° 34'S 113° 38'E)—that the 2008/09 survey extent covered, expanding westwards to fly from Bunger Hills allowed the inclusion of two more polynyas: the Shackleton polynya (65° 16.8'S 104° 13.2'E) and the Davis Sea (near 64°S 100°E). In various IDCR/SOWER surveys (CPII and CPIII), a reasonable number of minke whales have been observed around the Shackleton Ice Shelf. Unfortunately, the IDCR/SOWER voyages have largely been denied access to the Davis Sea due to heavy sea ice conditions; the most recent attempt was the 2008/09 summer season (Ensor *et al.* 2009). During a multidisciplinary survey between 80° and 150°E (BROKE; Nicol *et al.* (2000)), very few whales of any species were observed in the east Davis Sea, although a spike in primary production was measured in the area (Strutton *et al.* 2000). Therefore, despite a lack of historical observations of whales in the area, a small amount of effort in the Davis Sea was justified.

From a logistical point-of-view it was also possible to extend the existing survey edge east from Casey station, north of Totten Glacier (67° 00'S 116° 20'E) and over towards 120°E. A reasonable density of minke whales sightings from a number of voyages have been observed east of 113°E (i.e., IDCR/SOWER and BROKE (Thiele *et al.* 2000)). However, this would have placed sections of the survey area inside and out of a gyre that circulates clockwise between 90° and 115°E (Bindoff *et al.* (2000); Nicol *et al.* (2000). As this is not desirable to survey across different water masses, the Cape Poinsette polynya remained the eastern boundary of the 2009/10 season aerial survey.

Survey design

The process of shifting the survey base from Casey station to Bunger Hills and back again created a series of natural divisions or phases in the planned survey progression. The first phase, henceforth referred to as CA1, began on 16 December, 2009 and ran until 27 December (on-schedule) and was a repeat of the aerial survey undertaken in Vincennes Bay in the 2008/09 season. The area for the CA1 phase is presented in Figure 2, along with the areas of the other two phases. As per the survey in 2008/09, transects were parallel and systematically spaced at 10 nm, and orientated north-south, see Figure 3. The planned total transect length for the CA1 phase was to be around 1905 nm (or around 35 hours of flying). The location of the western boundary of the CA1 survey area was based on aircraft flying range (approximately 600 nm). The location of the northern boundary was placed to include sea/pack ice north of the shelf break (1000m bathymetric contour), an area considered to be rich in Antarctic krill (Nicol *et al*. 2000). All of Vincennes Bay and the western half of the Cape Poinsett polynya were included in the CA1 area.

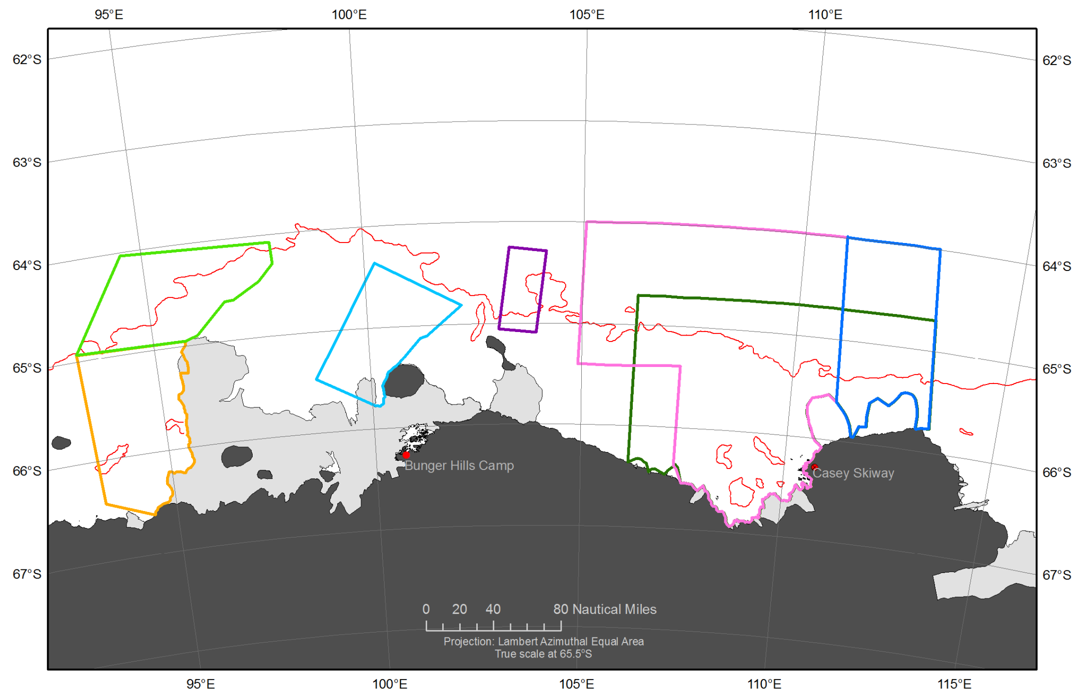

Figure 2 The single stratum of the CA1 phase (Vincennes Bay) is in dark green; strata within the BH1 phase (Shackleton Ice Shelf and Davis Sea) given in yellow, bright green, aqua and purple; strata within the CA2 phase (Vincennes Bay) given in pink and blue. Details of specific strata are given below in Figure 4. Continuous red line is the 1000m bathymetric contour.

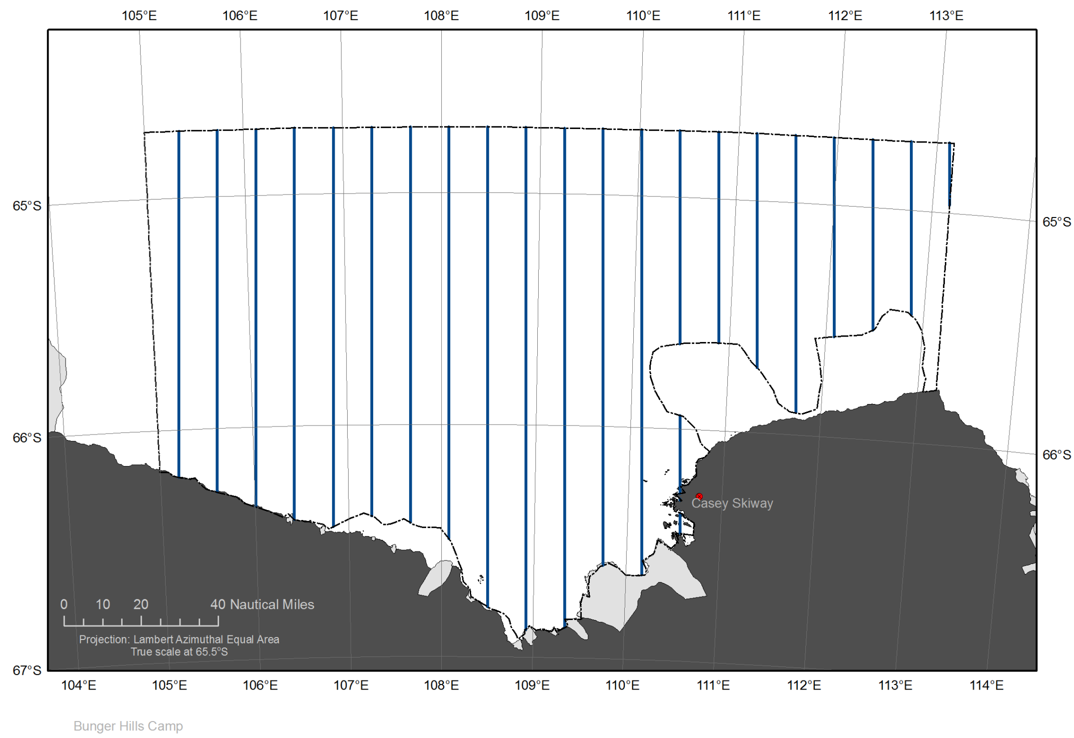

Figure 3 Planned effort for the CA1 phase. There were 21 north-south orientated transects.

The second phase, referred to as BH1, was flown from the Bunger Hills field camp and ran from 29 December, 2009 to 16 January, 2010 (on-schedule), and shifted survey effort to the north and east of the Shackleton Ice Shelf and into the eastern section of the Davis Sea. As we had to be frugal with fuel, in addition to the absence of any obvious gradient in pack-ice concentrations, an equal-spaced zigzag transect design was selected for the BH1 phase, see Figure 4. A number of smaller strata were produced to accommodate the shape of the Shackleton Ice Shelf and the location of the Shackleton polynya, see Figure 4, *viz*. Davis Sea south (DSS), Davis Sea north (DSN) and the Shackleton polynya (SCN). As with the CA1 phase, the boundaries of the strata in the BH1 phase were dependent on pack-ice concentrations in late December, 2009; in particular, we were targeting polynyas within the pack-ice zone. The western and northern extents of survey area in the BH1 phase were tightly constrained by fuel availability. The planned transect length for the BH1 phase was 1320 nm (around 25 hours of flying).

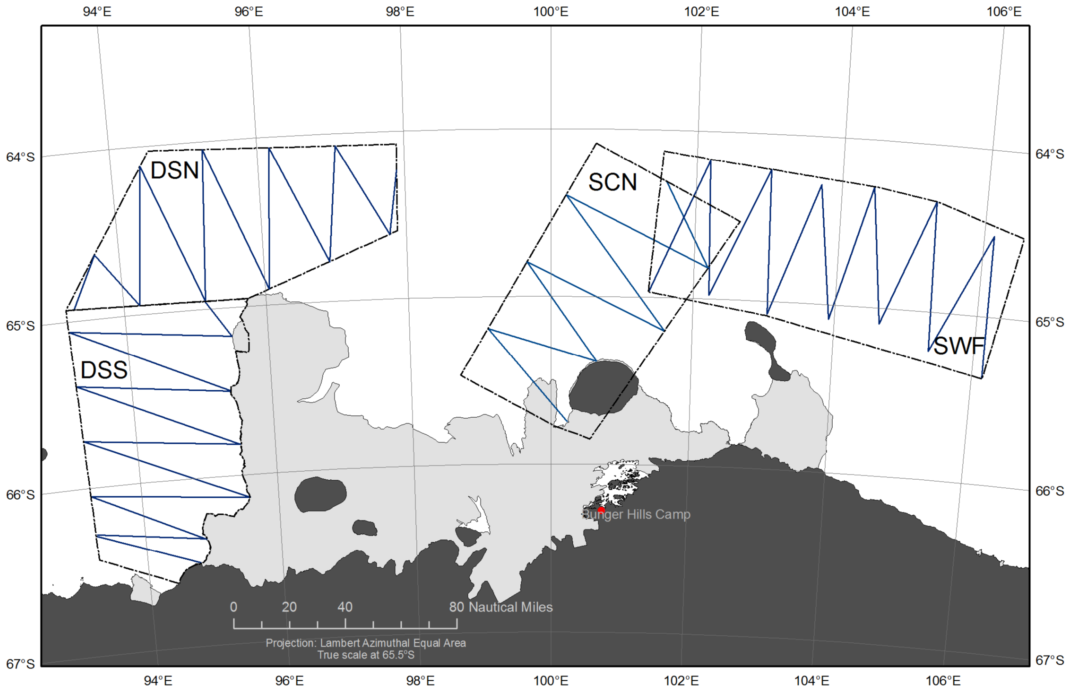

Figure 4 Planned effort for the DSN (Davis Sea north), DSS (Davis Sea south), SCN (Shackleton) and SWF (SOWER follow) strata in the BH1 phase. Presence and location of SWF stratum is explained below. There are 29 zigzag transects (not including SWF stratum).

The third and final phase, referred to as CA2, ran for a week from 25 January to 5 February (was scheduled to run from 17 January to 5 February) and repeated the survey effort of the CA1 phase (i.e., Vincennes Bay area), but with transects extending further north, around 40 nm beyond the sea ice boundary in open water, see Figure 5. The planned transect length for the CA2 phase was 2824 nm (around 40 hours of flying).

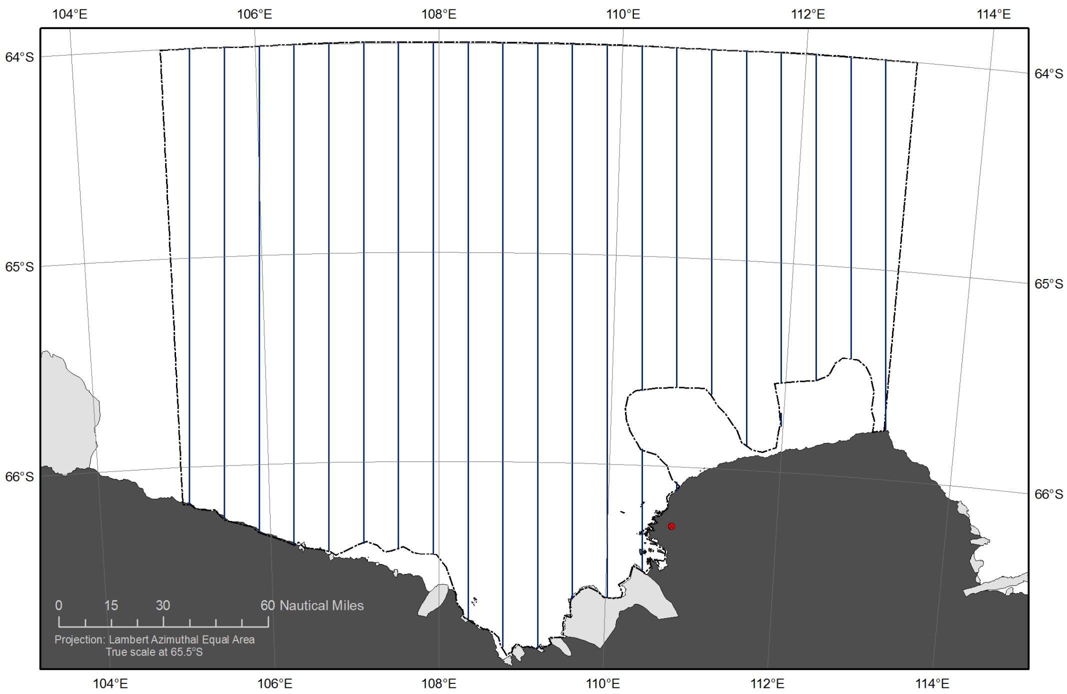

Figure 5 Planned effort for the CA2 phase. There were 21 north-south orientated transects. Note, transects extend further north as compared to the CA1 phase (as per Figure 3).

The planned total lengths of transects for each of the phases were based on minke whale encounter rates from last season; estimated bad weather (which will ground the aerial survey, on average, every second day; similar rates expected at Bunger Hills (pers. comm. Gronset[2])); a maximum flying range of the aircraft of 600 nm; having to share the aircraft resource with another deep-field project based at Mill Island (just north of Bunger Hills); and having the possibly that the aircraft could be used in medievac operations (as actually happened in early January, 2010, when the CASA-212 aircraft was used to evacuate a patient from a Chinese station near Prydz Bay). In particular, as mentioned above, the total transect length that could be flown out of Bunger Hills was greatly constrained by the amount of fuel that could be cached there. These planned total transect lengths were theoretical maximum values and substantial decreases in actual distances flown were likely result from unforeseen logistical constraints.

These phases also helped in the development of formal hypotheses for minke whale distribution with both time and space. The data from the first phase will allow a between-year comparison of whale abundance and distribution in the Vincennes Bay area (comparing data from December 2008 and December 2009). Whale observations from Shackleton Ice Shelf and the Davis Sea will allow for comparisons of distributions and densities over a 20º band of longitude. And, finally, data from last phase will allow an intra-season comparison of whale abundance and distribution.

The total area of all three survey phases (double counting overlapping areas in phases CA1 and CA2) is approximately 55,559 nm^2. The non-overlapping area was around 34,159 nm^2, an area that represents around 5.2% of the total area between the east Antarctic coast line (which includes permanent ice sheets) and the 62°S line, between 30° and 160°E.

Both the parallel systematic transect designs of the CA1 and CA2 phases and the zigzag designs of the BH1 phase were created with the programme *Distance 6* (Thomas *et al.* 2009). AMRS-E sea ice data[3] (Spreen *et al.* 2005; Spreen *et al.* 2008) and AVHRR[4] sea ice images (on relatively cloud-free days) were used to delineate polynyas and other pack-ice features upon which survey strata were based. Survey designs were finalised a day or two before the scheduled start of each phase to ensure the most up-to-date sea ice information was used.

[2] Captain Jorn Gronset: Senior Pilot, Skytraders Pty Ltd.
[3] http://www.iup.uni-bremen.de:8084/amsr/amsre.html
[4] http://avhrr.acecrc.org.au/

Survey protocols

The survey platform was a CASA-212(400) fixed-wing aircraft. On-effort flying altitude was 228m (750ft) and speed was 204 km hr^{-1} (110 knots). Flights went ahead only if wind speed at the skiway/station (with some extrapolation to wider survey area given by Bureau of Meteorology forecasters) was less than 22.2 km hr^{-1} (12 knots) and the cloud deck was higher than 244m (800ft).

On board were four observers (two per side of aircraft), a flight leader (A. Hodgson; seated at the left-rear) and two pilots. The survey was double-platform: the front and back observers were isolated visually with a thick curtain and were not able to hear one another through the intercom system. Observations where recorded onto time-stamped MP3 format files. Observers were encouraged to search ahead and as close to the trackline as possible. This was, however, quite difficult as the CASA-212 windows are quite small and flat (width: 280 mm; height: 270 mm). The observations themselves consisted of cue counting (where possible) and angle of declination when animals are perpendicular, or abeam, to the observer (using a *Suunto* inclinometer). The time at which an observer sees a whale ahead is noted, followed by any time the animal cues. Cues were not recorded after the animals had moved past abeam. Cues were also not recorded if the group size was large (applied to killer whale observations only). At abeam, angle of declination of groups was measured at the centre of the group. Perpendicular distance out to animals was calculated using angle of declination and flying height (but no correction for curvature of the earth or aircraft drift angle was applied; this year aircraft roll and pitch angles were measured and we intend to include these in future analyses of perpendicular distance). Other information recorded included species, group size (minimum, maximum and best estimate), cue type, number of animals at surface when perpendicular, direction of travel and any behavioural features of the animal(s). The flight leader also made a number of whale observations on the left of the aircraft, particularly if the left-side observers failed to detect the animals. Other than during an observer training phase at the start of the aerial survey, no attempt was made to loop back and re-sight observations to confirm species or group sizes. Although this is often common in aerial surveys for whales, whale re-sights within this aerial survey were rare due to the reasonably low manoeuvrability of CASA-212 aircraft.

The flight leader recorded variables that potentially influence the quality of observations, such as Beaufort sea state, glare, cloud cover and type, and an overall sightability score (a four-level compound variable detailing the overall quality of sighting conditions: none, poor, fair and good sightability), at the start of each transect and each time these variables changed; and also continuously observed environmental covariates such as concentration of pack-ice and incidental information, such as the presence of birds or seals. GPS data, altitude and flying speed were continuously recorded on the aircraft's data logger.

Photographic and video equipment

There was also a video/digital stills camera system located in the base of the aircraft. These cameras recorded the presence of whales in the area under the aircraft inaccessible to the observers and also recorded pack-ice information. The digital-still camera system consists of three Nikon D-200 cameras; one in the bottom of the fuselage and two mounted obliquely at windows on either side of the aircraft to provide wide coverage, including under the aircraft and replicating the observers' field-of-view (30º to 60º from the horizon). The cameras took images approximately every second which, at survey speed and altitude, gave complete coverage along track. The high-definition video system consisted of two cameras pointing out in opposite directions from the aircraft, covering from the trackline out to 30º. There was also a GPS and aircraft telemetry system recording position and pitch and roll. An infrared camera was also installed in the base of the fuselage, but this was only used intermittently.

This video/photographic system is mentioned here for completion, but as analysis of the video/photographic data is only partially completed, these are not included in this report. It is hoped this data will be analysed over the coming 12-18 months.

Triple-platform sightings

In the CA2 phase, a fifth observer (M. Bravington) joined the survey team. A fourth seat was slotted in on the left-side of the aircraft, to join the flight leader and two existing observers. Approximately 2132 nm of on-effort survey distance was achieved in this triple-platform configuration and seven whale sightings were made by the fifth observer. There is, however, an occupational health and safety cost in having the third-platform in the CASA-212 aircraft in that the fifth observer was not able to periodically switch sides or to move further away from the propeller.

Achieved Effort

Achieved transect distance and strata areas are given in Table 1.

Table 1 Details of the 2009/10 aerial survey strata and transects

Stratum	Area (nm2) - planned	Area (nm2) - realised	Phase	Start and end date	Total Transect Length (nm) - planned	Total Transect Length (nm) – achieved*
Casey 1 (CA1)	18 724.5	16 238.3	CA1	16 Dec – 27 Dec 2009	1 905.1	1 470.2
Davis Sea South (DSS)	5 181.3	5 181.3	BH01	29 Dec – 30 Dec 2009	560.2	552.9
Davis Sea North (DSN)	5 052.9	4 627.4	BH01	30 Dec – 31 Dec 2009	457.9	393.6
Shackleton Polynya (SCN)	5 290.9	3 396.7	BH01	31 Dec 2009 – 9 Jan 2010	334.3	277.9
SOWER follow (SWF)	6 319.8	1 081.6	BH01	16 Jan – 16 Jan 2010	601.1	96.7
Casey 2 (CA2)	27 993.2	24 917.8	CA2	17 Jan – 5 Feb 2010	2 824.0	
CA2-East (CA2E)		5 567.8	CA2	5 Feb – 5 Feb 2010		317.4
CA2-West (CA2W)		19 466.1	CA2	17 Jan – 5 Feb 2010		1 814.9
Totals	**68 562.6#**	**55 559.2~**			**6 682.6**	**4 923.8**

#Total planned survey area, minus overlapping areas, is 47 163.3 nm^2.
~Total realised survey area, minus overlapping areas, is 34 159.9 nm^2.
*Does not include observer break/rest periods.

Over the duration of each phase, planned effort was both added and removed, depending on prevailing pack-ice conditions and survey time constraints. Maps of realised effort are given below in the section describing sightings. In the CA1 phase, three transects in the far west of the survey area were dropped from the flying plan as these transects were located over high pack-ice concentrations (and, therefore, unlikely to yield many, if any, minke whale observations) and we needed move onto the BH1 phase. In the BH1 phase, the northern-eastern most transect in the SCN stratum was removed as it was going to coincide with transects in the newly-added SWF stratum (see below for more details). In the CA2 phase, transects in the far west were shortened to approximately half the north-south extent as, again, high pack-ice concentrations in the south-west of the area were unlikely to yield many minke whale sightings. Also, transect spacing was increased from 10 to 20 nm in the north-eastern corner of the area covered by the CA2 phase in order to maintain wide spatial coverage in the face of diminishing flying opportunities (these transects were the last flown for the entire survey).

In order to maintain even spatial coverage of effort, some stratum boundaries were altered (i.e., the design was post-stratified). The area of the CA2 phase was split into two new strata: CA2E (east) and CA2W (west). These changes are reflected in Table 1.

In total there were 27 flights, and we covered a distance of 11,660 nm over 108 hours, which includes off-effort and transit periods. There were six flights, totalling more than 1,769 nm (or 16 hours), that resulted in no usable effort due to poor weather.

Extra flying in the BH1 phase (attempt to fly along recent IWC-SOWER track)

In the early days of the BH1 phase, we had good weather and an available aircraft. Given the pace we were setting, we put a proposal together (dated 2 January, 2010) for extra flying in order to directly follow the path of the IWC-SOWER vessel along a sea ice edge. This added stratum was called SOWER-follow (or SWF). The IWC-SOWER vessel reached the sea ice edge located at 100°E on 7 January. After experiencing some bad weather for a couple of days,, the IWC-SOWER vessel commenced their zigzag survey design on 9 January (started at 63° 37’S 100° 0’E). Over the following weeks the IWC-SOWER vessel would follow a zigzag transect pattern along the sea ice edge across to 115°E and back (planned to take around a month the complete).

The original plan was for our aerial survey to indirectly collaborate with the IWC-SOWER vessel from mid-January onwards (our final phase; CA2); the boat operating outside the ice and the aircraft within the ice between 105°E and 115°E. This indirect collaboration should provide a general comparison of the numbers of minke whales inside/outside of the ice, which will then be used to help calibrate current IWC estimates of circumpolar minke whale abundance.

The proposed extra survey effort required three flights, totalling around 1450 nm.

The plan for extra flying was contingent on fuel being taken across to Bunger Hills and the needs of a higher-priority ice drilling project at nearby Mill Island. During earlier planning for this season's aerial survey, a plan to closely follow the IWC-SOWER vessel along the sea ice from 100°E was considered. This plan was, however, shelved as there were too many unknowns to buffer against during the BH1 phase.

The requested extra fuel was flown across to Bunger Hills 5-6 January.

We originally proposed to follow the IWC-SOWER vessel along the sea ice boundary from 100° to 105°E over a period of 8-16 January. These dates slipped somewhat due to changes to the flight schedule and bad weather; longitudinal boundaries moved further east to target areas more recently visited by the IWC-SOWER boat; track set out in Figure 4. During this waiting period, the ice edge receded further south, and the boundaries of SWF strata began to overlap with the SCN strata.

On 16 January, 2010, after a long period of poor weather, the aerial survey programme finally targeted transects under the proposed extra flying. We completed two transects under the zigzag design (totalling approximately 100nm) when mechanical complications with the aircraft became apparent. At this point we returned to Casey station for repairs. Bad weather closed in around Casey station and Vincennes Bay and a decision was made to end the BH1 phase and to begin the CA2 phase. This is truly unfortunate as the sea ice boundary between 103° and 107°E was straight and graded from 100% to 0% sea ice concentration in a uniform manner, over a distance that was reasonable to target using CASA-212 aircraft.

Ice conditions across survey phases

Between 93ºE and 113ºE, the pattern of sea ice (both concentration and northerly extent) was about average for mid-December 2009, see Figure 6 (start of aerial survey; historical AMSR-E data not shown). The polynya in Vincennes Bay had started to open up around late October, but a wide layer of ice, approximately 60 nautical miles in north-south extent, closed the bay off from the open ocean. The Cape Poinsette polynya had also started to clear by this time. The southern section of the Davis Sea had started to break-out in early October, and then began to clear in earnest in early November. As is quite usual for the northern Davis Sea, a large gap in the pack-ice, approximately following the 1000m bathymetric contour, was showing signs of developing in mid-October, but started to properly open up in late November. The Shackleton polynya started appearing in mid-November, and was well developed by late December.

Changes in pack-ice concentration across the survey area are shown in Figures 6-8. A major feature to note is the persistence of a wide layer of ice, approximately 60 nm in north-south extent (but thinning to 40 nm in early February), across Vincennes Bay.

Furthermore, in addition to a large section of the DSN stratum, only in a couple of spots had the major ice edge receded south of the shelf-break (notably 103-104ºE) during the different survey phases.

The distribution of pack-ice concentrations within each stratum, around the mid-point date each was being completed, is given in Figure 9.

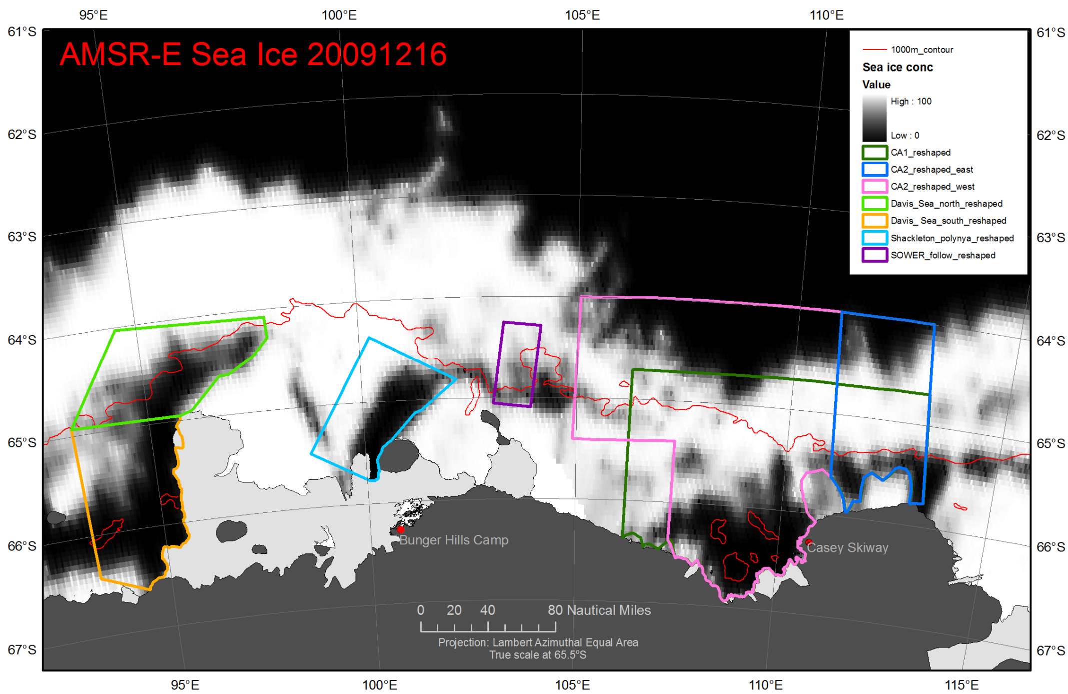

Figure 6 Large-scale concentrations of pack-ice (using AMSR-E data) on 16 December, 2009 (first day of survey), with realised aerial survey strata.

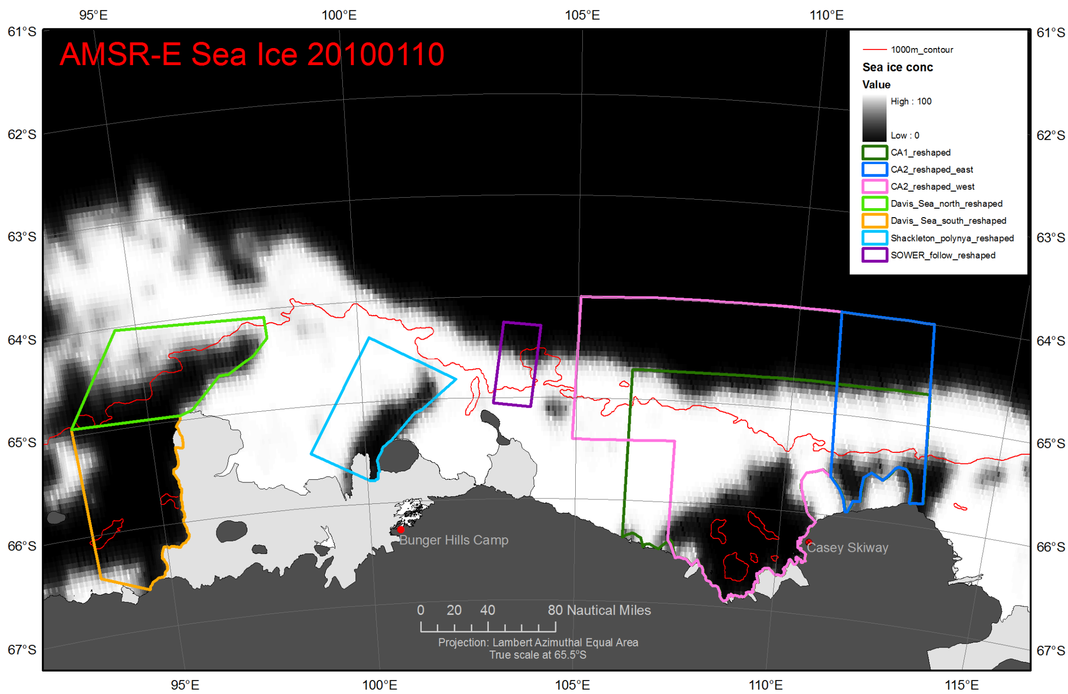

Figure 7 Large-scale concentrations of pack-ice (using AMSR-E data) on `10 January 2010 (approximate half way of survey), with realised aerial survey strata.

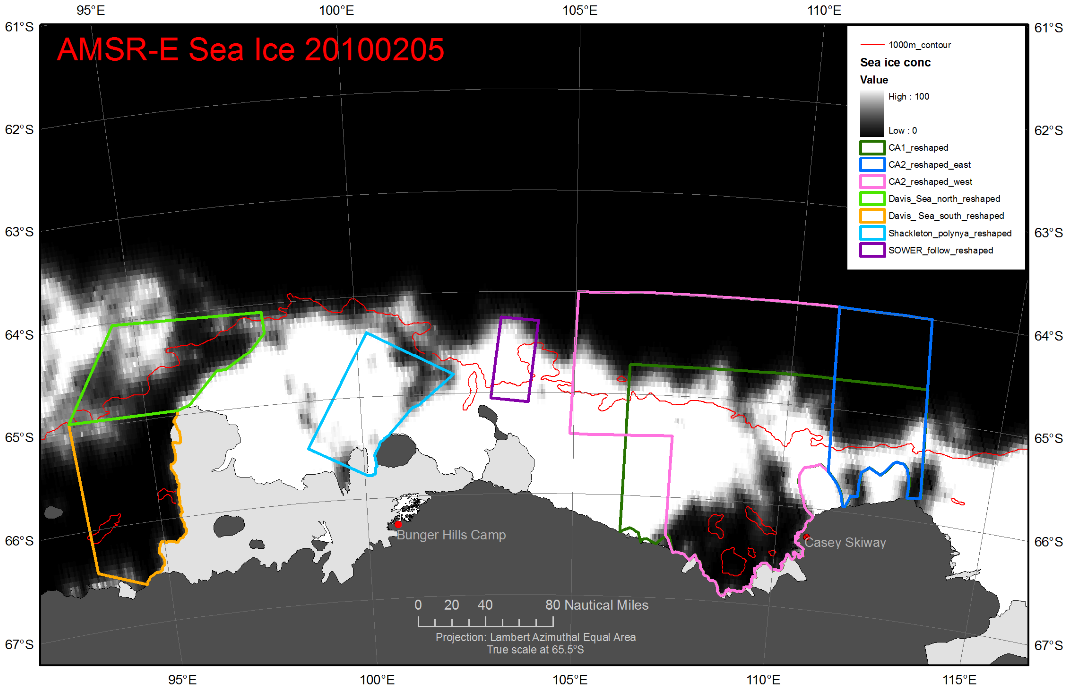

Figure 8 Large-scale concentrations of pack-ice (using AMSR-E data) on 5 February 2010 (last day of survey), with realised aerial survey strata.

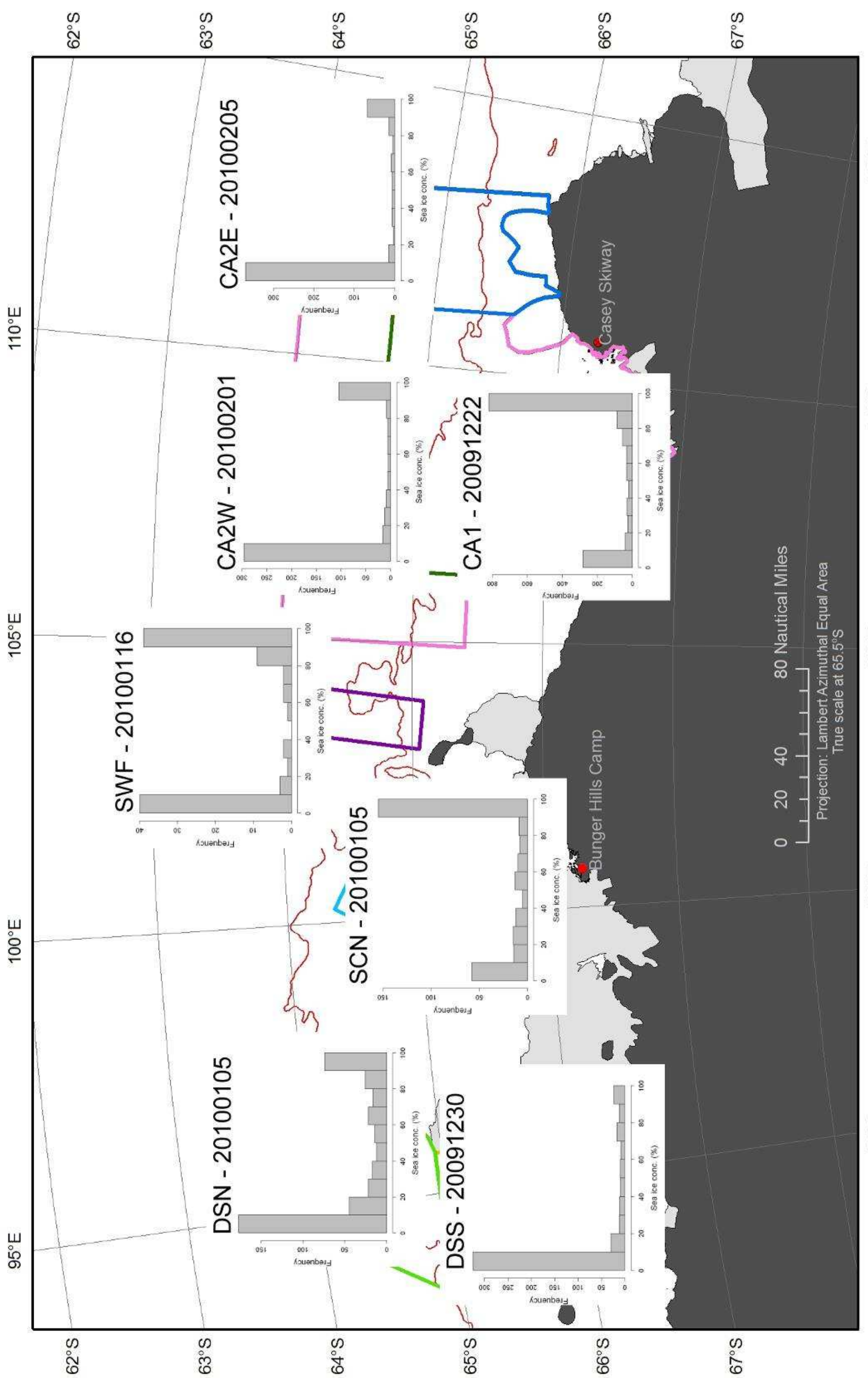

Figure 9 Frequency distributions of the sea ice concentrations (from AMSR-E grid data) for each stratum at the approximate mid-date being surveyed.

Quality of flying

The rate at which usable effort was achieved across the entire survey, and the operational rating for each day, are given in Figure 10. Of the 52 days of the survey period, only 20 were available for flying.

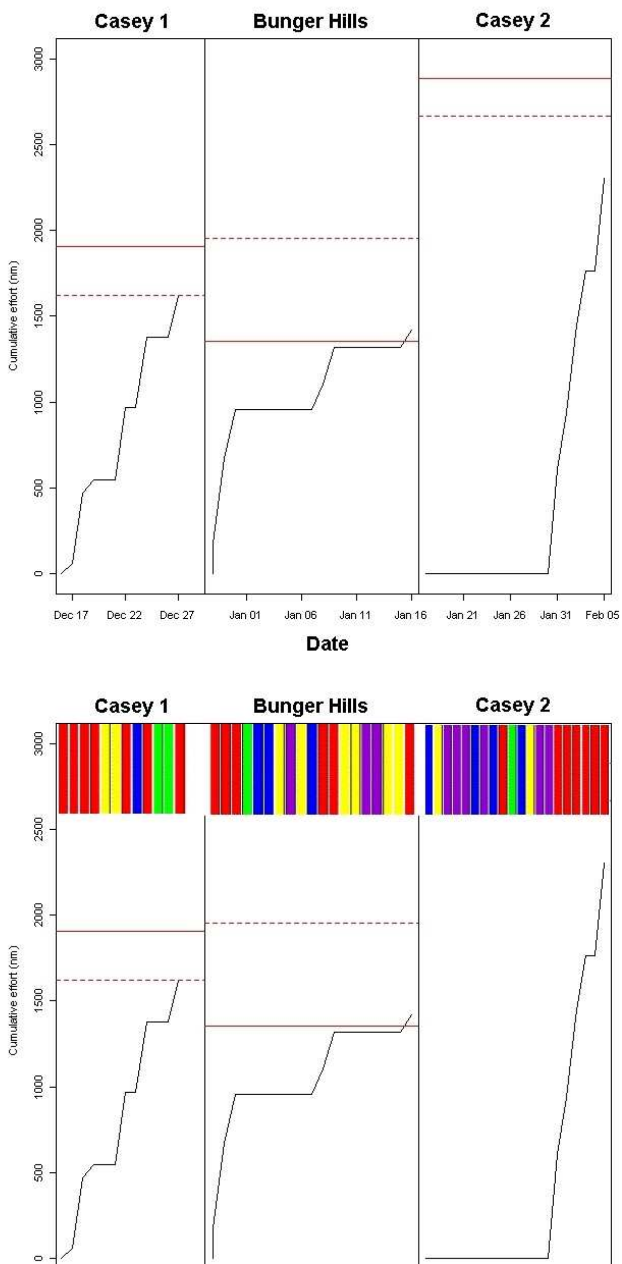

Figure 10 (Top Panel): Accumulation of survey effort (in nautical miles) over each phase. Red solid line corresponds to initial planned effort prior to commencing phase, the red dashed line to planned effort after any changes during phase, and the solid black line denotes the actual cumulative effort. (Bottom Panel) : Information repeated, but for each day its aircraft operational class indicated: red, flying day; yellow, maintenance or lack of remaining pilot hours; dark blue, poor weather; purple, other projects with aircraft needs; green, public holiday; and white, phase change over.

The quality of effort, or ‘sightability’, is judged by the flight leader along a transect. Sightability is a compound variable based on light, fog, glare and Beaufort sea state. Four categories are used to summarise sightability: none, poor, fair and good. The effort completed in each sightability category is given in Figure 11. Of note is the low proportion of effort rated to have good sightability in the BH1 phase; due to a lower level of fuel availability at the Bunger Hills camp we could not repeat transects if the overall sightability for these flights was not high.

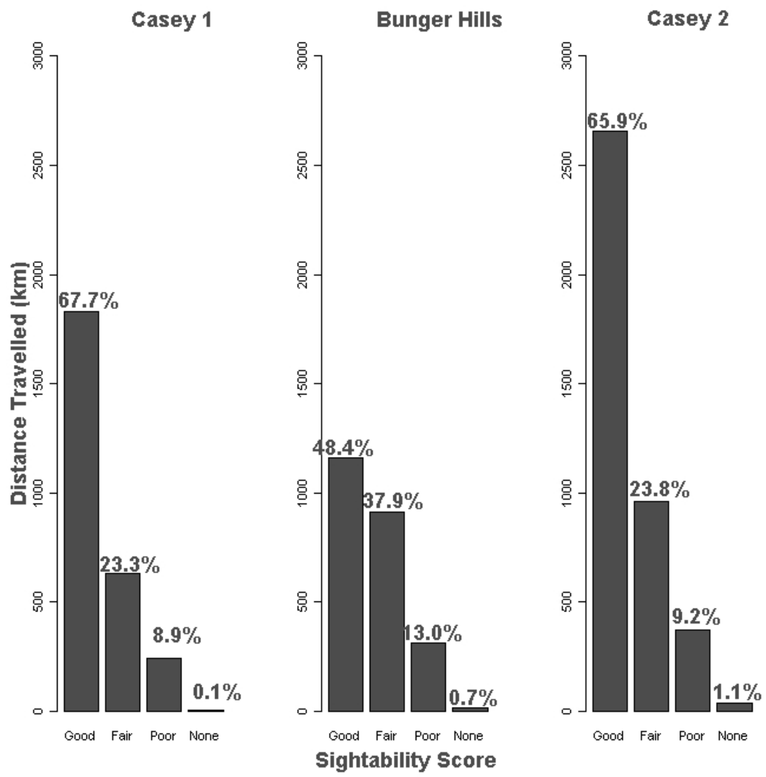

Figure 11 Classification of effort (in kilometres travelled) by sightability scores, per survey phase.

Sightings

Minke whales

Sightings of minke and 'like' minke whales are given for each stratum in Tables 2 – 4. Distribution of minke whale sightings, in each survey phase, are given in Figures 12, 14 and 16.

Table 2 Numbers of minke whale sightings within each stratum, for both primary (front) and secondary (back) observers; total number of individual animals given in brackets.

Stratum	Primary observer	Secondary observer	Both	Total
CA1	2 (3)	1 (2)	1 (2)	2 (3)
DSS	3 (4)	2 (2)	2 (2)	4 (5)
DSN	3 (5)	1 (1)	1 (1)	2 (4)
SCN	2 (2)	2 (2)	1 (1)	3 (3)
SWF	2 (8)	2 (8)	2 (8)	3 (9)
CA2W	5 (5)	3 (3)	2 (2)	10 (10)
CA2E				
Total	21(31)	13(20)	9 (16)	24 (34)

Table 3 Numbers of 'like' minke whale sightings within each stratum, for both primary (front) and secondary (back) observers; total number of individual animals given in brackets.

Stratum	Primary observer	Secondary observer	Both	Total
CA1				
DSS				
DSN				
SCN				
SWF	1 (1)			1 (1)
CA2W	3 (3)	2 (2)	1 (1)	2 (2)
CA2E	1 (1)			1 (1)
Total	5 (5)	2 (2)	1 (1)	5 (5)

Table 4 Numbers of minke whale sightings within each stratum, for both primary (front) and secondary (back) observers during 'off-effort' periods ; total number of individual animals given in brackets.

Stratum	Primary observer	Secondary observer	Both	Total
CA1	1 (1)	1 (1)	1 (1)	1 (1)
DSS				
DSN	1 (1)			1 (1)
SCN				
SWF	1 (1)	1 (1)	1 (1)	1 (1)
CA2W				
CA2E	2 (2)	2 (2)	2 (2)	2 (2)
Total	5 (5)	4 (4)	4 (4)	5 (5)

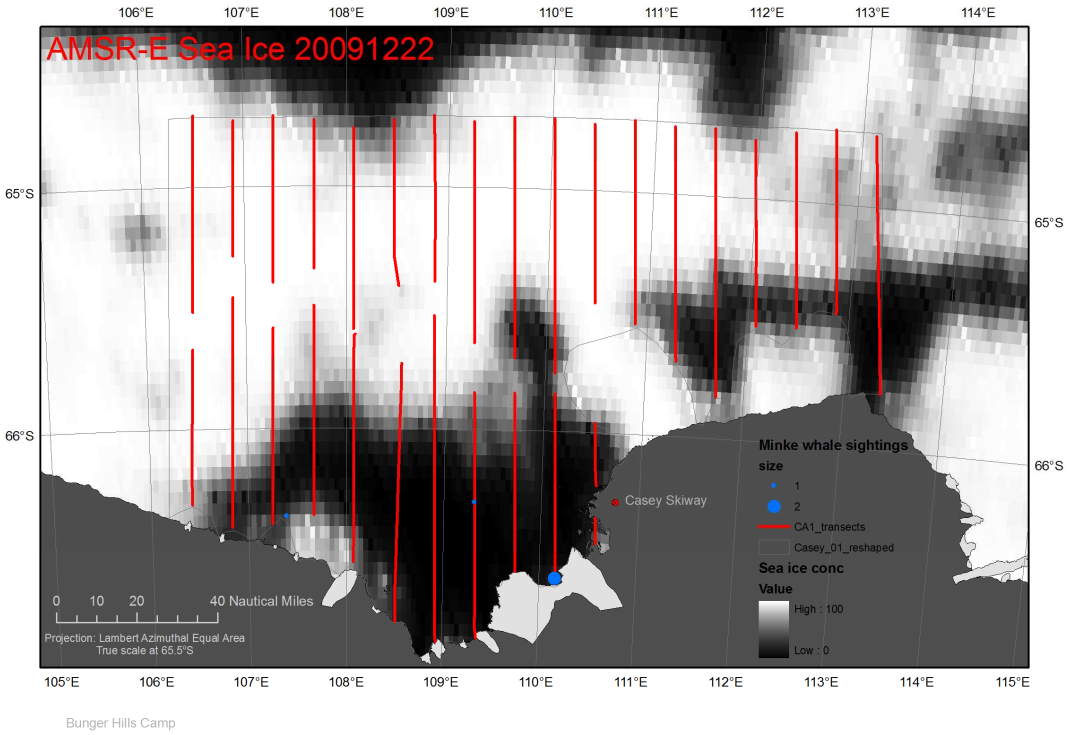

Figure 12 Minke whale sightings across the CA1 phase, with realised effort in red. Minke group size indicated by circle diameter (either 1 or 2 in this example). Gaps in effort can represent either poor weather or observer breaks. The sea ice data in the background is from around the middle date of the CA1 phase.

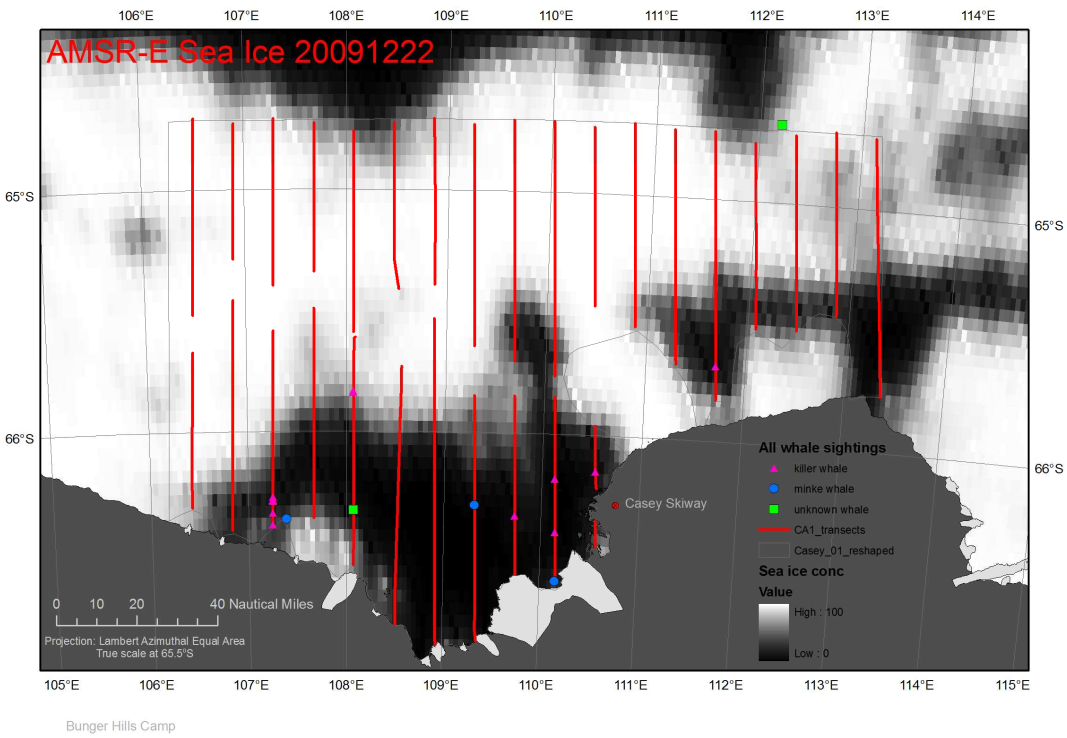

Figure 13 Other whale species sightings across the CA1 phase, with realised effort in red. Gaps in effort can represent either poor weather or observer breaks. The sea ice data in the background is from around the middle date of the CA1 phase.

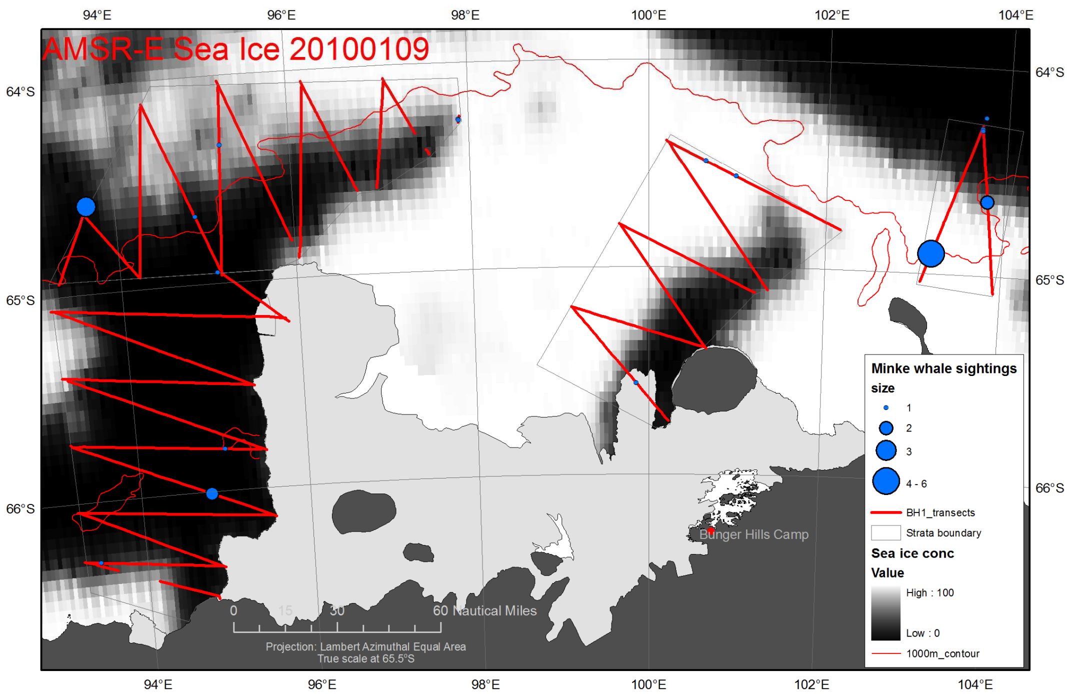

Figure 14 Minke whale sightings across the BH1 phase, with realised effort in red. Minke group size indicated by circle diameter. Gaps in effort can represent either poor weather or observer breaks. The sea ice data in the background is from around the middle date of the BH1 phase. Please note the GIS layer representing the Shackleton Ice Shelf was awaiting updating at time of production of this report and this explains why effort was registered 'over land' in DSS and SCN strata.

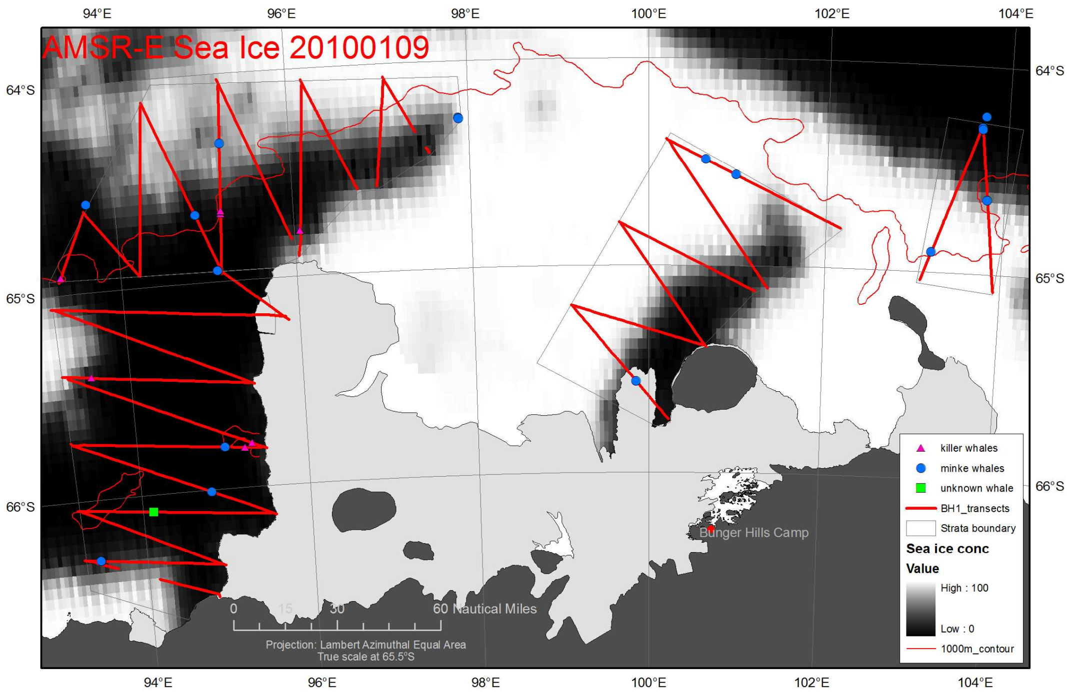

Figure 15 Other whale species sightings across the BH1 phase, with realised effort in red. Gaps in effort can represent either poor weather or observer breaks. The sea ice data in the background is from around the middle date of the BH1 phase.

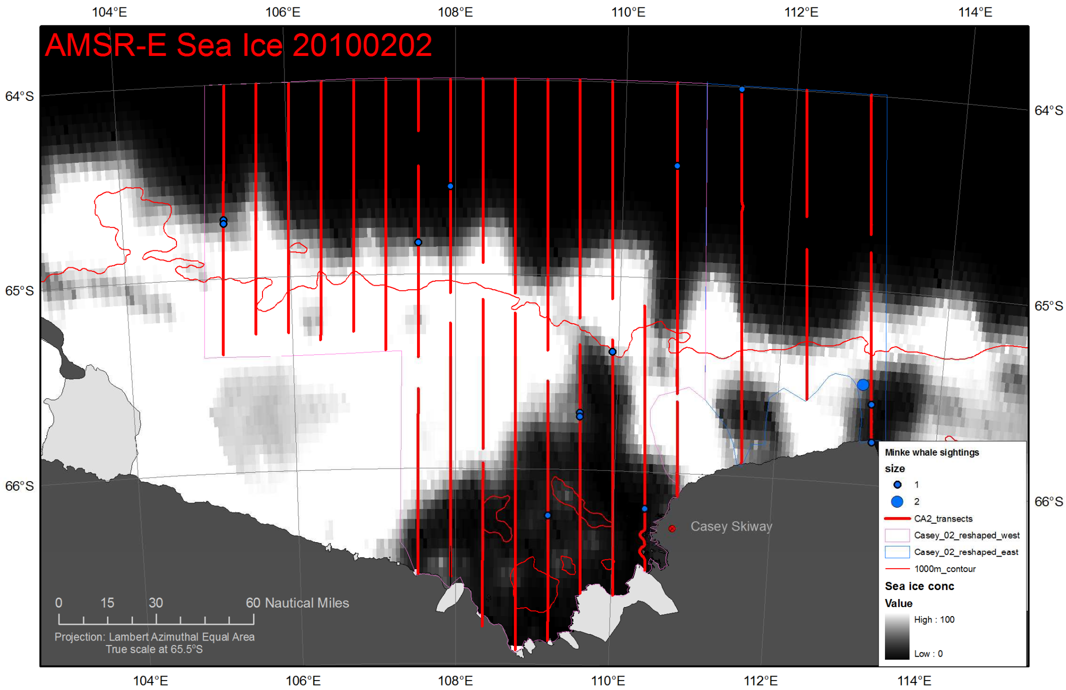

Figure 16 Minke whale sightings across CA1 phase, with realised effort in red. Minke group size indicated by circle diameter. Gaps in effort can represent either poor weather or observer breaks. The sea ice data in the background is from around the middle date of BH1 phase.

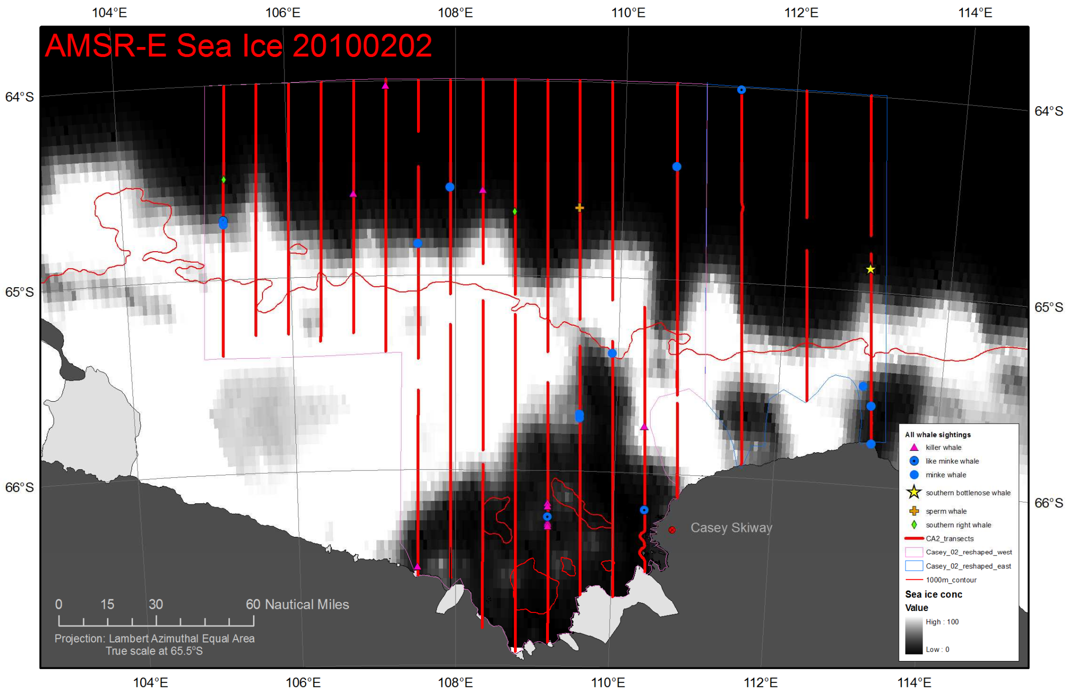

Figure 17 Other whale species sightings across the CA2 phase, with realised effort in red. Gaps in effort can represent either poor weather or observer breaks. The sea ice data in the background is from around the middle date of the CA2 phase.

The frequency of minke whale group sizes across all strata (there were too few sightings to meaningfully split sightings into individual stratum) is given in Figure 18. The accompanying distribution of sightings within 20% bin-width sea ice concentrations is given in Figure 19; sea ice concentration was estimated using a classification algorithm working with digital stills taken beneath the aircraft (for more details on this method, see Kelly *et al.* (2010)).

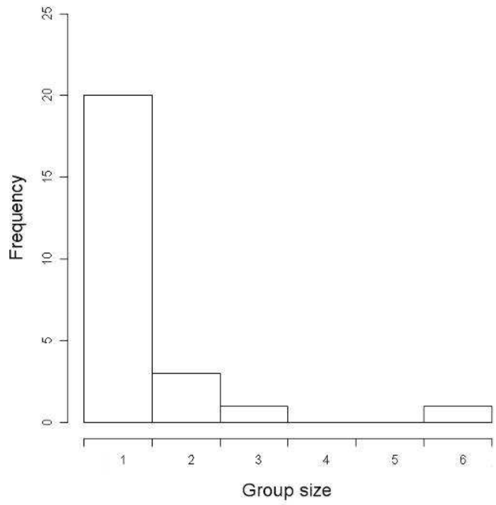

Figure 18 Frequencies of groups sizes of Antarctic minke whales observed across all strata in the 2009/10 aerial survey.

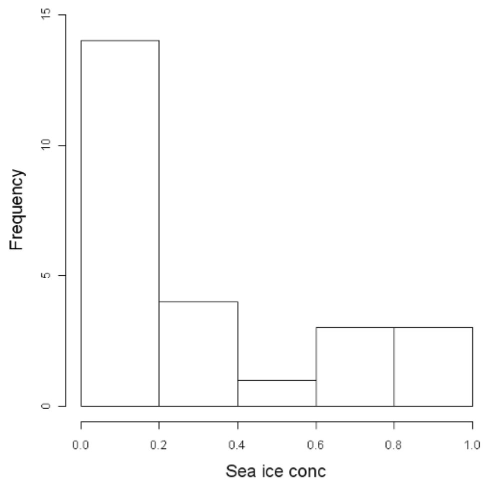

Figure 19 Frequency of sightings by estimated local sea ice concentration across all strata in the 2009/10 aerial survey.

Other Species

Sighting counts of other whale species, by phase, is given in Table 5. Notably, we did not have any confirmed sightings of humpback whales, despite flying over areas where the IWC-SOWER voyage reported many such sightings (Sekiguchi *et al.* 2010).

Table 5 Counts of sightings by species, across each phase; number of sightings, with total number of individual animals given in brackets.

Species	CA1	BH1	CA2
Killer whales	13 (74)	8 (60)	11 (28)
Southern right whales			2 (3)
Sperm whales			1 (1)
Southern bottlenose whales			1 (4)
Unknown species	1 (2)	1 (2)	1 (1)

One noteworthy sighting was of mysterious ‘whale like’ shapes deep in the water column, observed in the CA1 phase (22 December, 2009; 66º 19.6’S 108º 4.6’E) in the far south of Vincennes Bay, see Figure 20. The experienced observer thought they may have been blue whales, but the sighting was far from certain. A rough comparison with photographs animals at a similar distance from the trackline suggest these objects may be around three times the length of a killer whale.

Figure 20 Two large pale shapes under the water. The experienced observer at the time of the sighting thought these objects may have been blue whales (22 December, 2009; 66º 19.6’S 108º 4.6’E).

Video and Stills matching: observer validation

During this year’s survey season 211 hours of video and 531,000 digital still images were taken. As a quick preliminary test to establish if the still camera system could be a viable tool we examined the still images corresponding to each observer sighting, for obvious whales (see Table 6). Generally, most animals seen by human observers were clearly evident in the still images. As expected, killer whales were slightly harder to detect in still images than the larger minke whales. Many images were certainly clear enough to aid with species ID, group size and swim direction.

Table 6 Ability to identify observer whale sightings in corresponding still images.

Species	Number of potential matching opportunities	Identified in corresponding digital still image	Match rate %
Killer whale	17	12	70.6 %
Minke whale	16	16	100%
Southern Right whale	2	2	100%
Unknown whale	3	3	100%
Unknown object	2	2	100%

An example of a matched digital still image is given in Figure 21. This sighting was made on the 25 February 2010 (113º 2.7'E 65º 26.8'S) with a declination of 32° (from the horizontal); the observer called two minke whales with a cue of a body and a blow. Interestingly, the whales are clearly visible on the corresponding still image even though 32° is close to the limit of the camera coverage, where the whale will appear at its smallest due to the oblique mounting of the camera.

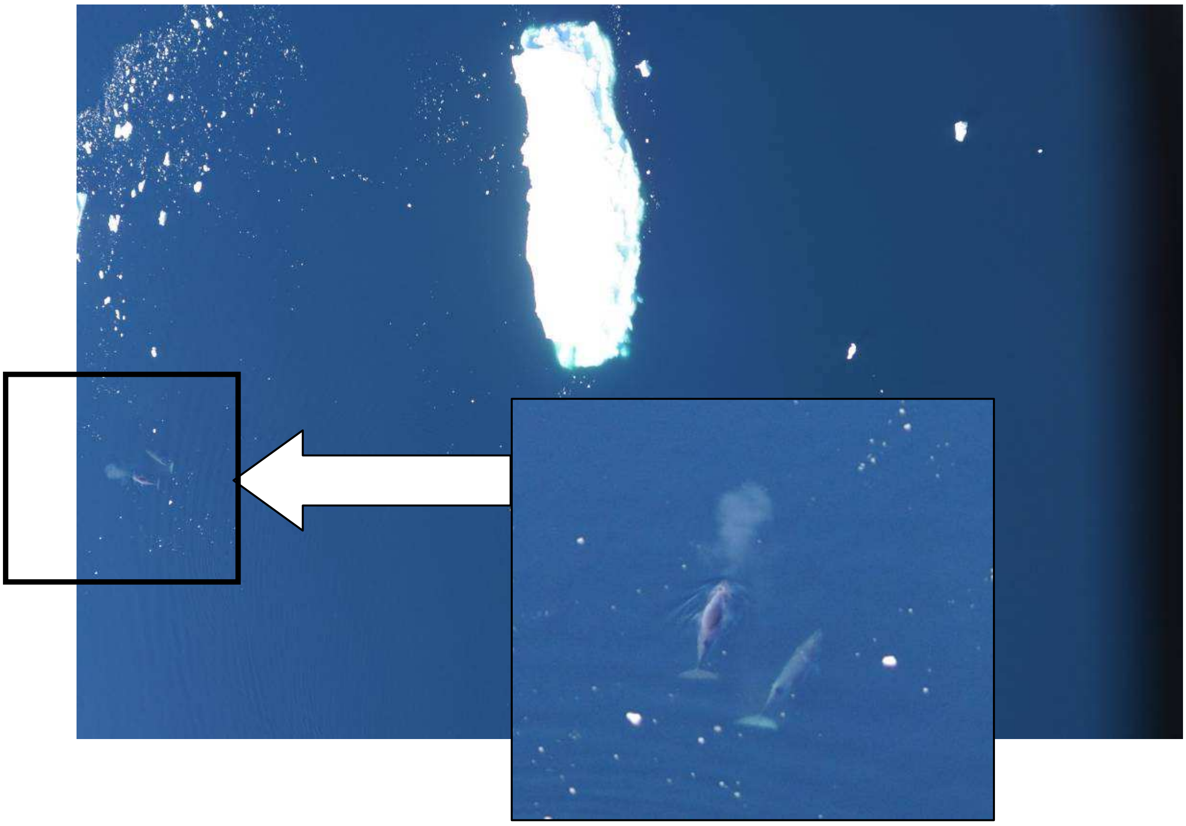

Figure 21 Example of a still image of two minke whales that was successfully matched to an observation.

Surface or near-surface krill patches
The observers noted many dark orange-brown ‘blobs’ in the water; these were generally assumed to be Antarctic krill. These patches were predominantly observed in the final phase (CA2), see Figure 22. It is likely that the high ice-to-water visual contrast prevented more krill patches being noted in higher ice areas.

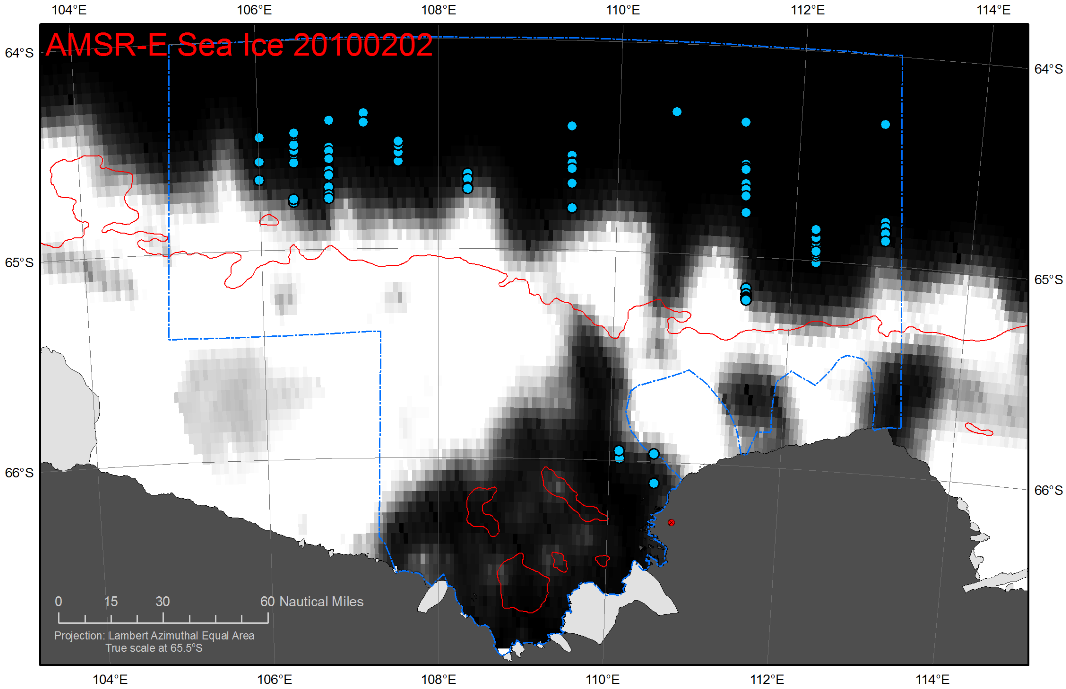

Figure 22 Distribution of krill patches observed from the air during the CA2 phase; patches indicated by aqua circles.

Collaboration with 2009/10 IWC-SOWER voyage

A primary aim of aerial survey programme in the 2009/10 summer season was to collaborate with a concurrent IWC-SOWER voyage (see Sekiguchi *et al.* (2010) for further details).

It was desirable that we would be flying in the same location at the same time as the IWC-SOWER vessel, but bad weather and other operational constraints on aircraft time conspired against us. During the eastern track of the IWC-SOWER voyage (10-21 January, 2010), we able to complete some flying (around 100 nm) in the SWF strata (specifically, 16 January) about 7 days after the IWC-SOWER vessel had moved through the area, see Figure 23; there was around 214.2 nm^2 of area overlap. During the western track of the IWC-SOWER voyage (22 January-5 February), we were flying over seas through which the boat had moved between 4-14 days earlier, see Figure 24; around 11,711.5 nm^2 of area overlap between this western IWC-SOWER track and the CA2 flying area.

Even though no direct joint survey effort was achieved in the 2009/10 season, the proximity (in both space and time) of survey areas of both programmes is still a great achievement; it is hoped that analysis of the corresponding data might help shed light on the numbers of minke whales inside pack-ice relative to the adjacent open water.

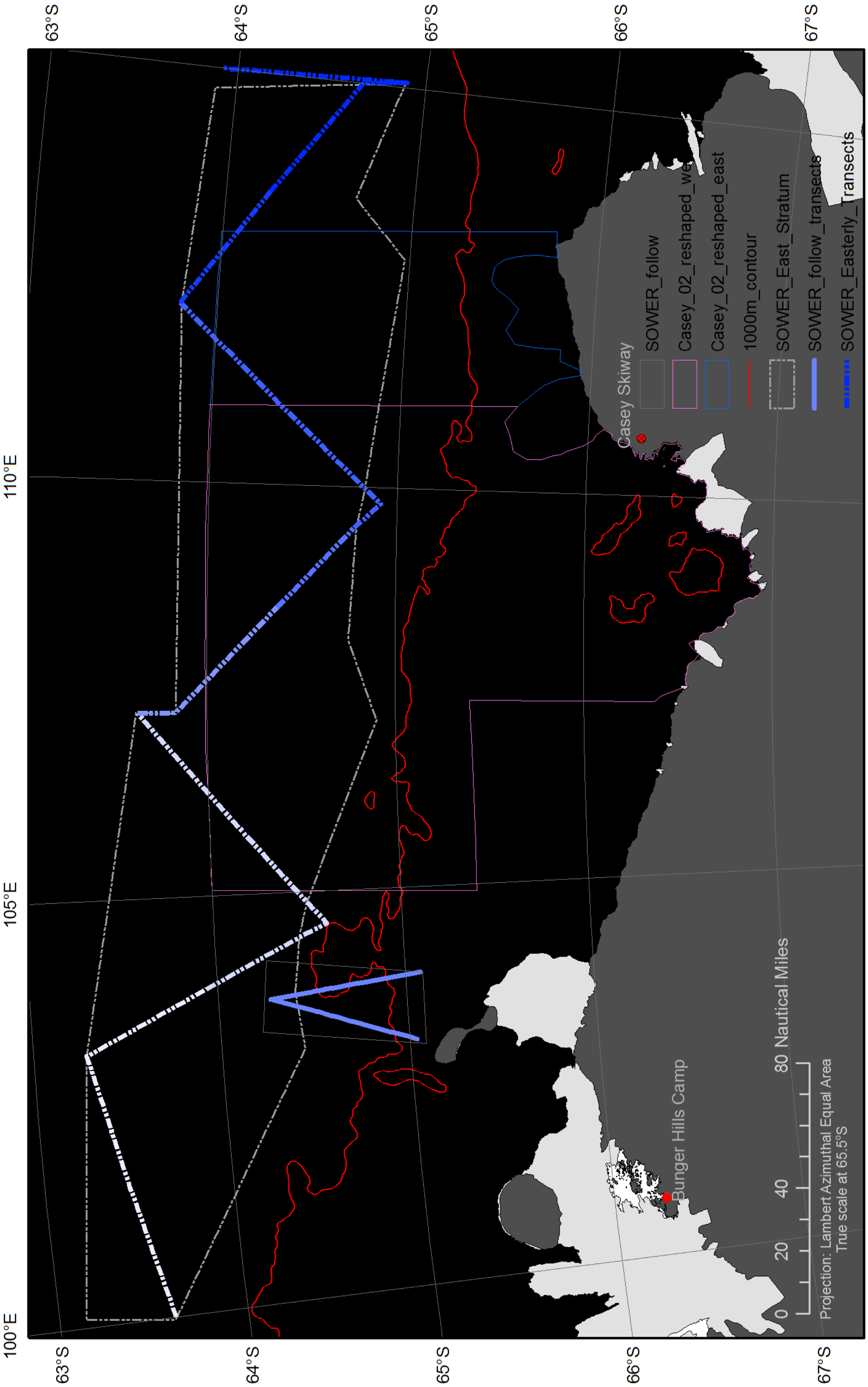

Figure 23 East-bound IWC-SOWER track (dot-dash line) and aerial survey transect (solid line within aborted SWF stratum) flown within a similar 11 day period (10 January – 21 January). Line colour indicates time since vessel/aircraft travelled particular line. Darkest blue indicates 22 January, fading out to white, indicating 10 January.

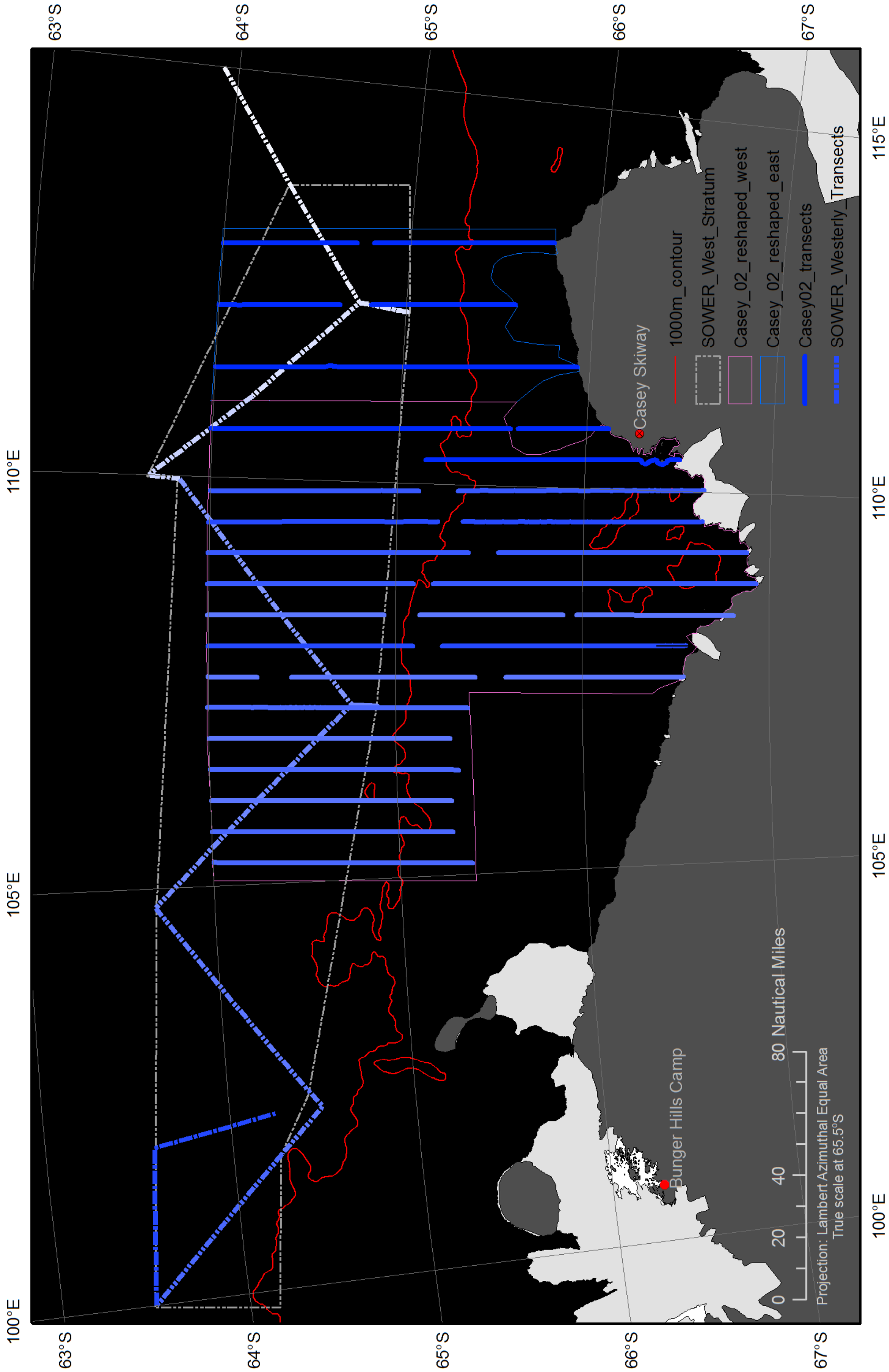

Figure 24 West-bound IWC-SOWER track (dot-dash line; also includes some of the last couple of days of 'extra' IWC-SOWER voyage time) and aerial survey transects (solid lines; CA2 phase) flown within a similar 14 day period (22 January – 5 February). Line colour indicates time since vessel/aircraft travelled particular line. Darkest blue indicates 5 February, fading out to white, indicating 22 January.

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