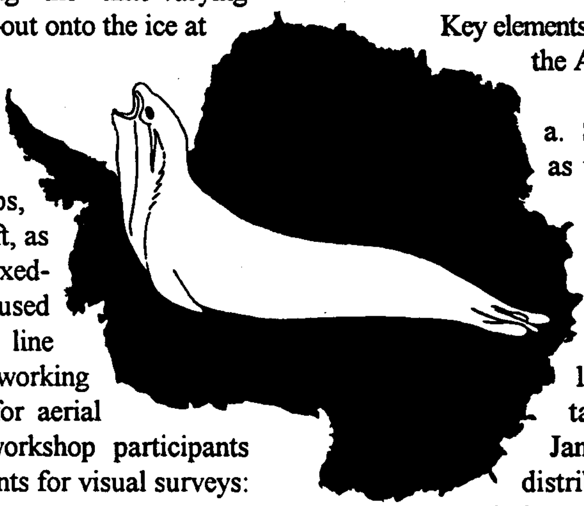
Report of the 1996 APIS Survey Design and Implementation Workshop

Executive Summary

The logistical complexity and high costs of properly surveying the remote and vast area of pack ice around Antarctica dictates the need for a multinational effort to achieve an integral goal of the Antarctic Pack Ice Seal (APIS) Program: estimating the circumpolar abundance of pack ice seals. Planning, coordination and collaboration between the national programs are essential. At the British Antarctic Survey, Cambridge, U.K., from 29-31 July 1996, nineteen scientists from nine nations participated in a workshop to develop standard survey methods and a circumpolar survey design. Participants discussed techniques for surveying seals that are visible on the pack ice and the equally important aspect of measuring the time-varying proportion of seals that are hauled-out onto the ice at the particular time when a survey is conducted.



The Antarctic pack ice will be surveyed visually from ships, helicopters, and fixed-wing aircraft, as well as photographically from fixed-wing aircraft. The workshop focused on visual surveys based on line transect sampling and tasked a working group to coordinate protocols for aerial photographic surveys. The workshop participants agreed on the following key elements for visual surveys:

1. The perpendicular distance (or distance interval) to observed seal groups must be measured to implement line transect sampling. A range of adequate methods for measuring distances were identified that could be adapted for different observation platforms;

2. Observers should be trained and tested in species identification, measuring distance, and data recording. Observer training should stress the importance of detecting all seals close to the platform rather than attempting to detect as many seals as possible. Independent observer experiments are encouraged where possible;

3. Mandatory core survey data were defined and a group was tasked with developing a database and standard data forms for each type of survey. Individual surveys may collect a broader set of data, but will be expected to conform to the minimum set of required data; and

4. Ice type and coverage is an important correlate of seal abundance and was included in the core survey data. A task group was established to define protocols for ice classification and to identify the resolution of region-wide satellite imagery required to interpret survey results.

Key elements of survey design issues agreed for the APIS survey protocols included:

a. Survey lines should be oriented so as to sample across the bathymetric gradient to reduce inter-transect variation in the seal encounter rate;

b. East Antarctica (approx. 10-130°E) will be surveyed during the target months of December and January when the patchiness in seal distribution and the possibility of missing seals hauled out in non-surveyed areas (e.g., pockets of glacial ice) are minimized;

c. West Antarctica will be surveyed during January and February when the ice extent is at a minimum to enable large regions of pack ice to sampled effectively;

d. Surveys should target the following time periods to minimize the impacts of the diel pattern of haul-out: 0800-1800 for ship surveys and 1000- 1500 for aircraft surveys; and

e. The survey task group will develop an initial survey design using the ideas developed here for revew at the next meeting.

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APIS
ANTARCTIC PACK ICE SEALS
An international research program coordinated by the SCAR Group of Specialists on Seals

APIS Report No. 2

Report of the 1996 APIS Survey Design and Implementation Workshop

British Antarctic Survey
Cambridge, England

29-31 July 1996

1. INTRODUCTION AND BACKGROUND

1.1 A workshop for planning the design and implementation of a multi-national circumpolar survey was held at the British Antarctic Survey from 29-31 July 1996 in conjunction with the planning meeting for the Antarctic Pack Ice Seals (APIS) Program. Dr. John Bengtson, Chairman of the APIS Program Steering Committee, welcomed the participants, which were comprised of nineteen scientists from nine nations (Appendix 1).

1.2 An integral component of the 5-year APIS Program is a multi-national circumpolar survey to estimate abundance of pack ice seals (Figure 1). The greatest level of coordinated logistic planning among national programs participating in the APIS Program is required for this circumpolar survey (which has the 1998/99 austral summer as its focal field season). Although the APIS Program addresses a broad range of topics pertaining to pack ice seals (e.g., genetics, foraging ecology, energetics, disease and pathology), the unifying objective of the 1998/99 surveys will be to obtain an updated estimate of pack ice seal abundance. Plans are being laid to coordinate the deployment of ships and aircraft from as many as ten nations during 1998/99 to support this effort.

1.3 During the 1995 APIS planning meeting, the need for a workshop was identified to initiate planning a survey design and to develop a set of standard methods for surveys. Drs. Colin Southwell and Jeff Laake, Co-Conveners of the Abundance and Distribution Task Group, had agreed to convene the workshop, and they jointly led the workshop.

1.4 The workshop goals were to:

a. Develop a common understanding of abundance estimation concepts among the participants,
b. Identify and agree on key elements of a survey protocol, essential complementary information (e.g., sea ice), and data standards that will allow sufficient flexibility for varying survey platforms and observer arrangement while ensuring data compatibility to produce a reliable estimate of the circumpolar abundance of pack ice seals, and
c. Initiate development of a survey design to facilitate implementation of a coordinated circumpolar survey of pack ice seal abundance and distribution.

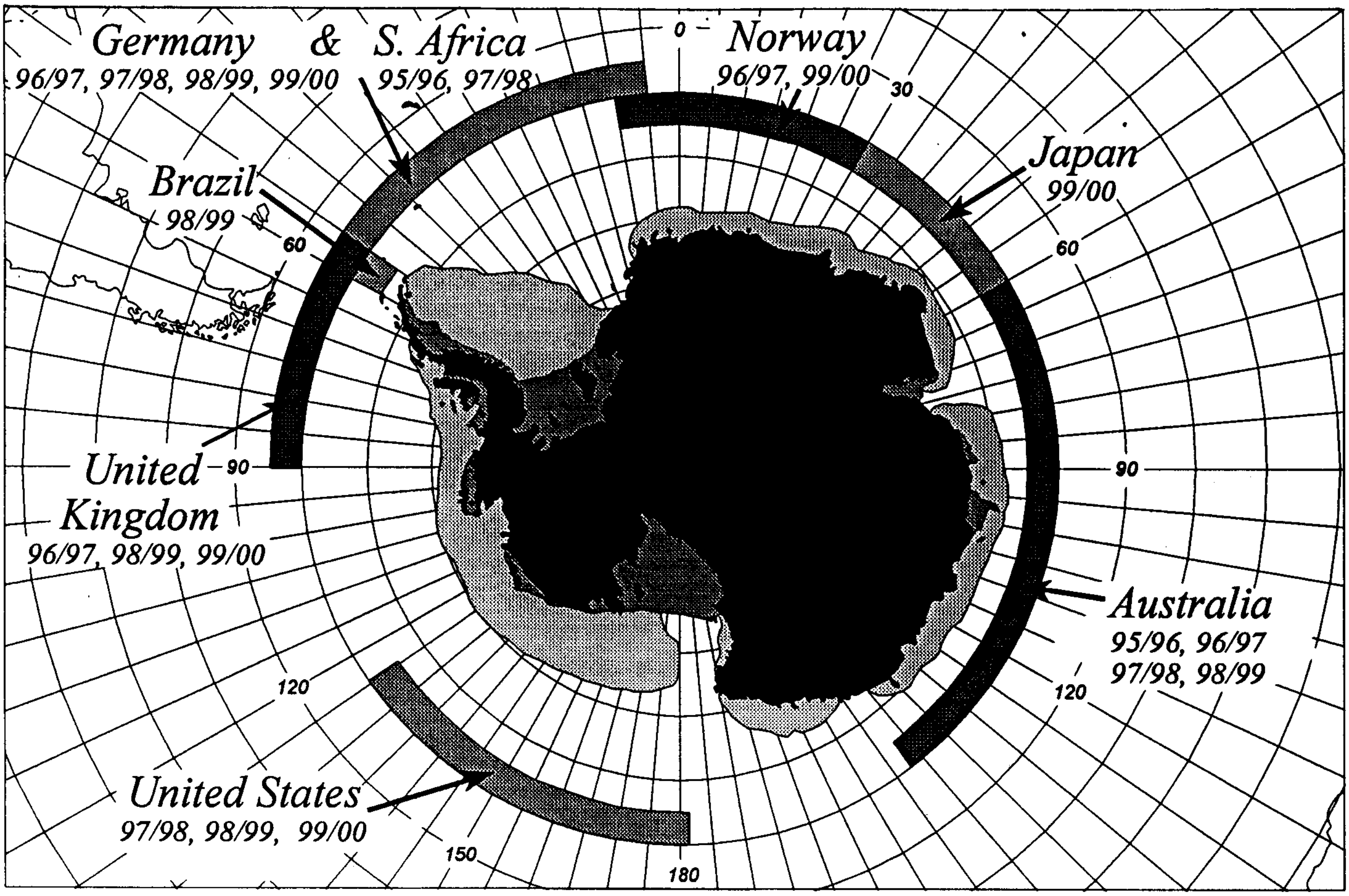


Figure 1. Participation of national Antarctic programs in the international APIS Program (years when research was conducted or is being planned are indicated). In addition to the countries listed, Argentina, Belgium, Chile, and China are also in the process of seeking funding and ship or aircraft support for APIS research.

2. SURVEY AND ABUNDANCE ESTIMATION CONCEPTS

2.1 The general equation for estimating wildlife abundance from a visual survey is:

$$N = \frac{c}{fpv}$$

where N is population size, c is the number of animals counted, f is the fraction of the entire region that is surveyed, p is the fraction of the animals in the survey area that are detected, and v is the fraction of the animals that are available to be counted. The simplest method is a true census in which f, p, and v are all equal to 1 and there are no fractions to estimate. A true census of an animal population is rarely achieved and usually some or all of the fractions must be estimated.

2.2 Ice seals are no exception and each fraction must be estimated to obtain an accurate population size. From the entire pack ice region A surrounding the Antarctic continent, a relatively small area a will be surveyed; therefore, $f = a/A$. Ice seals are quite visible on the ice but there are a multitude of factors that will preclude detecting all of the seals in the survey area (a), so p will typically be less than 1. Ice seals are only available to be counted when they haul onto the ice. During austral summer, the fraction of the seals hauled onto the ice v follows a diurnal pattern with a broad flat peak near mid-day which is typically less than 1. Estimation of each of the fractions f, p, and v will require specific data to be collected and their validity will depend on satisfying some assumptions.

2.3 Historically, the abundance of pack ice seals in the Antarctic has been estimated from ship and helicopter surveys based on strip transects. A strip transect is a rectangular survey area $a = 2WL$ (length L and width $2W$), so $f = 2WL/A$. Ship surveys were conducted with $W = 1/8$ mile and aerial surveys were conducted with $W = 1/4$ mile. In each case, all seals hauled onto the ice were assumed to have been counted within the defined strip (i.e., $p=1$). The estimate of population size is:

$$N = \frac{Ac}{2WLv}$$

2.4 Assuming perfect detectability within a strip may be reasonable if the strip is sufficiently narrow and the animals are highly visible. However, without collecting additional data there is no way to test whether the assumption has been satisfied and if seals are routinely missed within the strip, the estimate will be negatively biased. Also, if a very narrow strip is surveyed to ensure that $p=1$, the count (n) and sampling fraction, f, are greatly reduced, which decreases precision of the estimate.

2.5 Line transect sampling generalizes strip transect sampling by allowing many of the seals to be missed within the strip of width $2W$ (Buckland *et al.* 1993). Let $g(x)$ represent the probability of detecting a seal at perpendicular distance x from the line to a seal on either side of the line ($0 < x < W$). The strip transect assumption that all seals are seen within the strip ($p=1$ or the equivalent $g(x)=1$ for all x) is replaced with the assumption that all seals on the line are seen ($g(0)=1$). An estimate of p is obtained from the set of perpendicular distances to observed seals. Line transect sampling can be conceptualized as a series of parallel strips. If the strips are of equal width (e.g., 8 parallel strips of width W/4) and $p=1$, the expectation is that each strip should contain an equal number of seals. However, depending on the width W and a multitude of factors that affect whether seals are detected, it is more likely that fewer seals will be seen in the outer most strips (bins). By fitting a curve $g(x)$ to the counts in each bin, an estimate of p can be computed (Buckland *et al.* 1993) and N can be estimated as:

$$N = \frac{Ac}{2WLpv}$$

2.6 Because ice seals are often seen in discrete groups, the detections of individual seals are not independent. Therefore, the perpendicular distance to the seal group is measured and the number of seals in the group is recorded. The equation for N is modified slightly:

$$N = \frac{An\bar{c}}{2WLpv}$$

where n is the number of seal groups seen, $\bar{c} = c/n$ is the average number of seals in a group. If the size of a group affects its chances of being seen (size-bias), the average group size is adjusted (Buckland *et al.* 1993).

2.7 In order of importance for ice seal surveys, the 3 primary assumptions of line transect sampling are:

a. All seals on the line are detected ($g(0)=1$),
b. The perpendicular distance to the seal group is measured without error. If distances are recorded by classifying seals into bins, it is assumed the group is assigned to the correct bin, and
c. All seals are seen at their initial location and there is no observer-caused movement either away from or towards the line.

2.8 Assumption 3 is very reasonable for Antarctic pack ice seals because they demonstrate little or no response to approaching ships or helicopters. Assumption 2 can be easily met by choosing one of several methods of measuring distance and testing its adequacy. The most important assumption is that all seals on or near the line are counted. If this assumption is violated (i.e., $g(0) < 1$), abundance will be underestimated.

2.9 Although it is possible that seals will be missed along the ship's path, it is more likely that $g(0) < 1$ during helicopter surveys because of the survey speed and the flight altitude that limits the minimum distance to the seal. Training observers to search primarily close to the line can help minimize the problem but does not assure the assumption is satisfied. An alternative is to survey with 2 observers that search the same area simultaneously and independently. This is the only way to test if indeed $g(0) = 1$. By matching the locations of seals detected by each observer, an estimate of the fraction of seals detected along the line, $g(0)$, can be obtained and p can be estimated appropriately.

2.10 Historically, the fraction of seals available to be counted (i.e., hauled onto the ice) at the time of the survey was estimated by conducting stationary counts throughout the day (Erickson *et al.* 1989). However, it was necessary to assume that all seals were hauled onto the ice at the peak of the curve during mid-day. The development of satellite-time-depth recorders (SLTDRs) allows an accurate assessment of the fraction of seals available to be counted, *v*, during the course of the survey.

3. DATA REQUIREMENTS FOR SHIP AND AERIAL SURVEYS

3.1 The survey data required for abundance estimation of ice seals includes effort, sighting and covariate data (Table 1). Effort data are required to determine the sampling fraction, the time and location of survey transects, and the effort by specific observers. Sighting data provide measurements for each seal group detected during the survey. Covariate data include measurements that may affect the abundance and distribution of seals and the ability of observers to detect seals.

Effort data

3.2 Effort data are required to determine the sampling fraction, and also can be used to locate the position of transects in space and the effort by specific observers. The frequency of effort parameters varies: date and time conversion need only be recorded each day, time and location need to be recorded at the start and end of transects, and at intervals throughout the transect, while observers and platform position need to be recorded whenever they change.

Sighting data

3.3 Sighting data are recorded at the time of each sighting of a seal group. A seal group can consist of more than one seal species. Only seals that were on the ice when first sighted are recorded. If seals dive into the water after first being sighted on the ice they should still be recorded, but seals first seen in the water are ignored. For each seal group, the vital measurements are: a) the perpendicular distance, b) the number of seals in the group by species.

Covariate data

3.4 Covariate data are recorded at regular intervals throughout a transect. These should only be recorded regularly if time is available. Ice classification information collected in real time is considered valuable, and should be recorded in a consistent manner for both ship and aircraft operations. Remote sensing data may also be useful, but it needs to be ground truthed/validated by observers on the observation platform. Weather data can be collected from the ship's officers. Visibility is to be recorded qualitatively. It was not yet possible to come to agreement on whether it would be recorded in relation to distance, type of light (glare, shadows), or differences on either side of the platform.

Sea ice data

3.5 It is critically important that local ice characteristics are recorded during seal surveys. These data are crucial for studies of habitat, species composition and distribution, for "ground truthing" of remotely-sensed (satellite) ice data, and to facilitate links between the survey results and APIS process-oriented studies and complementary studies of lower trophic levels. The types of local ice data, and the frequency or scale at which they are collected should be defined to best meet the needs for all these uses.

3.6 The importance of obtaining the most up-to-date synoptic data on sea ice distribution was recognized. This would require liaison with other scientists with specific interests in sea ice and with knowledge of sources of ice data and data interpretation. The SCAR Working Group on Sea Ice is in the process of developing a new program (ASPECT). The meeting agreed that it was essential to develop the common interests of APIS and EASIZ in sea ice alongside this new SCAR initiative, and to develop close ties to ASPECT as appropriate.

3.7 Therefore, a task group was established to provide recommendations on the minimum set of variables that should be monitored and the appropriate sampling frequency and to ensure that appropriate and adequate sea ice data will be available for analysis of seal survey data. At present, this group is comprised of Drs. M. Bester, P. Boveng, and A. Erickson.

Table 1. Core data to be collected during all ship/aerial surveys of pack ice seals.

Effort data

Transect identifier	Id number/code
Date	Day, month, year, GMT
Time	Hours, minutes, GMT
Time	Hours, minutes, GMT/LT (for conversion of GMT to local time)
Location	Degrees, minutes, decimal seconds, latitude and longitude, GPS
Observers	Initials
Platform position	e.g., left, right, front, back, bridge, above-bridge
Observer altitude	Meters

Sighting data

On/off effort	On/off
Date (GMT)	Day, month, year
Time (GMT)	Hours, minutes for single observer systems Hours, minutes, seconds for double observer systems
Group size	Number of seals in the group
Species	Code for species detected
Distance estimated*	Meters
Distance/angle measured	Meters/degrees, decimal minutes
Instrument**	Code for device used for distance/angle measurement
Side of platform	Left/right

*Note that on shipboard surveys, it is useful to estimate the distance to a seal without using instruments before measuring with an instrument. When the horizon is not visible and distance estimating equipment cannot be used , distance will have to be estimated unaided. The comparison between the observer's 'guesses' and measurements can be used to calibrate 'guesses' made when measurements cannot be made in poor weather. The substrate where seals are first seen (ice or water) can be recorded optionally.
**A task group on survey protocols will recommend distance measurement devices.

Covariate data

Required	
Ice type	Ice categories to be determined
Ice cover	Meaured in tenths
Visibility	3 or 5-point scale
Optional	
Temperature	Degrees celsius
Wind speed	Knots
Cloud cover	Measured in tenths

3.8 The task group's terms of reference are to:

a. Review the protocol for ice classification established in the handbook on seals research methods (Laws 1993), and

b. Contact sea ice researchers to determine the spatial and temporal resolutions and information contents of sea ice data that are or will be available for incorporation into survey analyses and to inquire about their interest in data that could be collected during surveys. These contacts will most efficiently be established through members of ASPECT, EASIZ, and GLOCHANT who have similar interest and needs for sea ice data.

3.9 It was agreed that the results of these investigations and the task group's recommendations will be reported to the next APIS planning meeting.

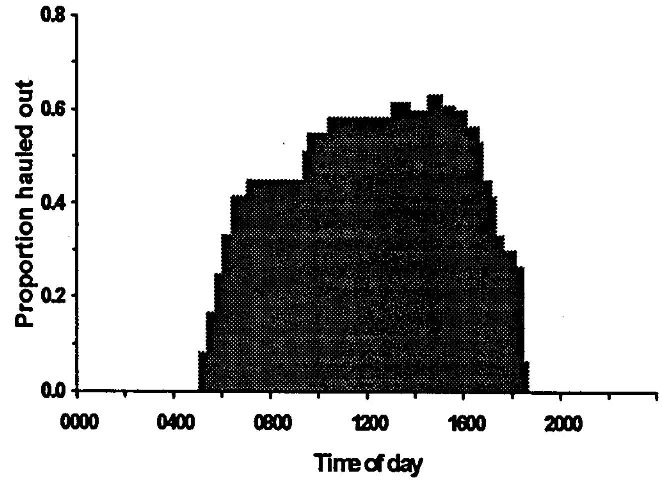
Haulout behavior and temporal availability

3.10 Timing of surveys is a central issue for ensuring accurate estimates of population abundance in any year and for providing estimates that can be directly compared among years for assessing long-term demographic changes in pack ice seal populations. Circumpolar surveys of Antarctic pack ice seals are not generally practical during the breeding season owing to greater geographic extent and thickness of pack ice and because several age classes of male and female portions of the populations may not be hauled out and available for detection (i.e., assumption that D=1, or even that D>0, is not valid). However, most age classes of males and females, except perhaps pups-of-the-year, evidently haul out and are available for detection during the molt season and this is often when population index surveys are conducted for pinnipeds where counts of a complete year newborn cohort are not possible or practical. There are only limited data on the population characteristics of molt in Antarctic pack ice seals. Nonetheless, those data do not suggest that seals in various preparatory or active molt stages refrain from hauling out on pack ice nor that they are absent from the pack ice habitat during the late summer molt seasons. For example, Jochen Plötz (unpublished data) reported that there is no readily apparent difference in the diving and haulout patterns among molting and non-molting Weddell seals in the eastern Weddell Sea.

3.11 The data available for crabeater seals, Weddell seals, Ross seals, and leopard seals (obtained from event recorders or from behavioral observations; Table 2) indicate that the most effective time of day to survey these species to yield correctable indices of abundance is around mid-day during the summer molt-season.

3.12 Earlier studies (Erickson *et al.*, 1989) dealt with the timing of haulout during the summer season. A series of static ice seal counts throughout the day suggested that haulout occurred around 0500 to 2000 local time. More recently, studies (e.g., Bengtson and Cameron *in prep*; Southwell 1996) using satellite linked timed depth recorders (SLTDRs) on crabeater seals present a timing of haulout that corresponds well

Figure 2. Average daily haulout patterns of crabeater seals during February, 1995, off of east Antarctica. The timing of seals hauled out on pack ice was calculated with data obtained from satellite-tagged seals (after Bengtson and Cameron in prep.).



with earlier studies. Thus, in this respect historical survey data could be used for comparative purposes in the future. These more recent studies have also been able to estimate the proportion of seals hauled out on the ice at different times of the day in different months. While a large amount of day to day variation occurs within the records of an individual seal, when averaged over all seals for an entire month or more a distinct haulout curve is observed. The shape of this unimodal curve is similar for all summer months and is bell shaped with tails at dusk and dawn, steep sides, and an extended plateau of maximum proportion of haul out (approximately 0.7) around mid-day (Figure 2).

3.13 The shape of crabeater seal haulout curves changed as the season progressed (Bengtson and Cameron *in prep*). A bimodal haulout pattern was observed in September and April with October and March appearing to be transitional months where juvenile crabeater seals exhibited a bimodal pattern prior to the adults. This bimodal curve is expected to become unimodal again with peak haulout at or about midnight during the winter months. These characteristics of summer month haulout curves and the extreme variability in the haulout patterns of other months were seen as indicators that the APIS pack ice seal survey should take place in the summer months when a large proportion of seals are hauled out at or near their maximum proportions for a long period of the day during daylight hours. A strong recommendation

Table 2. Data available on haulout patterns of Antarctic pack ice seals.

Species	Year	Month	Gender	Age/Size	Latitude	Longitude	Data Type*	Data Source
Lobodon carcinophagus	1985-1995	January-December					SLTDR & PTT	Bengtson *et al.* (1993)
Lobodon carcinophagus	1994/95	Feb/March-Jan.	4 females 5 males	7 adults 2 juveniles	64°03'S to 69°03'S	95°E(Queen Maud Land) 75°E(Prydz Bay) 35°W(E. Weddell Sea)	SLTDR (4 Ad. males; 2 Ad. females; 2 juv. females; 1 juv. male)	Bengtson and Cameron (*in prep*)
Lobodon carcinophagus	1985						PTT (4)	Shaughnessy (1990)
Lobodon carcinophagus	1994-1996						SLTDR (6)	Southwell (1996)
Lobodon carcinophagus	1986	mid-March					TDR (6)	Bengtson and Stewart (1992)
Lobodon carcinophagus	1993	22-26 Feb.-June	3 females 5 males	125-220kg body mass	70-72°S	7-16°W (Queen Maud Land)	SLTDR (6)	Nordøy *et al.* (1995)
Leptonychotes wedellii						McMurdo Sound	TDR	Castellini *et al.* (1992)
Leptonychotes wedellii		Feb.-October	Females	=>6yrs		McMurdo Sound	SLTDR (26)	(Testa 1994)
Leptonychotes wedellii							TDR (2)	J. Plötz (unpublished data)
Ommatophoca rossii	1987	March (2.5 days)				W. Weddell Sea	TDR (1)	Bengtson and Stewart (*in press*)
Hydrurga leptonyx	1991-1995	March-November				Bird Island, South Georgia	Behavioral observations	A. Walker and Ian Boyd (pers. obs.)

* SLTDR = satellite-linked time-depth recorder; PTT = platform terminal transmitter (satellite tags); TDR = time-depth recorder.

was made to deploy SLTDR's configured to show haulout prior to surveying to determine haulout proportions in each area. Also, because of the resolution of the haulout proportion data available from these instruments, surveys should be conducted whenever daylight and other conditions permit.

3.14 In addition to haulout proportion, further observations from the SLTDR data were discussed concerning the biology and life history crabeater seals. The two SLTDR's deployed by John Bengtson that were still operational during the breeding season had a very large counter-clockwise migration and rarely moved north of the continental shelf. Also, both of those seals instrumented by Bengtson and those by Colin Southwell in 1993/94 spent a portion of every day during the breeding season in the water. However, two seals that Southwell instrumented in 1994/95 had multiple consecutive days of 100% haulout followed by a high proportion of time spent in the water. It was also noted that when the periods of 100% haulout were removed from the haulout curves, the curves were very similar to those of seals which did not haulout for multiple days. Researchers also observed a period (from seven days to one month) in which no data were reported. It is believed that this absence of data is due to an as yet undetermined behavior. Also, speculation as to the cause of the seasonal change in haulout patterns was discussed and focused mostly on the effect of light availability on the crabeater seal's ability to forage effectively.

3.15 Finally, observational data on leopard seal haulout at Bird Island (Tony Walker) was presented. While the resolution of sightings at this site did not allow for determination of haulout proportions, observations did reveal a high level of site fidelity and a distinct population of resident seals. These characteristics were seen as an indication that using SLTDR's to determine haulout proportions is possible as well as required for a circumpolar ice seal census.

4. SURVEY DESIGN

4.1 A basic premise for the APIS circumpolar survey design will be to spread our sampling effort throughout the pack ice surrounding the continent. We want to avoid having large gaps longitudinally (e.g., entire areas of residuals pack-ice should not be left un-sampled) and we want to sample across the pack-ice area latitudinally (e.g., we want to avoid only sampling the ice edge). To achieve as large a sample as possible, we should use both visual and photographic surveys, if possible, and survey from all vessels that are transiting through the pack into and out of research stations. Although, opportunistic effort is not ideal and will require post-stratification of regions, it may be necessary to provide sufficient sampling of the entire continent.

4.2 Ideally, we would like to place transect lines across any density gradient (e.g, from high to low) to reduce the inter-transect variance For example, if there is a latitudinal gradient associated with the continental shelf or the ice edge, we should place transects oriented roughly north-south crossing all latitudes to the fast ice. This can be accomplished with parallel lines following along longitudinal lines or with a sawtooth pattern that is oriented in a north-south direction but the lines cross longitudinally at a pre-defined angle. Transects should be spread as far apart as needed to cover the entire region with the amount of effort available.

4.3 The precision of the estimate will depend primarily on the amount of variation in the spatial distribution (i.e., degree of patchiness) of seals and the number of replicate lines and total line length (i.e., % of the area sampled). This introduces a trade-off in terms of the timing of sampling within the year. The patchiness of seals will decrease as the ice extent increases from its minimum and seals spread across the pack (note: it will also decrease the chances of encountering very high sighting rates that over-load the observer); however, also as the ice extent increases, a smaller percentage of the area is sampled with a given amount of effort. The minimum nor maximum ice extent will be optimal. The maximum ice extent will provide the lowest sampling fraction and much time will be spent in areas of 0 or very low density. However, the minimum ice extent may not be optimal for all areas either because the pack ice disappears entirely from sections of the coast, possibly concentrating seals on the remaining residual pack ice or near glacial ice which would not be surveyed or forcing seals to spend more time in the water. A reasonable alternative may be an intermediate ice extent between its absolute maximum and minimum. Possibly a target would be the month at which the ice extends across the shelf but only to a distance such that the survey platform can easily reach the coast.

Table 3. Stratification of survey effort by region.

Region	Percentage area[1]	Percentage abundance[1]
Amundsen and Bellingshausen Seas 60°W-130°W	17%	9%
Ross Sea 130°W-160°E	29%	19%
Southern Pacific Ocean 90°E - 160°E	16%	14%
Southern Indian Ocean 20°E-90°E	10%	11%
Eastern Weddell Sea 20°E-20°W	5%	11%
Western Weddell Sea 20°W - 60°W	22%	36%

[1] Percentages constructed from pack ice areas and abundance estimates given by Erickson and Hanson (1988).

This is unlikely to occur at the same month around the entire continent, so it maybe necessary to sample within a range of months, and choose the best month(s) for each sector of the continent. Clearly, this has implications on the timing of the survey within the year which may also be influenced by the ability to collect availability data at the same time. This issue needs a fair amount of discussion.

4.4 Each participating nation has identified a sector in which they will likely sample (see Figure 1); however, we will not be at a stage of specifying the detail for a design until we know how much time is available from each platform. Workshop participants agreed that the survey design should be viewed as a continuing and dynamic task for the APIS Program's "Abundance and Distribution Task Group", which will need further discussions at future planning meetings. In the meantime, Drs. Laake and Southwell agreed to evaluate the feasibility of specifying detailed survey designs for each of the circumpolar sectors in which APIS surveys are to be conducted.

4.5 It was estimated that 9,000 nm (16,668 km) of survey effort, as proposed after the previous planning meeting, should be the target sampling effort to achieve 10% precision (e.g., CV=0.10) on the abundance of ice seals in the pack ice. This is a much larger effort than has ever previously been attempted. The estimates of Erickson and Hanson (1988) are based on 5400 nm (13,000 km) of aerial sampling and 2900 nm (5400 km) of shipboard sampling; however, the sampling was spread over 3 decades. It is not sufficient to achieve this level of effort and exclude areas of pack ice entirely from the survey. The effort must be apportioned around the continent to achieve the goal of a continent-wide abundance estimate (Table 3).

Identification and specifications of platforms which may participate in the APIS survey

4.6 The circumpolar survey requires the use of multiple platforms throughout the pack-ice in the recommended survey time of summer 1998/99. Survey platforms will comprise both ships (dedicated and non-dedicated) and aircraft (fixed wing and helicopter). Dedicated ships will be able to determine their cruise track. Non-dedicated ships will have a cruise track determined by other purposes, but will still be able to make a useful contribution to the APIS survey. Non-dedicated ships would include ships used for re-supply of stations on the continent, and tourist ships. It was recommended that information on the platforms available or potentially available, and their specifications, be collated for consideration when designing the survey layout (for preliminary summaries, see Tables 4 and 5).

Table 4. Characteristics of ships potentially available as survey platforms for the APIS Program.

Country	Platform name	Viewing position/height	Helicopters Accommodated	Helicopters Available	Ice breaking capacity
Argentina	Alm. Irizar	Not available	2	2	
Australia	Aurora Australis	Bridge -16 m above bridge - 18m	2	2	Class A1
China	Xuelong	Bridge - 22 m above bridge - 25 m	2	0	Class A2
Germany	Polarstern	Crow's nest - 24 m	2	2	
South Africa	SA Agulhas	Bridge - 17 m Above Bridge - 19m	2	2	Class A1+
United States	Polar Star/ Polar Sea	Bridge - 19m Aloft con - 32m	2	2	Class A1
United States	N.B. Palmer	Bridge - 20m Aloft con - 22m	2	0	Class A2
United States	L.M. Gould	Bridge - 15m Aloft con - 17m	0	0	Class A1

Table 5. Characteristics of aircraft potentially available as survey platforms for the APIS Program.

Country	Platform Type	Minimum speed / cruising speed (kts)	Maximum range: single/paired (km)*	Observer Capacity	Direction of view	Window dimensions (width x height in cm)	Declination angle	Bubble Window	Camera
Argentina	Puma	Not available	Not available	Not available	Not available	Not available	Not available	No	?
Australia	Sikorsky-76	0 / 80	300/600	4	Lateral	Front to rear 1 - 80x75 2- 40x 75 3 - 70 x 75 4 - 30x75	50	No	No
Germany	Dornier DO 228-??? Fixed-wing	/135	800-1000	5	Lateral	50 x 50	90	Yes	Yes
South Africa	Puma 330 J (Oryx)	0/80	100/415	6-8	Forward & lateral	Lateral - 4 windows (43.5 x 31)	90	No	Yes
United Kingdom	Twin Otter	90-120	1800	4	Lateral	34 x 34	50	N/A	Yes
United States	Aerospatiale Dauphin HH-65A	40/120	90/185	2	Lateral	Left - Right -	60	No	Possible
United States	LC-130	130	5500/5500	64	Lateral	variable	50	Possible	Possible

* excluding safety fuel

Determination of total sampling effort required

4.7 For planning purposes, it will be necessary to predict to total effort required to obtain an abundance effort with desired precision, and allocate effort in the most efficient manner. A preliminary assessment of total effort was undertaken by examination of historical data. It was recommended that further examination of historical data be undertaken to determine the optimal allocation of total effort within regions.

Transect layout

4.8 Taking into consideration the total effort required, available platforms and their range specifications, a preliminary survey design (transect placement) will be established. The design will aim to achieve the most representative sample of pack-ice possible, taking into consideration the total effort required, allocation of effort within regions and specifications for available platforms, while maximizing efficiency. Wherever possible transect lines will be designed to have end-points near stations to facilitate combining survey and re-supply work. A saw-tooth transect layout, designed to allow for variations in the edge of the pack-ice, is recommended.

Considerations for implementing the survey design

4.9 Important issues identified for design implementation included:

a. Protocol for following transect lines (what to do when this is not possible due to ice conditions);
b. Time of day for sampling for ships and helicopters; and
c. Protocol for adapting to changes in the ice edge and area of ice

4.10 Other aspects of the survey protocol which require attention are:

a. Transect layout-sawtooth design; avoid following leads in the ice,
b. Ships--avoid going towards or away seals,
c. Helicopter--ladder design; allows breaks along legs,
d. Spacing of transects--throughout ice pack in circumpolar sense,
e. Replicates--day of effort, and
f. Stratification--logitudinal: different pack ice masses, organize surveys by countries; latitudinal: within a pack ice mass, shelf break/distance to ice edge.

5. SURVEY IMPLEMENTATION

Platform characteristics

5.1 Details of aircraft and ship characteristics that are available for APIS surveys are provided in Tables 4 and 5. Useful information on platforms (ship or aircraft) is provided by line drawings, technical specifications and photographs. Bubble windows on aircraft improve observers' ability to see seals by:

a. Increasing the angle of declination to 90° (i.e., straight down), and
b. Enabling a view ahead, which provides time for seals to be identified before their perpendicular distance to the flight path is estimated.

5.2 Most nations plan visual counts from ship or helicopter platforms. In addition, several nations are planning possible aerial photography surveys:

a. Germany--4 flights of 5 hours in 2 days,
b. Norway--RC20 camera with 150mm lens,
c. UK--using twin Otter from Rothera Station,
d. US--using Twin Otter from McMurdo Sound,
e. Chile--using Twin Otter, King George Island.

Data management

5.3 A task group was formed (Gelatt, Laake, Siniff, Southwell) to design a database to collate information from surveys and to design forms for the collection of data. Both should include a set of core fields and data that are to be collected. Although format for forms will be suggested, different situations will lead to some variation on the form of core data. Three types of data should be collected during surveys:

a. Effort data, to define the area sampled,
b. Sighting data, of seals observed, and
c. Covariate data on ice conditions, weather, and bathymetry.

Effort data

5.4 Effort data (e.g., on/off sighting effort, number of observers, etc.) are to be recorded at regular intervals (e.g., 15 minutes) and for each significant event (e.g., change of ship's course, change of observer). Time and date should be recorded routinely as GMT.

Sighting data

5.5 The perpendicular distance of seals from the platform is a vital parameter. For ship surveys, a task group (Laake) was formed to provide information on distance measuring instruments.

5.6 Each row on the sighting data form is to refer to a group of seals; group size and species composition are to be recorded. On shipboard surveys, it is useful to 'guess' the distance to a seal without using instruments before measuring with an instrument. When the horizon is not visible and distance estimating equipment cannot be used , distance will have to be estimated unaided, then the comparison between the observer's 'guesses' and measurements can be used to calibrate 'guesses' made in poor weather. The substrate where seals are first seen (ice or water) can be recorded optionally.

Covariate data

5.7 These should only be recorded regularly by seal observers if time is available. Ice classification information collected in real time is considered valuable. The task group on sea ice classification will recommend the type of data to be collected. It should be consistent for ship and aircraft operations. Remote sensing data may also be useful, but it needs to be ground truthed/validated by observers on the observation platform.

5.8 In general, audio-cassette recorders are considered a good method for collecting data, so that observers can watch the ice continuously. One person should also record data on paper simultaneously.

5.9 Weather data can be collected from the ship's officers. Visibility is to be recorded qualitatively. It was not agreed whether it would be recorded in relation to distance, type of light (glare, shadows), or differences on either side of the platform.

Species identification

5.10 Species identification should be included in training programs before surveys begin. This should include written descriptions, line drawings (e.g., Antarctic seals handbook) photographs and video footage showing movement patterns which aid identification. Helicopter time should be allocated to such training: record species at the survey altitude and then check identification at low altitude and close range (then return to regular course using GPS.

5.11 Such training can be conducted effectively in helicopter loiter time

5.12 It must be acknowledged that not all seals can be identified to species at a distance; honesty in such situations should be rewarded

5.13 In surveys it may be sensible to restrict species identification to bins 1 and 2 while still counting seals in more distant bins.

5.14 In aerial photographic surveys, it may be necessary to allocate some low altitude runs for species identification, while estimating density from higher altitude runs.

Estimating g(0) using double observers

5.15 In aerial surveys, seals on the flight path or near it may not be seen from some types of aircraft. Consequently, the proximal bin is moved laterally to where seals can be seen. To satisfy the assumption that all seals are recorded on the transect line, a double observer scheme can be used. This involves two independent observers counting the same area on one side or both sides of the platform. Data are analyzed as in a mark-recapture experiment, with animal conceptually marked by each observer. Sightings then need to be matched, requiring precise estimates of time, especially in helicopter surveys.

5.16 Australian researchers have developed a system that includes:

a. A 4-track tape recorder,
b. A keypad system that records data on a PC connected to a GPS, an altimeter and a sighting gun to measure angle of declination from the horizon to the seal,
c. Four observers, and
d. A fifth person (co-ordinator) who checks that the PC screen accords with information on the tape recorder.

5.17 The double observer system provides an important approach to enable assumptions to be tested about:

a. Comparability of survey aircraft, and
b. Performance of observers over long periods of observation.

5.18 The design will be made available to other researchers. The APIS group looks forward to seeing detailed results of this research.

5.19 Another approach to estimating g(0) might be aerial photography.

Density overload

5.20 In areas of high density it may be impossible to record all seals. Options to cope with this problem are:

a. Decrease helicopter speed,
b. Restrict counting to the proximal 2 or 3 bins,
c. Rely on a video recorder or photography, if available, and
d. Increase the number of observers.

Observer training

5.21 Training of observers is a very important aspect of the survey preparation. Important issues include:

a. Search pattern,
b. How to use distance measuring devices,
c. Species identification, and
d. Using computer images of sea-ice, leads, icebergs and seals generated in PowerPoint.

Helicopter altitude and speed

5.22 Important trade-offs are that lower altitude jeopardizes safety but improves ability to identify species. Other considerations that affect choice of altitude are:

a. Aircraft characteristics,
b. Legal and permit requirements, and
c. Operational requirements of ship and/or helicopter.

5.23 At an altitude of 500 feet or higher, species identification is a problem. To enable seal species to be identified satisfactorily, aerial surveys should be conducted at altitudes between 200 and 400 feet, depending on aircraft characteristics and speed.

Definition of seal groups

5.24 Seal groups are defined in the Antarctic Pinniped Handbook (all seals within a distance of x body lengths). When all species on a floe are considered to be in the same group, they are all recorded in a single bin according to the distance of the center of the group from the platform. Problems with the definition of a group are encountered in fast -ice where seals are evenly spaced along the fast-ice edge or along tide cracks.

Aerial photography and remote sensing

5.25 Aerial photography and remote sensing of pack ice seals can provide valuable information on seal distribution and abundance over broad areas. These techniques can be used both to evaluate the efficacy of visual surveys conducted by ship or aircraft as well as providing data in areas inaccessible to ship-based surveys.

5.26 Therefore, a task group on aerial photography and remote sensing was established to investigate these topics and to recommend the best approaches for APIS to incorporate into its survey design. At present, the group consists of Drs. I. Boyd, J. Laake, T. Øritsland, J. Plötz, and D. Torres.

5.27 The group's terms of reference are to provide advice on:

a. Platforms available including type of aircraft, mounts for equipment and availability of aircraft,
b. Camera types, especially for: 1) B&W large format photography, 2) video, 3) infra-red,
c. Survey design, including problems associated with species identification and sightability of animals, altitude and area of coverage,
d. Locations that can be surveyed,
e. Provision of information on ice type, especially as ground truth for synoptic satellite data, and
f. Advantages and disadvantages of vertical versus oblique methods.

6. WORKSHOP SUMMARY

6.1 Workshop participants discussed techniques for surveying seals and the equally important aspect of measuring the time-varying proportion of seals that are hauled out onto the ice at any one time. The pack ice will be surveyed from ships, helicopters, and fixed-wing aircraft. Although the workshop focused on visual surveys based on line transect sampling a working group was formed to coordinate complementary aerial photographic surveys. The workshop participants agreed on the following key elements for visual surveys:

a. The perpendicular distance (or distance interval) to observed seal groups must be measured to implement line transect sampling,
b. Observers should be trained and tested in species identification, distance measuring, and data recording,
c. Required core survey data were defined and a group was tasked with developing a database and standard data forms for each survey, and
d. Ice type and coverage is an important predictor of seal abundance and these features were included in the core survey data. A task group was developed to specify ice classification data and to identify the resolution of satellite imagery and its use in measuring the area of pack ice within each class.

6.2 Several important issues pertaining to survey design were also agreed:

a. Survey lines will be oriented so as to sample across the bathymetric and sea ice gradients to reduce inter-transect variation in the encounter rate,
b. The coastline of East Antarctica (i.e., approximately 10°W to 150°E) should be surveyed during the target months of December and January to reduce the patchiness in the distribution of seals and the possibility of seals being in non-surveyed pockets of glacial ice,
c. The remainder of the continental coastline (including the Ross and Weddell Seas) should be surveyed during January to February when the ice extent will allow large regions of the coastline to be sampled effectively, and
d. Surveys should target the following time periods to reduce the impacts of the diel pattern of haul-out: 0800-1800 for ship surveys and 1000-1500 for aircraft surveys.

6.3 Five task groups were charged with following-up on workshop discussions and to continue the development of various components of the APIS Program's circumpolar survey of the abundance and distribution of pack ice seals. The five task groups are:

a. **Survey protocols and guidelines** (Laake, Southwell): evaluate the feasibility of specifying detailed survey designs for each of the circumpolar sectors in which APIS surveys are to be conducted,
b. **Identify distance measuring devices** (Laake): identify and recommend distance measuring devices that would facilitate the collection of comparable data from the various APIS Program surveys,
c. **Sea ice classification** (Bester, Boveng, Erickson): recommend the set of sea ice variables that should be monitored and the appropriate sampling frequency, and ensure that appropriate and adequate sea ice data will be available for analysis of seal survey data,
d. **Aerial photograph and remote sensing** (Boyd, Laake, Øritsland, Plötz, Torres): evaluate techniques and protocols that can be utilized in standard, comparable ways by APIS investigators, and
e. **Database management** (Gelatt, Laake, Siniff, Southwell): design a database to collate information from surveys and design standard forms for data collection.

Appendix 1. List of participants in the APIS workshop for survey design and implementation, Cambridge, 29-31 July, 1996.

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Appendix 2. Agenda for APIS workshop for survey design and implementation, Cambridge, 29-31 July, 1996.

Monday 29 July

I. Introduction (0900 - 0920)
- a) Workshop Goals
- b) Overview of Agenda

II. Abundance estimation / line transect sampling concepts (0920 - 1200)
- a) Sampling concepts for abundance estimation of ice seals
- b) Comparison of line and strip transect sampling
- c) Why use line transect sampling?
- d) Assumptions
- e) What really matters?
- f) What can go wrong?
- g) What data must be collected?

III. Availability of seals /proportion hauled-out on pack ice (1300 - 1630)
- a) Results of recent SLTDR deployments
- b) Sources of variation
- c) Identify gaps

Tuesday 30 July

IV. Survey Implementation Issues (0900 - 1200, 1300-1400)
- a) Platform characteristics
    - i) Ships
    - ii) Aircraft
- b) Survey protocol
    - i) Platforms
    - ii) Observers
    - iii) Data definition/ collection
    - iv) Data recording
    - v) High density/data overload
    - vi) Independent observer schemes
- c) Observer Selection /Training
    - i) Suitability
    - ii)Training - practice sessions/simulations

V. Survey Design (1400 - 1630)
- a) Transect layout
- b) Stratification
- c) Timing (daily/seasonal)
- d) Sample size target

Wednesday 31 July

VI. APIS Survey Plan / National Commitments (0900 - 1200)
- a) Review of national survey zones / platforms / time available
- b) Organization of survey planning and coordination / timetable

Appendix 3. Provisional timetable for APIS survey planning tasks.

February, 1997	Report on the feasibility of developing detailed survey designs
May, 1997	Draft standard data forms, data collection protocols
June-August, 1997	APIS planning meeting: I. Status report from each participating national program a) Platforms and time secured for survey b) Identification of survey personnel c) Identification of resources needed for the survey II. Review and modification of initial survey design III. Review and modification of survey protocol and field guidelines
June-August, 1998	APIS Planning meeting: I. Review results of surveys conducted during Sep 1997 - Feb 1998 II. Finalize survey design
November, 1998	Continent-wide surveys begin (continuing through February, 1999)
June, 1999	Data submitted to APIS secretary
August, 1999	Analysis workshop I I. Review of survey trip reports II. Review data for completeness II. Develop data summaries III. Perform initial analyses and review results IV. Identify further analyses needed V. Assign sections of the report for intersessional work
August, 2000	Analysis workshop II I. Finalize analysis II. Complete report

Appendix 4. Literature cited.

Bengtson, J.L. and M.F. Cameron. *In prep*. Haulout patterns of crabeater seals in the Antarctic pack ice.

Bengtson, J. and B. Stewart. 1992. Diving and haulout behavior of crabeater seals in the Weddell Sea, Antarctica, during March 1986. Polar Biol. 12: 635-644.

Bengtson, J.L. and B.S. Stewart. *In press*. Diving patterns of a Ross Seal (*Ommatophoca rossii*) near the eastern coast of the Antarctic Peninsula. Polar Biol.

Bengtson, J.L., R.D. Hill, and S.E. Hill. 1993. Using satellite telemetry to study the ecology and behavior of Antarctic seals. Korean J. Polar Res. 4: 109-115.

Buckland, S.T., D.R. Anderson, K.P. Burnham, and J.L. Laake. 1993. Distance sampling: estimating abundance of biological populations. Chapman and Hall, London. 446 p.

Castellini, M.A., R.W. Davis, and G.L. Kooyman. 1992. Annual cycles of diving behavior and ecology of the Weddell seal. Bull. Scripps Inst. Oceanogr. Univ. Calif. No. 28.

Erickson, A.W. and M.B. Hanson. 1988.Continental estimates and population trends of Antarctic ice seals. In: Proceedings of the 5th SCAR Symposium on Antarctic Biology; Hobart, August, 1988.

Erickson, A.W., L.J. Bledsoe, and M.B. Hanson. 1989. Bootstrap correction for diurnal activity cycle in census data for Antarctic seals. Mar. Mamm. Sci. 5: 29-56.

Laws, R.M. 1993. Antarctic seals: research methods and techniques. Cambridge University Press, Cambridge. 390 p.

Nordøy, E.S., L. Folkow, and A.S. Blix. 1995. Distribution and diving behaviour of crabeater seals (*Lobodon carcinophagus*) off Queen Maud Land. Pol. Biol. 15: 261-268.

Shaughnessy, P. 1990. Tracking crabeater seals in the Antarctic pack ice. Argos Newsletter 40:11.

Testa, J.W. 1994. Over-winter movements and diving behavior of female Weddell seals (*Leptonychotes weddellii*) in the southwestern Ross Sea, Antarctica. Can. J. Zool. 72:1700-1710.

APIS
ANTARCTIC PACK ICE SEALS

An international research program coordinated by the SCAR Group of Specialists on Seals

Participation in the APIS Program is open to everyone who would like to become a collaborating contributor. Pinniped scientists, as well as those who study complementary elements of Antarctic marine ecosystems, are encouraged to join in the planning and implementation of this international research initiative.

If you are interested in being added to the APIS Program's mailing list, please contact a member of the Steering Committee, whose names, addresses, and numbers are listed below.

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