Overview of minke whale sightings surveys conducted on IWC/IDCR and SOWER Antarctic cruises from 1978/79 to 2000/01

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ABSTRACT

The IWC Southern Hemisphere minke whale assessment cruises (IDCR and SOWER) have been conducted since 1978/79 in the Antarctic regions of all six IWC management Areas for baleen whales (covering all, or more recently, part, of one Area each season). During the 23-year history of the programme to 2000/01, a total search distance on primary effort of 70,340 n.miles has been achieved during 2,448 ship-days in the Antarctic. A total of 6,027 primary minke whale school sightings were recorded. Over the years, there have been two major and some minor modifications to the survey design as a result of the development of survey procedures. These developments represent the best possible compromise between statistical needs and logistics. This paper outlines the most significant modifications that have occurred to the research equipment, protocols and data collection. Some preliminary results are also included. From 1985/86, the beginning of the second circumpolar set of cruises, the programme (initially a combination of Discovery marking and sightings) became essentially a dedicated line-transect systematic sightings cruise only. Modification of the survey design from the third circumpolar set of cruises (from 1991/92), to cover the whole region south of 60°S in the Antarctic resulted in a change in emphasis of the latitudinal coverage, especially in Areas I, II, III and V; the implications of this are discussed. The paper also describes: guidelines for the identification of minke whales; methods used for assessment of duplicate status in passing mode with independent observer; the protocol used for conducting the estimated angle and distance experiment; and methods used for determining the southern boundary of the research area (ice-edge). The programme has also enabled collection of biopsy, photo-identification, oceanographic and acoustic samples, and can be adapted to research programmes in other parts of the world. It is concluded that the programme has developed and established standard sighting procedures and has also improved the precision of whale identification standards in the Southern Ocean.

KEYWORDS: MONITORING; POPULATION ASSESSMENT; SURVEY-VESSEL; ANTARCTIC; ANTARCTIC MINKE WHALE; DWARF MINKE WHALE; SOWER

INTRODUCTION

This paper presents an overview of the minke whale (primarily the Antarctic minke whale *Balaenoptera bonaerensis*, with some dwarf minke whales, *B. acutorostrata*) sighting surveys component of the International Whaling Commission/International Decades of Cetacean Research (IWC/IDCR; 1978/79 until 1995/96) and IWC/Southern Ocean Whale and Ecosystem Research (IWC/SOWER; since 1996/97 – see review in IWC, 1997) austral summer Antarctic cruises, noting changes across years. With the start of the SOWER programme, a blue whale research component was added but all of the Antarctic cruises have been primarily minke whale assessment cruises designed for abundance estimation (Butterworth *et al.*, 1994). The first circumpolar series, hereafter CPI (i.e. all six management Areas covered longitudinally) was between 1978/79 and 1983/84, CPII was between 1984/85 and 1990/91, while CPIII is currently incomplete (from 1991/92). During the early years, there was a major change in emphasis of the cruises, with a shift from marking to sightings surveys. The sightings survey methodology underwent early development and standardisation phases during which many experiments were conducted and the current survey procedures were developed.

This paper does not attempt to provide a comprehensive description of all aspects of this research programme Details of the Soviet vessel activities (ice-edge mapping etc.), oceanographic survey (Shimada *et al.*, 1997) and the blue whale research (IWC, 1997), are not covered in this summary. The survey procedures, experimental design and the equipment developed and used during the first 10 cruises (1978/79 to 1987/88) are summarised in Joyce *et al.* (1988). After the first 10 years, the survey protocol became largely routine with no major changes but some refinement.

One motivation for the development of this paper is the observation that although the full third circumpolar set of cruises is not yet complete, the indications are that the abundance estimates for the set will be appreciably lower than those for the earlier surveys (IWC, 2001; Branch and Butterworth, 2001b). As part of ongoing efforts to determine whether this represents a real change in abundance or is a consequence of some other factors, this paper therefore describes some of the key areas where changes in protocol and data recording have been made.

SURVEY ITEM

Research area

First two circumpolar series (1978/79 to 1983/84, 1985/86 to1990/91)

One of the IWC Antarctic Management Areas (Fig. 1, see Donovan, 1991) was surveyed during each cruise in CPI and CPII. In each Area, longitudinal coverage took precedence over latitudinal coverage. The northern boundary of each Area was established around 60°S-61°S in Areas IV and VI, and at 62-65°S in Areas I and III, and 58-59°S in Areas II and V (Fig. 2a-f).

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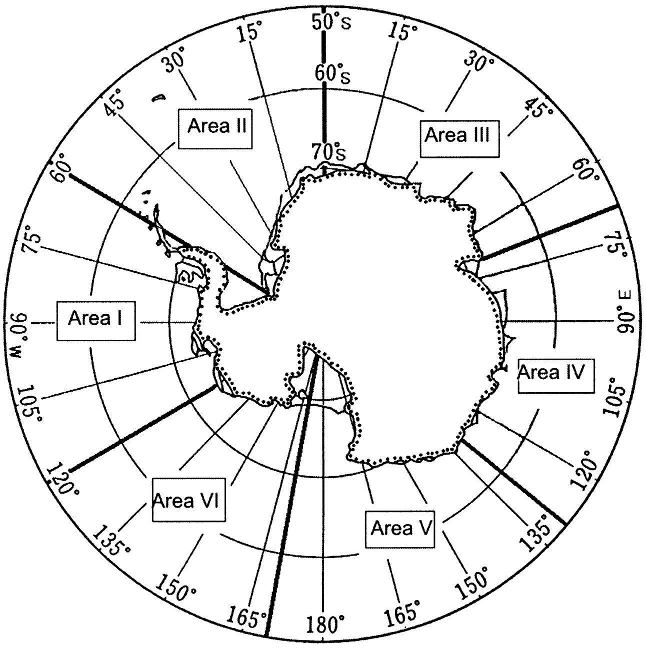

Fig.1. The IWC Antarctic Areas for the management of baleen whale species (except Bryde's whale).

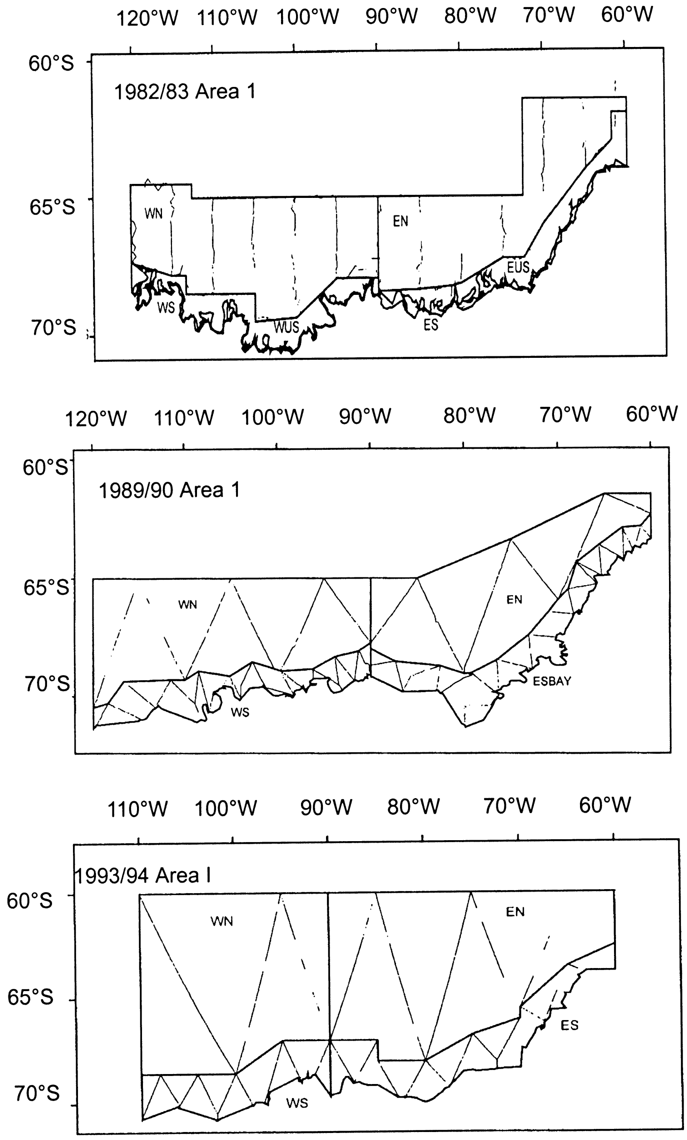

Fig. 2a. Strata surveyed in Area I throughout circumpolar sets from 1978/79 to 1997/98 (after Branch and Butterworth, 2001b).

Third circumpolar series (1991/92 to the present)

During CPIII, on all cruises since the 1991/92 cruise, priority has been given to latitudinal coverage (from the ice-edge to 60°S) instead of longitudinal coverage (i.e. there was additional coverage of northern waters compared with the first two circumpolar cruises). As a consequence of this modification (the aim was to correct for the bias of animals between 60°S and the northern boundary of earlier surveys), there has been an expansion in the width of the southern stratum (Fig. 2a-f).

Research vessels

Over the years, a total of eight vessels have been involved in the cruises. Six of the ships equipped with sighting platforms were provided by the Government of Japan: *Kyo Maru 27* (K27); *Toshi Maru 11* (T11); *Toshi Maru 16* and *18* (T16 and T18); and the *Shonan Maru* and *Shonan Maru 2* (SM1 and SM2). Two vessels were provided to the programme by the USSR: the *Vdumchivy 34* (V34) and the *Vderzhanny 36* (V36). One Soviet vessel was predominantly used for research in the vicinity of the ice-edge and to map the ice-edge between 1980/81 and 1986/87. SM1 and SM2 have been engaged in this programme for over 20 years consecutively (i.e. since 1981/82) and most of the sightings data has come from these vessels. A summary of ship deployment for each cruise is presented in Table 1. The specifications of the Japanese research vessels are shown in Appendix 1. Photographs of the research vessels are shown in Appendix 2.

Transit survey and homeports

On each cruise, a systematic sightings survey was conducted from homeport to Antarctic research area and vice versa using the same methodology as on the cruises. 'Closing' mode was used unless a schedule problem occurred in which case 'passing' mode was substituted (see below for definitions). The pre- and post-cruise meetings were held in the homeports and the ships re-fuelled and re-provisioned. In some cases, the Soviet research vessel met with a Soviet ship for fuel and supplies. The cruises have used a total of 10 homeports in 7 nations (Table 1).

Research periods

Table 2 shows the overall schedule for each cruise, comprising the schedule of the Antarctic research (minke component only) and the transits. Table 2 also shows the number of research days in each calendar month per cruise. The minke whale research component of the 1994/95 cruise, and all subsequent cruises, was delayed by a period of two or three weeks compared with the previous cruises. The aim of this was to facilitate cruise track construction by increasing the likelihood of the ice-edge receding prior to the survey to form a compact edge at a position more readily determined.

Change of the positioning (navigation) system

Prior to 1981/82, all vessels employed celestial navigation as the principal technique for determining position in the Antarctic. The Navy Navigation Satellite System (NNSS) was installed on the Japanese vessels from the 1981/82 cruise. From 1991/92, Global Positioning System (GPS) equipment was used on both research vessels. Each of these changes improved the accuracy of the positional data recorded during the research activities. From 1993/94, latitude and longitude on the sightings and effort data forms

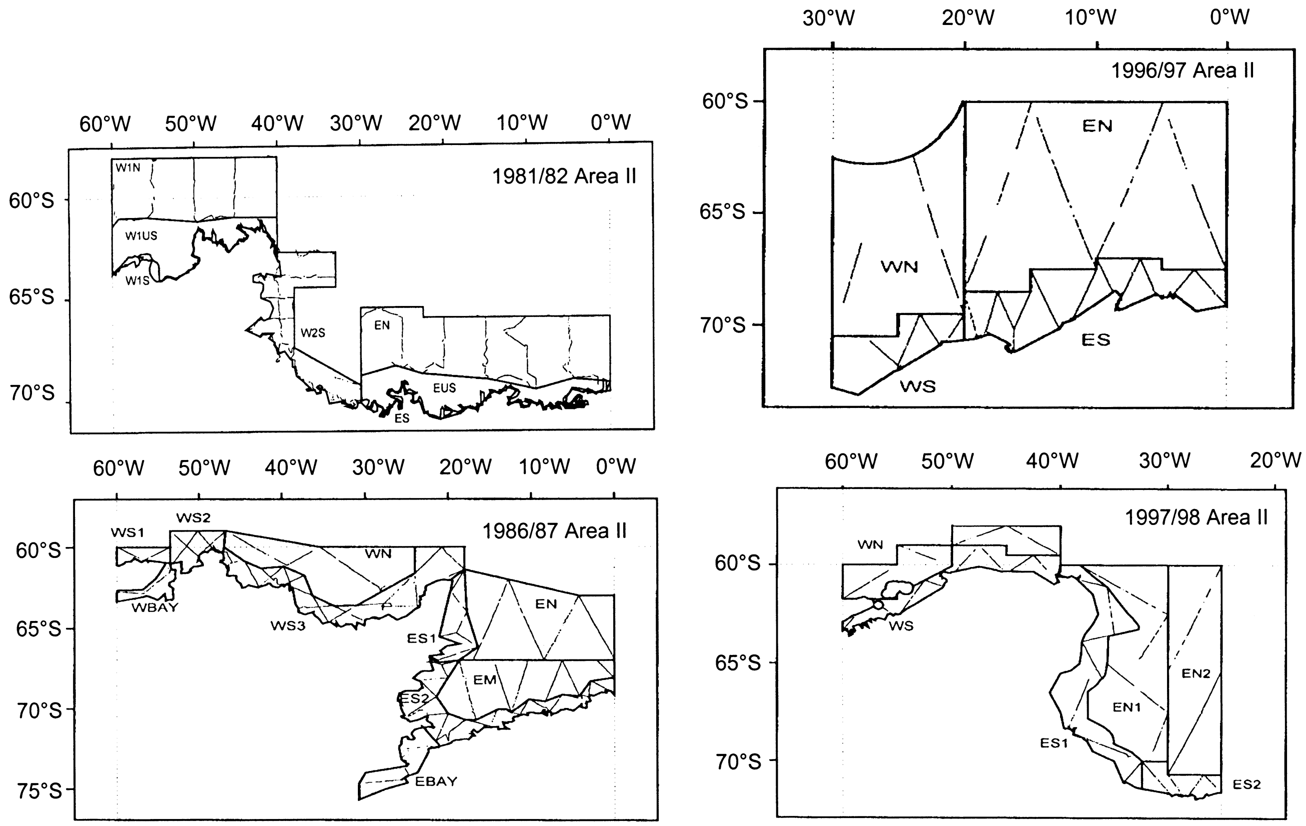

Fig. 2b. Strata surveyed in Area II throughout circumpolar sets from 1978/79 to 1997/98 (after Branch and Butterworth, 2001b). In the 3rd circumpolar survey for this Area was conducted by 1996/97 and 1997/98 cruises.

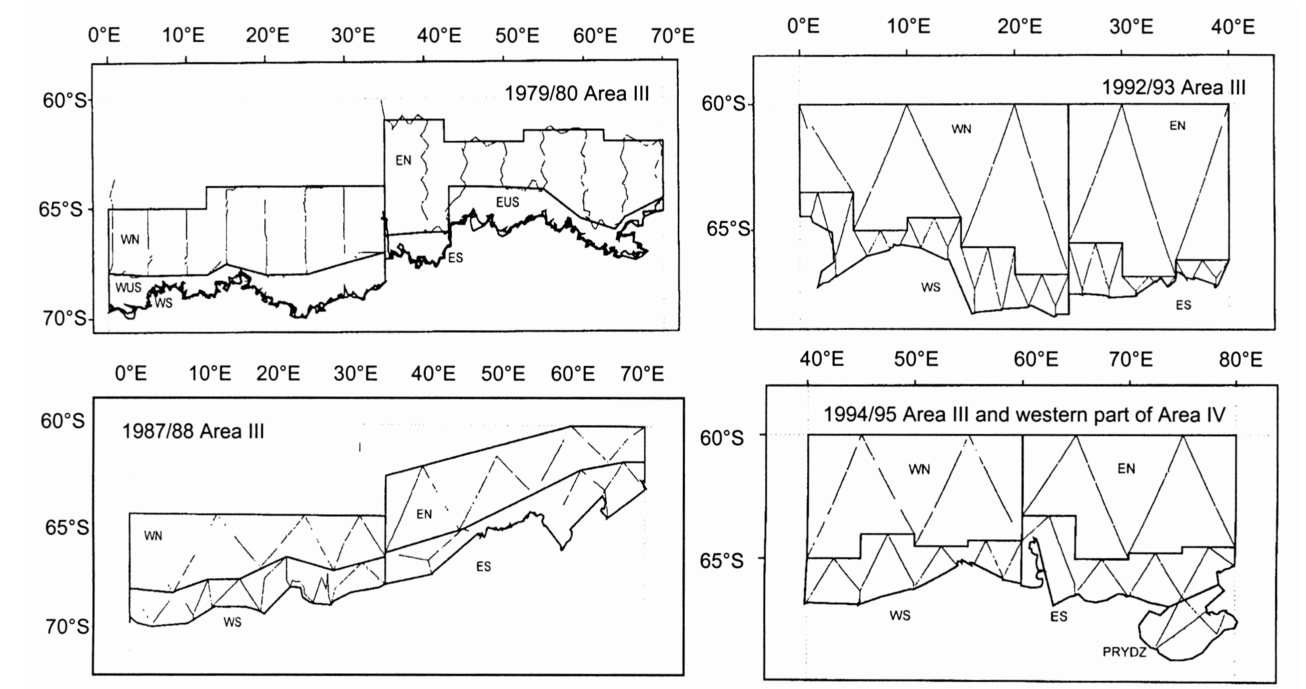

Fig. 2c. Strata surveyed in Area III throughout circumpolar sets from 1978/79 to 1997/98 (after Branch and Butterworth, 2001b). In the 3rd circumpolar survey for this Area was conducted by 1992/93 and 1994/95 cruises.

were recorded to the nearest one hundredth of a minute (instead of to the nearest minute). Additionally, the advent of GPS navigation coupled with the VDU (Visual Display Unit) track recorder, greatly enhanced the accuracy and ease of establishing the 3 n.mile bound on either side of the trackline (see Survey Protocol section) and the accuracy of positions recorded during such activities as chasing, returning to the trackline and during ice navigation etc. The precision of the GPS navigation also eliminated the need for 'major position shifts' (corrections to the positions), which had occurred on the earlier cruises and been recorded on the weather and effort data records.

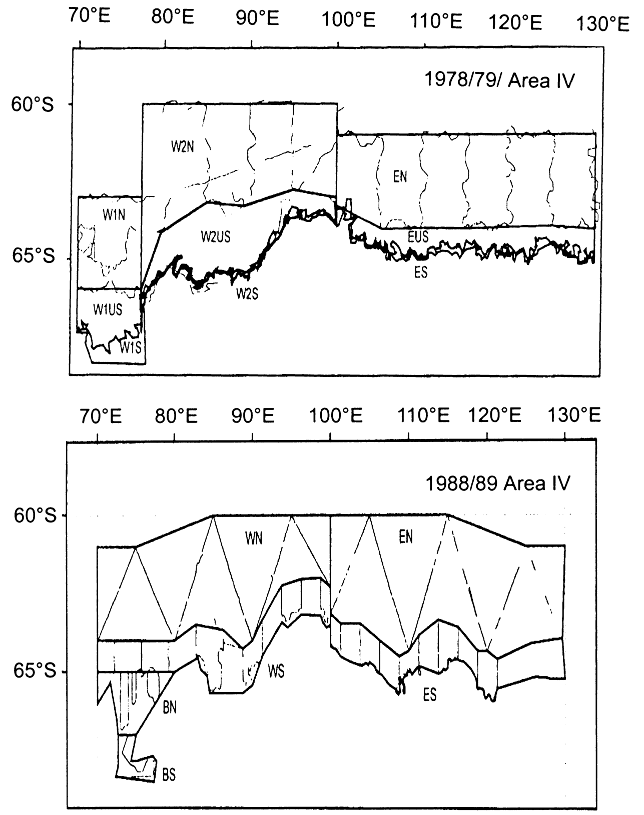

Fig. 2d. Strata surveyed in Area IV throughout circumpolar sets from 1978/79 to 1997/98 (after Branch and Butterworth, 2001b).

Measurements of angles and distances

As is well-known (e.g. Hiby and Hammond, 1989), the radial distance from the observer to the sighting, and the angle between the heading of the vessel and the sighting of the animal, are important measurements in line transect surveys. Together they are used to estimate the perpendicular distance from the cruise track to the sighting, essential information for distance-based estimation methods (Buckland *et al.*, 1993). Experiments to determine the reliability of distance and angle estimates are discussed below.

Use of reticle binoculars

Initially, all distances were estimated by eye. Reticle binoculars were developed and applied to estimate the distance between ship and whales from 1981/82. They have been used routinely (after considerable experimentation and development beginning in 1981/82) by observers in the top barrels and the Primary observers on the upper (front) bridge of the Japanese vessels since 1984/85 (Joyce *et al.*, 1988). Reticle binoculars were made available for the independent observer platform (IOP) from 1987/88. Since 1998/99, reticle binoculars have also used by the researchers on the upper bridge. The advantage of using reticle binoculars has recently been quantified by Kinzey and Gerrodette (2003).

Installation of angle boards

Angles were initially estimated by eye, using tape marks placed on the wind protection screen in all platforms as an aid. Angle boards, used in conjunction with a pointer on the binocular holder, were introduced to the top barrel and for use by the captain on the 1983/84 cruise (Joyce *et al.*, 1988)[1]. Angle boards were used routinely in the IOP from 1987/88. From the 1997/98 cruise, additional angle boards with

[1] Tape marks continued to be used as a back-up for several years.

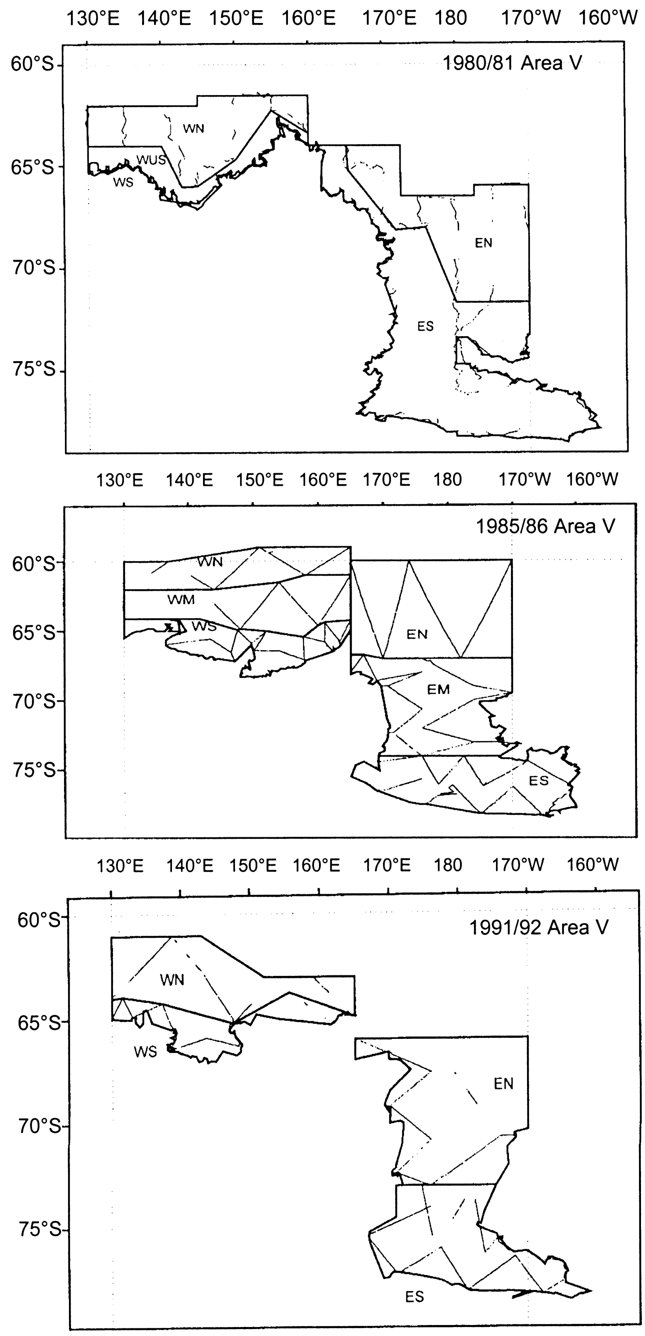

Fig. 2e. Strata surveyed in Area V throughout circumpolar sets from 1978/79 to 1997/98 (after Branch and Butterworth, 2001b).

pointers were installed on the front bridge; on SM1, they were available for the three researchers and the engineer, whilst on SM2, they were available for the three researchers, the engineer and the helmsman (the other primary observer). Improved pointers on the binocular holders were installed in 1998/99. New angle boards were installed in the IOP and for all upper bridge observers when the vessels were subsequently modified (SM1 prior to the 1998/99 cruise and SM2 prior to the 1999/2000 cruise).

Rebuilding of upper bridge and the IOP

IOPs were initially installed on SM1 and SM2 for the 1985/86 cruise; these could accommodate one person. These remained essentially the same until extensive modifications were made to the SM1 in time for the 1998/99 cruise. The wheelhouse and front bridge were removed and replaced with an upper bridge and a new IOP. The new IOP was larger

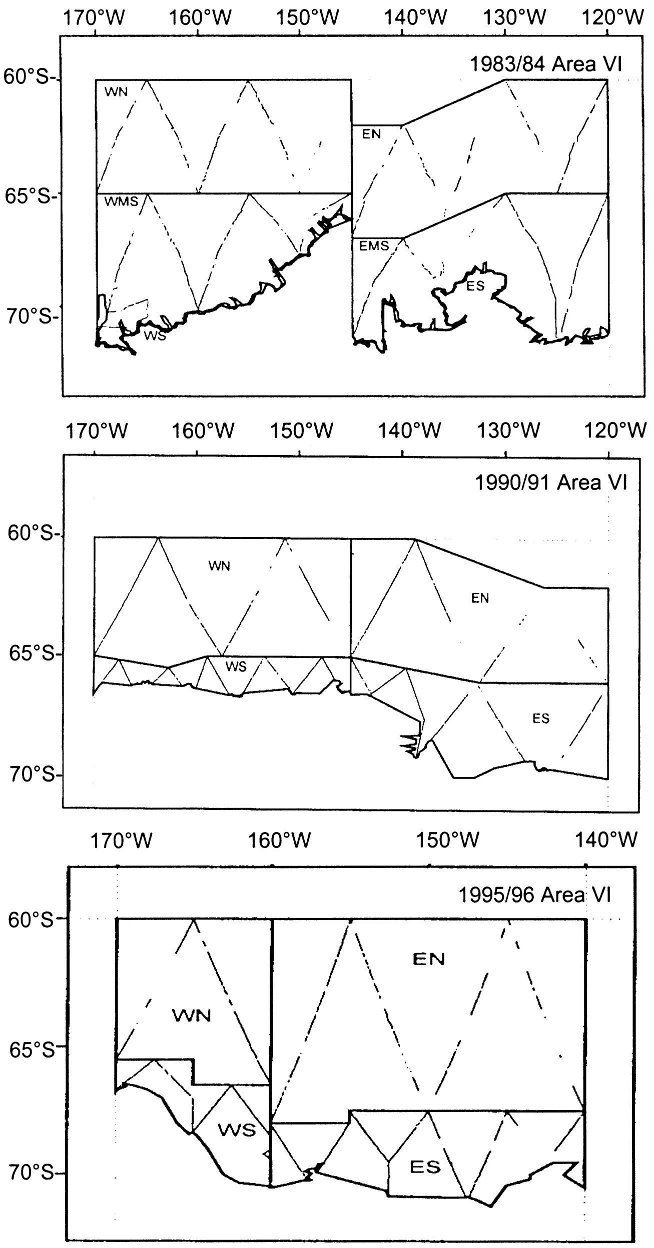

Figure 2f. Strata surveyed in Area VI throughout circumpolar sets from 1978/79 to 1997/98 (after Branch and Butterworth, 2001b).

with the potential to accommodate three observers, although there was no change to the standard procedure of using one observer in this platform. The heights above sea level of the IOP and upper bridge were not changed by the modifications. The new upper bridge and IOP had better wind protection and 360° visibility. At the same time, an identical new IOP was installed on the SM2. The following year (prior to the 1999/2000 cruise), the SM2 was extensively modified; the wheelhouse and front bridge were removed and replaced with an upper bridge such that it is now identical to the SM1.

Digital anemometers

From the 1996/97 cruise, digital anemometers were installed in the wheelhouse of the SM1 and SM2 (Ensor *et al.*, 1997). The new anemometers indicate true wind speed and direction. The previous anemometers had measured relative wind speed (from which the true wind speed was calculated by vector analysis). This modification has facilitated data recording by the vessels officers.

Data entry

Since the 1987/88 cruise, weather and effort data records have been entered onto computer files during the cruise. For the 1990/91 cruise, new programs were developed and these facilitated the routine entry of these data in addition to input of sightings and boundary/ice-edge data. The current data entry and utility programs (the Moon-Joyce Data form[2] and Plot programs) provide data entry, validation, summary and plotting capabilities. The data are usually entered each evening, after the end of the research day.

SURVEY PROCEDURE

Stratification, cruise track design and coverage

The areas surveyed by each cruise are outlined in Figs 2a-f, together with the tracklines followed while on primary searching effort. It is clear that the survey design for the first five cruises differs from that in later cruises.

First circumpolar series (1978/79 to 1983/84)

During the first circumpolar series of cruises (except for the 1983/84 cruise), one vessel followed the ice-edge closely (the 'S' stratum), while another vessel alternated between latitudinal and longitudinal legs (the 'N' stratum), typically 60 n.miles or more north of the pack ice. An unsurveyed area ('US') generally remained between the 'S' and 'N' strata. The S stratum generally covered an area twice that between the ice-edge and the vessel's trackline. From the 1983/84 cruise, vessels off the ice-edge followed the zigzag cruise track design that was used in subsequent cruises (Branch and Butterworth, 2001a).

Second circumpolar series (1984/85 to 1990/91)

The research areas were typically divided into four strata (East-North, East- South, West-North and West-South). Exceptions occurred when there were bays in the South strata. The 1984/85 cruise was experimental (Joyce *et al.*, 1988). A zigzag cruise track design within each stratum was used in CPII. A square trackline design was adopted in 1988/89 but only in the southern strata. Details of the cruise track design, including construction of waypoints were reported in the appendix of each planning report (IWC, 1988; 1989; 1990; 1991)[3]. New survey procedures were introduced in 1984/85 when part of the survey was conducted in Passing mode, and in 1986/87 Passing mode with independent observer was introduced and covered half of the planned tracklines; see Survey mode section).

Third circumpolar series (from 1991/92 to the present)

From the 1992/93 cruise onwards, the research area (and the cruise track construction) was divided into sectors of 10° longitude. Each sector was divided into two strata (Southern and Northern). The Southern Stratum extended from the estimated ice-edge (or the 100 fathom line if this extends beyond the ice-edge) to the southern boundary of the Northern Stratum. The Northern Stratum extended from the northern boundary of the Southern Stratum to the northern boundary of the research area (60°S). The boundary between the Northern and Southern strata in each sector was a line of fixed latitude. The position of the Interstratum Boundary was intended to achieve a Southern Stratum width of approximately 60-90 n.miles. The northern waypoints were placed on the Interstratum Boundary. Details of the cruise

[2] *Moon Joyce Resources, 11740 Exeter Ave. NE, Seattle, WA 98125, USA.*

[3] Planning reports are available from the IWC Secretariat.

Table 1

Summary of the cruises from 1978/79 to 200/01 (Area, Vessel and home port). Abbreviations: SM2 = *Shonanmaru No.2*, T16 = *Toshimaru No.16*, T18 = *Toshimaru No.18*, K27 = *Kyomaru No.27*, V34 = *Vdumchivyi No.34*, V36 = *Vyderzhanny No.36*, * = experiment cruise.

			Longitudinal coverage		Latitudinal range			
CP	Cruise	Area	Range	Degrees	(average)	Research vessel	Departure home port	Arrival home port
CP I	1978/79	IV	70E-130E	60	ice-61S	T16,T18	Fremantle	Fremantle
	1979/80	III	0-70E	70	ice-63S	K27,T11	Cape Town	Cape Town
	1980/81	V	130E-170W	60	ice-62S	K27,T11,V34	Wellington	Wellington
	1981/82	II	60W-0	60	ice-63S	SM1,SM2,V34	Buenos Aires	Cape Town
	1982/83	I	120W-60W	60	ice-64S	SM1,SM2,V34	Ushuaia	Wellington
	1983/84	VI	170W-120W	50	ice-61S	SM1,SM2,K27,V34	Wellington	Wellington
CP II	1984/85*	IV	70E-130E	60	ice-61S	SM1,SM2,K27,V34	Fremantle	Fremantle
	1985/86	V	130E-170W	60	ice-60S	SM1,SM2,K27,V36	Wellington	Wellington
	1986/87	II	60W-0	60	ice-62S	SM1,SM2,K27,V34	Ushuaia	Port Luis
	1987/88	III	0-70E	70	ice-63S	SM1,SM2	Fremantle	Port Luis
	1988/89	IV	70E-130E	60	ice-61S	SM1,SM2	Fremantle	Fremantle
	1989/90	I	120W-60W	60	ice-64S	SM1,SM2	Ushuaia	Wellington
	1990/91	VI	170W-120W	50	ice-61S	SM1,SM2	Wellington	Wellington
CP III	1991/92	V	130E-170W	60	ice-63S	SM1,SM2	Wellington	Wellington
	1992/93	III W	0-40E	40	ice-60S	SM1,SM2	Cape Town	Fremantle
	1993/94	I	110W-60W	30	ice-60S	SM1,SM2	Wellington	Valparaiso
	1994/95	III E, IV W	40E-80E	40	ice-60S	SM1,SM2	Cape Town	Fremantle
	1995/96	VI W	170W-140W	30	ice-60S	SM1,SM2	Hobart	Wellington
	1996/97	II E	30W-0	30	ice-60S	SM1,SM2	Cape Town	Cape Town
	1997/98	II W	60W-25W	35	ice-60S	SM1,SM2	Punta Arenas	Cape Town
	1998/99	IV	80E-130E	50	ice-60S	SM1,SM2	Cape Town	Hobart
	1999/00	I E, II W	80W-55W	25	ice-60S	SM1,SM2	Valparaiso	Punta Arenas
	2000/01	VI E, I W	140W-110W	30	ice-60S	SM1,SM2	Wellington	Papeete

Table 2

Summary of the cruises from 1978/79 to 2000/01. * = for the minke whale component.

		Research period		Number of research days								
				Transit			Antarctic				Area[a]	
Cruise	Area	Home port to home port	Antarctic*	to	from	Total	Dec.	Jan.	Feb.	Total	No. of strata[b]	(n.mile^2)
CP I												
1978/79	IV	12/12/78 - 14/02/79	28/12/78 - 07/02/79	16	7	23	4	31	7	42	9	427,496
1979/80	III	20/12/79 - 21/02/80	27/12/79 - 14/02/80	7	7	14	5	31	14	50	6	493,908
1980/81	V	17/12/80 - 12/02/81	22/12/80 - 06/02/81	5	6	11	10	31	6	47	5	480,280
1981/82	II	19/12/81 - 14/02/82	27/12/81 - 06/02/82	8	8	16	5	31	6	42	7	398,021
1982/83	I	30/12/82 - 26/02/83	02/01/83 - 15/02/83	3	11	14	-	30	15	45	6	372,005
1983/84	VI	29/12/83 - 01/03/84	04/01/84 - 19/02/84	6	11	17	-	28	19	47	6	725,179
CP II												
1984/85	IV	21/12/84 - 01/03/85	29/12/84 - 19/02/85	8	10	18	3	31	19	53	6	-
1985/86	V	18/12/85 - 24/02/86	22/12/85 - 18/02/86	4	6	10	10	31	18	59	6	963,468
1986/87	II	27/12/86 - 20/02/87	28/12/86 - 04/02/87	1	16	17	4	31	4	39	10	495,208
1987/88	III	11/12/87 - 08/02/88	20/12/87 - 25/01/88	9	14	23	12	25	-	37	4	479,730
1988/89	IV	21/12/88 - 20/02/89	29/12/88 - 11/02/89	8	9	17	3	31	11	45	6	577,099
1989/90	I	26/12/89 - 19/02/90	28/12/89 - 10/02/90	2	9	11	4	31	10	45	4	429,512
1990/91	VI	29/12/90 - 23/02/91	03/01/91 - 11/02/91	5	12	17	-	29	11	40	4	557,424
CP III												
1991/92	V	21/12/91 - 17/02/92	31/12/91 - 08/02/92	10	9	19	1	31	8	40	4	443,845
1992/93	III W	17/12/92 - 16/02/93	25/12/92 - 04/02/93	8	12	20	7	31	4	42	4	445,316
1993/94	I	23/12/93 - 21/02/94	03/01/94 - 14/02/94	11	7	18	-	29	14	43	4	667,776
1994/95	III E, IV W	05/01/95 - 06/03/95	13/01/95 - 25/02/95	8	9	17	-	19	25	44	5	428,564
1995/96	VI W	06/01/96 - 04/03/96	14/01/96 - 21/02/96	8	12	20	-	18	21	39	4	446,418
1996/97	II E	07/01/97 - 26/02/97	16/01/97 - 14/02/97	9	12	21	-	16	14	30	4	445,715
1997/98	II W	14/01/98 - 26/02/98	18/01/98 - 14/02/98	4	12	16	-	14	14	28	6	306,981
1998/99	IV	31/12/98 - 01/03/99	20/01/99 - 22/02/99	20	7	27	-	12	22	34	4	387,581
1999/00	I E, II W	06/01/00 - 18/02/00	15/01/00 - 13/02/00	9	5	14	-	17	13	30	4	-
2000/01	VI E, I W	05/01/01 - 05/03/01	16/01/01 - 22/02/01	11	11	22	-	16	22	38	4	-

[a]1978/79-1997/98, Branch and Butterworth (2001); 1998/99-2000/01, Ensor *et al.*, (1999, 2000, 2001). [b]Cruise reports.

track design including construction of waypoints are reported in the appendix of each planning report (IWC, 1991; 1992). From the 1993/94 cruise, there were some additional changes in relation to coverage: the guideline for minimum coverage in the northern stratum was reduced from 100% total coverage to 50%; and survey transects were sub-divided by mode into equal-length segments restricted in length to less than 100 n.miles. For the 1995/96 cruise, the guideline for minimum coverage on primary effort in the northern stratum was reduced from 50% to 46.5%. From the 1996/97 cruise, the lower limit of coverage in southern stratum was reduced (from total coverage) to 80%. The guideline for minimum coverage in the northern stratum was reduced to 45%. The current cruise track construction methods and guidelines for coverage are unchanged (IWC, 2000)[4].

Conditions acceptable for primary search effort

Primary search effort is only conducted in acceptable weather conditions. These conditions were formalised for the 1984/85 cruise as being able to see a minke whale blow (or other sighting cue) at a distance of at least 1.5 n.miles, with wind speed < 25 knots and Beaufort Sea state < 6. Prior to the 1984/85 cruise, the same criteria were used in practice. These were unchanged until the 1996/97 cruise when they were redefined as being able to see a minke whale blow (or other sighting cue) at a distance of at least 1.5 n.miles, with wind speed < 25 knots (in the vicinity of the ice-edge) and < 20 knots (remote from the ice-edge), and Beaufort Sea state < 6.

These conditions are used as guidelines; in some circumstances, less severe conditions may still be inappropriate for search effort. The assessment of acceptable conditions is subjective and depends on many other factors other than wind speed. The redefinition of acceptable wind speeds in 1996/97 did not result in any significant changes to assessments of acceptable survey conditions.

Survey mode

Since the 1985/86 cruise, the survey has been conducted in two primary modes: (1) Closing mode; and (2) Passing with Independent Observer mode. In both cases, survey speed averages about 11.5 knots.

Closing mode (NSC) survey protocol

Closing mode has been used since the first cruise. Although essentially the same, the procedure (see below) has been refined slightly over the years; most importantly with respect to standardisation of trackline procedures (from the 1983/84 cruise), establishing a 3 n.mile bound on either side of the trackline before closing (from the 1985/86 cruise) and then further refinement of return to trackline protocol following installation of the GPS (from the 1991/92 cruise).

Two topmen observe from the barrel at all times with no observer in the IOP. There are open communications between the barrel and the upper bridge. When a sighting is made, the topman (or upper bridge observer) gives an estimate of the distance and angle to the sighting and (apart from the cases outlined below) the ship turns immediately, regardless of the angle, to the sighting; vessel speed is increased to 15 knots to hasten the closure and then decreased when the group is neared, usually 0.2-0.4 n.miles from the initial sighting position. The species, group size, estimated lengths, number of calves present and behaviour are determined and recorded. After as many data as possible have been collected, other activities might take place, such as natural marking or biopsy experiments. All subsequent sightings are regarded as secondary until normal search effort is resumed.

Exceptions to this procedure of closing now include: if the initial sighting distance is more than 3 n.miles (perpendicular distance) from the vessel's trackline *and* the sighting is thought to be of minke whales; if the group can be positively identified as long-diving species (such as sperm whales or beaked whales) and it is considered (before or during closure) that the animals have dived. In such cases, either closing does not occur or is abandoned.

Passing mode with independent observer (IO)

Passing mode was introduced in 1985/86, to avoid possible bias in estimating sighting rate (number of sightings per unit distance) in closing mode arising from stoppages to go off effort when confirming, with associated secondary sightings having to be ignored in the abundance analyses. Passing mode with independent observer was introduced on an experimental basis in 1985/86 and routinely covered half of the planned trackline from 1986/87. Two topmen observe from the barrel at all times and a third topman is stationed in the independent observer platform (IOP). The topmen report information to the upper bridge observers, but no information is exchanged between the barrel and IOP. The observers on the upper bridge communicate with the topmen (using their independent telephone systems) only when clarification of information is required, thus avoiding disruption of the barrel and IOP's normal search procedure. The barrel and the IOP are not informed of any sightings made by the upper bridge. Separate sightings records are completed for all standard barrel and IOP sightings.

Immediately after a sighting is made from the barrel or IOP, the topman informs the bridge of his estimate of the distance and angle to the sighting (and also, if possible, the species, number of animals and their swimming direction), but does not change his normal searching pattern in order to track the sighting. The topman gives no further information to the upper bridge unless the whale group happens to surface again within the normal searching pattern of the topman. The observers on the upper bridge track sightings made from that platform, and attempt to locate and track sightings made by the barrel or IOP, to confirm the species and number before the sighting passes abeam of the vessel.

If the upper bridge makes a sighting prior to the same whale group being observed by the topmen in either the barrel or IOP, then a separate record is completed; otherwise any additional information from the resighting from the upper bridge information is added to the sighting record(s) completed for the barrel and/or IOP. Thus if the observers on the upper bridge are the first to sight a whale group, and it is subsequently seen from both the standard barrel and IOP, three sighting records will be completed for the same school, with independent estimates of angle and distance for initial sightings from each of the platforms.

ASSESSMENT OF DUPLICATE STATUS

The researchers on the upper bridge determine which of the sightings made from the barrel, IOP and upper bridge are duplicates. There is usually discussion among the researchers and the captain (and other upper bridge observers, if necessary). In almost all cases there is consensus of opinion regarding the assessments. In the rare cases of disagreement, a lower 'level' of duplicate status is selected. Duplicate status is assessed in the following

[4] Usage Notes are available from the IWC Secretariat.

categories defined below. Although the assessments are largely subjective (there are no fixed rules), they are conservative and take into consideration *inter alia* comparability of estimated angles and distances, temporal and spatial relationship of sightings and type of cues, species, group size, swimming direction, behaviour and the compactness of the group.

DEFINITE
These are often simultaneous (or almost simultaneous) sightings from the different platforms, and/or with estimated angles within approximately 5° and estimated distances within approximately ±20%, and where the species (and group size) are the same. If the sighting times are somewhat separated, then for this category, the sighting has usually been tracked by the upper bridge. If not tracked then the location of the sighting is exactly as anticipated taking into account vessel movement and the whale(s) swimming direction.

POSSIBLE
Here, the difference between the estimated angles and/or distances is just outside the threshold for definite status but the sightings are reasonably close spatially. There may also have been difficulty tracking the sighting(s). If not resighted from the upper bridge and tracking was not possible, the sightings may also have been temporally and spatially within the threshold for definite status but the platforms indicated that the species were different.

REMOTELY POSSIBLE
Here, there is an 'outside chance' the sightings are possible duplicates. Such cases may be the result of a combination of the following: (1) not seen by the upper bridge; (2) difficulty tracking the sightings and considerable difference between the estimated angles and/or distances; and (3) the platforms indicated a difference in species.

NON-DUPLICATE
This is when the sighting is from one platform only, or if there is a candidate, the spatial/temporal or other distinction between them is obvious.

UNKNOWN
This is used when uncertainty exists, for example when entering a high-density area.

The practice of a researcher (or the captain) plotting the ship's track and position of any sightings (using the estimated angles and distances) on plotting sheets (as first employed during the parallel ship experiments; see later section for explanation) has been routinely applied during survey in IO Mode. Upper bridge personnel have the option of using the plotting sheets as an aid in determining the duplicate status of sightings. In practice, few sightings are plotted in this manner, and the plotting sheets are usually only used to help resolve potentially confusing situations. The plotting procedure is particularly useful as an aid for tracking sightings with a large initial sighting distance in the vicinity of the trackline (with a concomitant long time interval before the sighting comes abeam) and particularly when such groups exhibit long dive times.

DATA RECORD
The observers and topmen always give the angle, distance, cue, and (if available) their initial estimate of the species, school size and swimming direction, etc. The observer's initial data for angle, distance, cue and swimming direction are those recorded on the respective sightings data forms. With regard to species, school size and the remainder of the data, the researchers on the upper bridge (even in the case when the observers on the upper bridge never see the group) evaluate what is the most reliable and detailed information and use that to complete the sightings data form. If more information is required, or if there is conflicting information from two or more platforms about one school, the researchers may communicate with the topmen via their independent telephone systems to request more specific information from them (usually after the sighting is estimated to have past abeam).

The following practice has been adopted as standard when completing the data forms:

(a) for sightings assessed as a Definite Duplicate, the data forms are completed with the SAME species and SAME numbers;
(b) for sightings assessed as Possible, Remotely possible, Unknown and Non-duplicate, the species and numbers on the data forms may be the SAME or may be DIFFERENT.

This practice of entering the SAME species and the SAME group size information on the respective data forms for Definite Duplicate sightings has not always been followed exactly, and this explains how there were some (although extremely few) sightings assessed as Definite Duplicates, where the species recorded for the various platforms were different. Another possible explanation is that errors were made in the data records, or the groups had been composed of mixed species and the observers in the different platforms observed separate species.

Normal passing mode (NSP)
This mode is identical to the IO mode except that there is no Independent Observer in place.

Research hours
Research hours used on the cruises are shown in Table 3. Hours on effort were reduced from the 1995/96 cruise onwards to comply with a revised agreement on Japanese labour rules (IWC, 1996).

Table 3

Maximum research hours per day.

First circumpolar series	
1978/79 – 1983/84	04:00-20:00 (16 hours)
Second circumpolar series	
1984/85 (Experiment cruise)	04:00-20:00 (16 hours)
1985/86 - 1990/91	06:00-20:00 (14 hours). Reduced to 13 hours when IO mode conducted.
Third circumpolar series	
1991/92 – 1995/96	06:00-20:00 (14 hours). Reduced to 13 hours when IO mode conducted.
1996/97 – 2000/01	06:00-19:00 (13 hours). Included for each a 30-minute meal when IO mode conducted.

Number of primary and secondary observers on effort
The total number of observers has not changed during the history of the cruises (apart from the additional observer used in IO mode, which became routine from the 1985/86 cruise). The number of observers on the front (upper) bridge has not changed, however, there has been a change in the status of one observer (the status of the helmsman was changed from secondary to primary in 1985/86). Details are given in Table 4.

Table 4

Numbers of observers.

First circumpolar series	
Top barrel	Two primary observers (06:00-18:00)
	One primary observer between 04:00-06:00 and 18:00-20:00
Front bridge	One primary observer (Captain)
Front bridge	Five secondary observers (three researchers, helmsman and one engineer)
Second circumpolar series	
Top barrel	Two primary observers (06:00-20:00)
IO platform	One primary observer (only IO mode)
Front bridge	Two primary observers (Captain and helmsman)
Front bridge	Four secondary observers (three researchers and one engineer)
Third circumpolar series	
Top barrel	Two primary observers
	(06:00-20:00 between 1991/92 and 1995/96)
	(06:00-19:00 between 1996/97 and 2000/01)
IO platform	One primary observer (only IO mode)
Front (upper) bridge	Two primary observers (Captain and helmsman)
Front (upper) bridge	Four secondary observers (three researchers and one engineer)

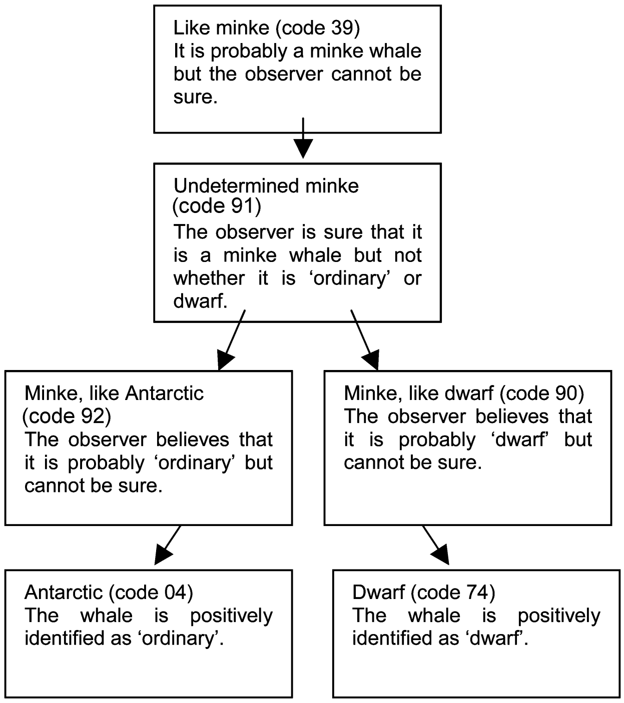

Fig. 3. Current classify the species identification diagram for Antarctic minke and dwarf form minke whales (International Whaling Commission, 2000 in Appendix 2).

Standardisation of species identification across years with particular reference to minke whales

The current *general* guidelines for identification on the IWC/SOWER cruises are as follows:

> Record the common or scientific name (such as ‘minke’ or ‘fin’) for *positively identified* species; a positively identified species is one for which the diagnostic features have been observed. Where this is not the case but the observer has seen enough to be reasonably sure of the species identity then record the qualification ‘like’ (e.g. use ‘like minke’ if a clear view of the body was not obtained but the observer believed the sighting was *probably* a minke whale).

For minke whales, in particular, the current identification guidelines are shown in Fig. 3 and further explained in the following sections. The final category decision is made by the cruise leader/senior scientist (or designated researcher).

Like minke (code 39)

The cue observed is usually the whale blow. In most cases there is no observation of the body or the view obtained is poor and insufficient to observe the diagnostic features of the species. Characteristics of the blow (small, ‘baleen whale type’ blow) indicate it is a probably a minke whale.

Undetermined minke (code 91)

The sighting is positively identified as a minke whale by observation of the diagnostic features of the body shape (shape of dorsal fin and head). The colouration pattern of the body is not clearly visible and it cannot be determined whether it is ‘Antarctic’ or ‘dwarf’.

The distance at which a sighting can be positively identified as undetermined minke depends on many factors such as the sighting conditions, swimming direction and behaviour of the animals. Under normal conditions positive identification is possible up to about 1.5 n.miles. Under very favourable circumstances, determinations are possible up to about 3.5 n.miles.

Minke, like Antarctic (code 92) or like dwarf (code 90)

The sighting is positively identified as a minke whale based on the diagnostic features of the body shape. The colouration pattern of the body is not viewed in sufficient detail for the observer to be able to positively discriminate between the two forms, however, based on the details of the colouration pattern the observer believes that it is probably ‘Antarctic’ or is probably ‘dwarf’.

Antarctic minke (code 04) and dwarf minke (code 74)

The sighting is positively identified as a minke whale based on the diagnostic features of the body shape. The colouration pattern of the body is viewed in sufficient detail for the observer to be able to positively discriminate between the two forms. The whale is positively identified as ‘Antarctic’ or ‘dwarf’.

For all codes, the distance at which such determinations can be made is variable and depends on many factors such as the sighting conditions, water clarity, swimming direction and behaviour of the animals.

Comparability across years

There has been an increase in the number of species codes for minke whales during the course of the cruises, particularly in recent years. However, although there have been changes to the codes, there is consistency shown in the guidelines for identification of ‘like minke’ across years. For the first six cruises, a ‘Status’ cell was used to record both whether the species was identified and whether the school size was confirmed. This cell was separated into two in 1984/85, and it is probable that the clear definition of ‘identified’ was first drafted for the 1985/86 cruise. However, there were minke whale sightings classed as unidentified in the first six cruises, and these were subsequently recorded as ‘like minke’ (code 39) in the Database Estimation Software System (DESS) program.

The identification guidelines for ‘like minke’ have been essentially the same since the 1985/86 IWC/IDCR cruise. The guidelines for identification of ‘like minkes’ are shown in the excerpt below (the ‘Identified’ category, a simple Y/N cell, was introduced to the sightings data record for the 1985/86 cruise):

Record as (Y) if the species (as indicated below) is 'positively' identified; otherwise record as (N) (i.e. both for 'probable' and 'unidentified' categories). 'Positive identification' of species is based on the multiple cues and usually requires the clear observation of the whale's body. Occasionally repeated observations of the shape of the blow, surfacing and other behavioural patterns may also be sufficient: this judgement should be made only by a researcher. Positively identified whale species are recorded as such on the sighting form (e.g. 'Antarctic minke' or 'undetermined minke'). 'Probable identification' of species is based on multiple cues but these are insufficient to be absolutely confident in identification. This usually occurs when blows are seen, the surfacing pattern is correct but the whales' body (characteristic of species) cannot be seen. Probable identifications are qualified with the term 'like' (e.g. 'like minke'). 'Unidentified' whales should be clearly indicated. The sighting may be qualified by size (unidentified small, medium, or large whale), order (unidentified baleen or toothed whale) or suborder (unidentified ziphiid). If a species is suspected but no additional information is available to provide possible or probable identification, the species should be listed with a query, in brackets, after listing it as unidentified (e.g. 'unidentified small whale [minke?]).

A similar situation existed for the identification of southern bottlenose whales before the 1984/85 cruise (Kasamatsu and Joyce, 1995). At that time there was neither an identification standard nor a great deal of experience in identification of this species. During this research period, whales described as 'Unidentified Ziphiidae' represented 'Unknown akabo' and 'Like akabo'. Researchers at the post-cruise meeting after the 1983/84 cruise resolved that many of the unidentified Ziphiidae were probably in fact southern bottlenose whales (Nishiwaki, pers. comm.) and following discussions there the identification of southern bottlenose whales became standardised, and more strict than unidentified Ziphiidae (Anonymous, 1986)[5].

The introduction of the passing mode procedure also had an influence on the relative numbers of the various categories of minke whale sightings. Positive identification in passing mode can be more difficult because of the differences in likely closest distance to a sighting. Most of the sightings identified to be 'like minke' and unidentified Ziphiidae in passing mode are sightings for which the closest distance exceeds 0.6 n.miles and for which there are few sighting cues. Thus, although passing mode was introduced to avoid possible bias in estimating sighting rate (see above), it also results in increasing the proportion of unidentified sightings and the precision of group size estimates.

Change of the species code

Whale species codes have increased over the years, from 22 codes used on the 1978/79 cruise to the current total of 82 codes. The number of codes increased due to additional species being encountered and clarification of levels of identification. The changes to species codes for minke whales are shown in Fig. 4. Code 39 (like minke) was entered in DESS during the course of data validation before the introduction of this code in the field. Further information can be found in the DESS user manual (Strindberg and Burt, 2000). Code 39 has been used since 1984/85. Branch and Ensor (2001) noted that code 39 (like minke/?minke) was used from 1978/79 to 1992/93, but that the description was somewhat misleading.

Confirmation of school size

Accurate determination of the school size of all sightings is not possible. It is the responsibility of the researchers to evaluate if the school size has been accurately determined. Schools where the number of animals, or an accurate estimated range of the number of animals, is determined are classified as *confirmed* schools. The data from the confirmed schools are used in the analysis to determine a mean school size. It is therefore critical that confirmed schools are representative in size of the schools that are in the survey area. Normally, schools believed to be confirmed are approached to within 0.3 n.mile, but sometimes it is possible to confirm school size at greater distances.

Ice-edge determination and definition of the Southern Boundary of the Research Area

For several years, the ice-edge was mapped by either the Soviet vessel or the southern survey vessel. Only in the later cruises did the present standard procedure develop. The southern boundary of the research area for the cruises has been established as either the 'ice-edge' or the 100 fathom isobath, if this has extended beyond the 'ice-edge'. The position of the 100 fathom isobath was established from the navigation charts. The position of the 'ice-edge' for each cruise was established using information from a number of sources: visual and radar observations of ice from the IDCR/SOWER research vessels; satellite imagery; and observations relayed from other ships and/or land bases. These sources of information have been used to construct an estimate of the 'ice-edge'. This 'ice-edge' has then been used in the construction of the cruise tracks. After the completion of the southern stratum of each sector, the senior scientist has used all the data to record the maximum (most northerly), minimum (most southerly), and best estimates of the 'ice-edge'.

Estimation of the position of the ice-edge from the IDCR/SOWER vessels

Fundamental to determination of the position of the 'ice-edge' from the IDCR/SOWER vessels is a definition of what constitutes the 'ice-edge'. From these vessels, the position of the 'ice-edge' has been established using visual observations (especially from the Top Barrel) and radar observations. Information from other sources (such as satellite imagery of ice concentration boundaries and bathymetric information from navigation charts) has also been used for confirmation. No single definition of what constitutes an 'ice-edge' can be used for all 'ice-edge' situations due to the variability in the ice concentration, ice type (e.g. sea ice, glacial ice), floe size and ice development (thickness). However, a common theme running through the estimations of all 'ice-edge' boundaries is the navigational safety of the ships. The ships are not ice-strengthened and although they frequently navigate through ice, difficult ice situations are avoided. The principles involved in defining the position of the 'ice-edge' and the range of difficulty involved in making that estimate is demonstrated in the following examples.

When the ice/ice-free boundary is well defined and the pack ice is of high concentration (7/10-10/10) and there are no large ice-free areas inside the pack ice, then estimation of the ice-edge is a simple matter. An 'ice-edge' such as this is usually obvious, both visually and on radar. The ice-edge waypoint is established 2.5 n.mile from the 'ice-edge.'

When the ice is of substantially lower concentration (3/10-4/10), or is highly variable in concentration, and/or the ice is arranged in belts separated by substantial ice-free areas (for example ice-free areas of physical dimension greater than 1 n.mile), estimation of the position of the 'ice-edge' is problematic. In this situation the position of the 'ice-edge' is determined largely by the limits of safe navigation of the ship. Attempts may be made to navigate through or around

[5] Cruise reports are available from the IWC Secretariat.

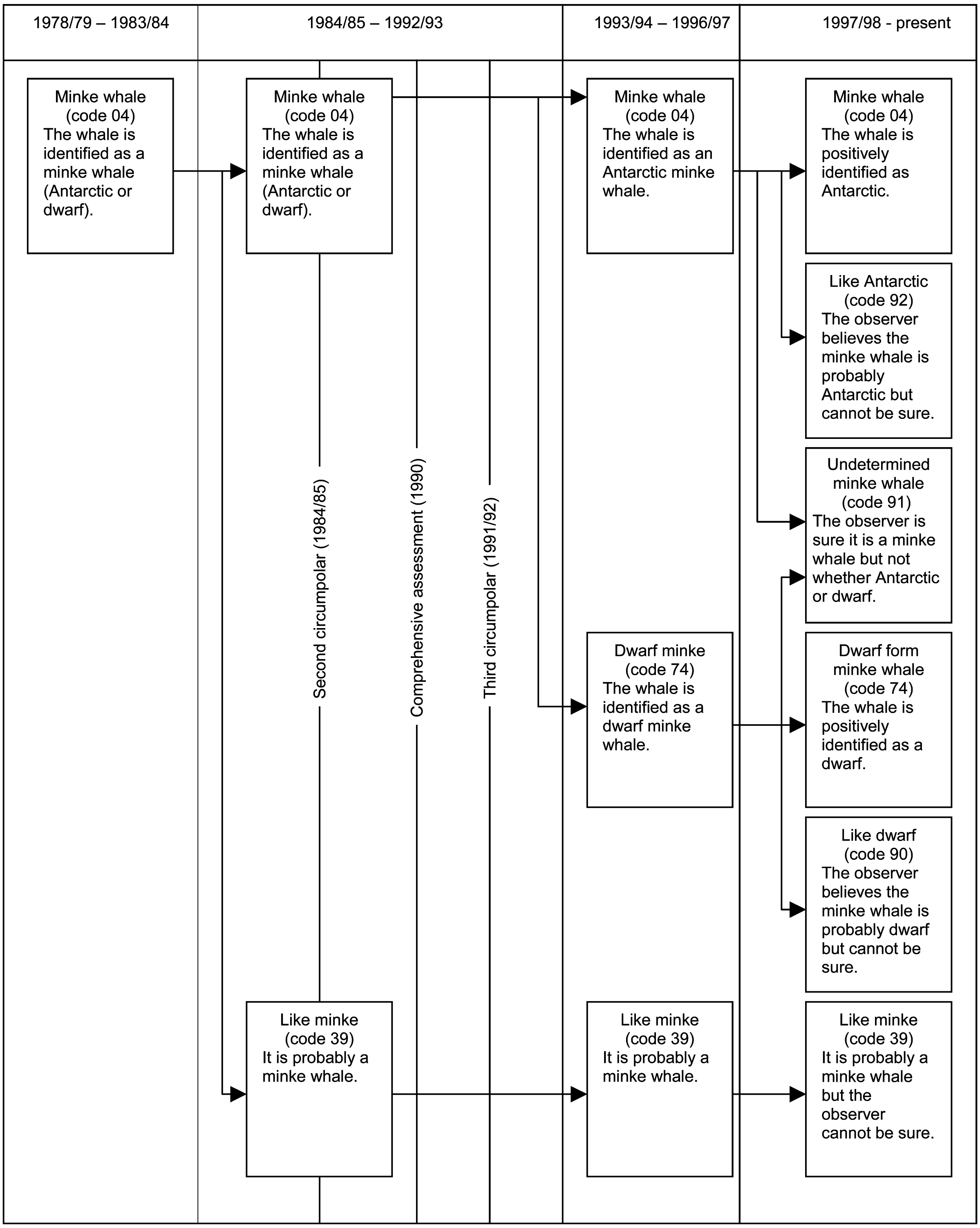

Fig. 4. Overview of the species code in IWC/IDCR and SOWER survey for Antarctic minke and dwarf form minke whale from 1978/79 to 2000/01.

the belts of sea ice to confirm the 'ice-edge' dependent on what areal extent of ice-free water is visible south of the outer limits of the ice (and depending on the relationship to other information such as bathymetry and perhaps satellite imagery). If navigation through the ice proves difficult, the 'ice-edge' is defined as the limit of safe navigation of the ship. The ice-edge waypoint on the cruise track is established 2.5 n.mile from this 'ice-edge'.

If there are no ice-free areas to the south and when the ice is composed of small melted floes and of very low concentration (1/10-2/10), estimating the ice-edge is also problematic. However, generally such scattered small ice is relatively consistent in concentration over a wide geographic area and this makes estimation of the 'ice-edge' easier than in the above case.

Estimation of the ice-edge is usually based on how the ice concentration and development relates to navigation of the vessels at normal searching speed (11.5 knots). The 'ice-edge' is usually defined as when the ice forms a continuous visual barrier (or radar image) on the horizon or when normal searching speed cannot be maintained for the majority of time without help from the topmen to navigate through the ice. The ice-edge waypoint on the cruise track is established 2.5 n.mile from this 'ice-edge'

Expansive ice-free areas or pack ice of much lower concentration may be visible inside the pack ice extending beyond the horizon south of the 'ice-edge'. In such cases, the areal extent of ice-free areas extending beyond the horizon cannot be substantiated and whether the ice represents the true 'ice-edge' or is separated from the main ice-edge cannot be established. The position of the ice-edge and details of the ice-edge observations from the research vessels are indicated on the detailed cruise track charts produced during the cruise.

Estimation of the position of the ice-edge from satellite information

Cruise vessels have received satellite information from the US Navy NOAA Joint Ice Center (JIC) and latterly the National Ice Center (NIC). Summaries of these analyses were sent to the ships by morse code from at least the 1980/81 cruise. Also during the early cruises, an estimation of the ice-edge for the entire Antarctic, based on both satellite and aerial observations, was available twice monthly (via weather chart radio fax) from the Soviet station *Molodezhnaya*, located in Enderby Land. More detailed information was received by facsimile after the Inmarsat system was installed on the ships for the 1991/92 cruise (and by e-mail on recent cruises). The type of satellite information received, and its usefulness has generally remained the same across the years, with a variety of satellite methods: passive, microwave radiometers, visible and infrared sensors, synthetic aperture radar, or sometimes only estimated boundaries. The JIC/NIC ice information has been vital for estimating the position of the ice-edge and has been more important in the absence (since the 1985/86 cruise) of the Soviet vessels and their dedicated ice-edge role in mapping and survey.

Ice information from other ships and/or land stations

Useful ice information has been received, from time to time, from other ships and Antarctic land bases.

Consistency of estimates of the ice-edge/southern boundary over years

The methods used for estimating the position of the ice-edge have not changed significantly during the history of the cruises. The only major change is that the estimates for later cruises lack the precision of the earlier cruises when the position was determined by the ice-edge survey and mapping vessels. On the later cruises there has been a trend towards fewer ice-edge waypoints due to changes in the cruise track construction methods. However, since the information for estimating the ice-edge has come from a number of sources and uses a variety of methods it is fair to say there has been consistency over time. The Antarctic pack ice is a highly variable, dynamic system, the distribution and characteristics of which are determined by, and strongly reflect, the underlying oceanographic processes (and on a shorter temporal scale, the meteorological conditions; particularly wind force). 'Ice-edge' characteristics are not necessarily restricted to the northernmost sea ice/open water boundary. The positions of the estimated ice-edges established during these cruises, are based mainly on the safe navigation of the research vessels.

Discovery marking

From the 1978/79 to 1983/84 cruises, the primary method of abundance estimation was the mark-recapture method. The procedure was basically to conduct a sightings survey until an appropriate whale group was observed and then the group would be pursued for marking. Minke whales at least 8.0m in length were the primary target but sperm and humpback whales were also marked in some of the cruises. Minke whales were marked using the small 0.410 Discovery mark, while sperm and humpback whales were marked with the more standard 12-gauge Discovery mark. Details of these activities and results are given in the cruise reports and the first 10-year review paper (Joyce *et al.*, 1988). Discovery marking was discontinued after the 1983/84 cruise after an analysis by Cooke (1986) showed that it was unlikely an adequate number of marks could be deployed and recovered to provide an accurate population estimation.

Experiments

Over the years, experiments have been conducted during the cruises to answer specific questions related to abundance estimation. Experiments related to Discovery marking took place only during the first circumpolar cruises and are reviewed in Joyce *et al.* (1988). The first major experiments relating to sighting surveys came from the 1980 Workshop on the Design of Sightings Surveys (IWC, 1982). Subsequently, other experiments arose from Annual Meetings of the IWC Scientific Committee, the Tokyo planning meetings, and especially the occasional specialist meetings held in conjunction with the Tokyo planning meetings. Experimentation reached a peak during the 1984/85 cruise when over half the cruise was dedicated to conducting sighting experiments. A special workshop on minke whale sightings was held in 1985 to evaluate the results of these experiments (IWC, 1986). Tables 5 and 6 list the experiments conducted on the cruises since 1978/79.

Routine experiments for recent cruises

Estimated distance and angle experiment

This experiment was designed to examine the precision and accuracy of distance and angle estimates to a sighting. A buoy with a radar-reflecting transponder is used as the sighting target and distance and angle estimates are made by the observers while the ship is underway at normal searching speeds. Buoys of the same design have been used for the entire history of this experiment. The mast of the buoy is 3.5-3.6m high. The design of buoy is shown in the 1984/85 cruise report. At pre-determined distances and angles from the buoy, visual observations by the observers are taken simultaneously with radar readings.

Six trials per observer, per sighting platform are scheduled. Primary observers are tested from platforms where they normally conduct sightings effort, using the same procedures and equipment as during normal searching. It is stressed to the observers that all angle readings must be made using angle boards with pointers, both during the experiments and during sightings effort. The experiment is conducted during weather and sea conditions that are not unrepresentative of the conditions encountered during the survey. However, due to radar imaging problems, the experiment has usually been conducted in better-than-average conditions. Additionally there is a safety aspect, since the deployment and retrieval of the buoy requires relatively calm conditions.

For both theoretical and practical reasons, it is preferable for the experiment to be scheduled in the middle of the survey period. Since sea conditions near the ice-edge are usually less changeable, it is recommended that the experiment be attempted near the middle of the cruise about the time that the vessels swap strata. The cruise leader/senior scientist randomly selects distances from six of the following seven ranges (in n.miles): 0.00-0.25; 0.26-0.50; 0.51-1.00;

Table 5

Summary of the cruises from 1978/79 to 2000/01 (positioning system and non-sightings related experiments). Abbreviations: CP = circumpolar survey, Cel = Celestial, NS = Naval navigation Satellite System, GPS = Global Positioning System, V = Vessel observation, J = Joint Ice Centre Information, N = Naval Ice Centre Information, Eff = Recovery efficiency, Tf = Trial-firing for dart modification and target position, Ver = Mark verdict experiment using VTR, Pid = Photoidentification or natural marking, Biop = Biopsy, Md = Marine debris observation, Poll = Air and sea pollutants, Ac = Acoustic survey, CTD and XBT = Oceanography.

								Experiments									
			Positioning system			Ice info					Marking			Environment			
CP	Cruise	Area	Cel	NS	GPS	V	J/N	Pid	Biop	Ac	Eff	Tf	Ver	Md	Poll	CTD	XBT
CP I	1978/79	IV	Y	-	-	Y	-	-	-	-	Y	-	-	-	-	-	-
	1979/80	III	Y	-	-	Y	-	-	-	-	Y	Y	-	-	-	-	-
	1980/81	V	Y	-	-	Y	Y	-	-	-	-	-	-	-	-	-	-
	1981/82	II	Y	Y	-	Y	Y	-	-	-	-	-	-	-	-	-	-
	1982/83	I	Y	Y	-	Y	Y	-	-	-	-	-	Y	-	-	-	-
	1983/84	VI	-	Y	-	Y	Y	-	-	-	-	Y	Y	-	-	-	-
CP II	1984/85	IV	-	Y	-	Y	Y	Y	-	-	-	-	-	-	-	-	-
	1985/86	V	-	Y	-	Y	Y	-	-	-	-	-	-	-	-	-	-
	1986/87	II	-	Y	-	Y	Y	Y	-	-	-	-	-	-	-	-	-
	1987/88	III	-	Y	-	Y	Y	Y	-	-	-	-	-	Y	-	-	-
	1988/89	IV	-	Y	-	Y	Y	Y	Y	-	-	-	-	Y	-	-	-
	1989/90	I	-	Y	-	Y	Y	Y	Y	-	-	-	-	Y	-	-	-
	1990/91	VI	-	Y	-	Y	Y	Y	Y	-	-	-	-	Y	-	-	-
CP III	1991/92	V	-	-	Y	Y	Y	Y	Y	-	-	-	-	Y	-	-	-
	1992/93	III W	-	-	Y	Y	Y	Y	Y	-	-	-	-	Y	-	-	-
	1993/94	I	-	-	Y	Y	Y	Y	Y	-	-	-	-	Y	Y	Y	-
	1994/95	III E, IV W	-	-	Y	Y	Y	Y	Y	Y	-	-	-	Y	Y	Y	-
	1995/96	VI W	-	-	Y	Y	Y	Y	Y	-	-	-	-	Y	Y	Y	Y
	1996/97	II E	-	-	Y	Y	Y	Y	Y	-	-	-	-	Y	-	Y	Y
	1997/98	II W	-	-	Y	Y	Y	Y	Y	Y	-	-	-	Y	-	-	-
	1998/99	IV	-	-	Y	Y	Y	Y	Y	Y	-	-	-	Y	-	-	-
	1999/00	I E, II W	-	-	Y	Y	Y	Y	Y	Y	-	-	-	Y	-	-	-
	2000/01	VI E, I W	-	-	Y	Y	Y	Y	Y	-	-	-	-	Y	-	-	-

1.01-1.50; 1.51-2.00; 2.01-2.50; 2.51-3.00. Similarly the angles are randomly selected from six of the following seven trials (in degrees): 00-10 two trials; 11-20 two trials; 21-40 two trials; 41-60 one trial.

Potential sources of bias that would not occur in normal searching have been identified and avoided; the following procedures are followed:

(1) observers should not know the distances and angles being examined;
(2) observers should not discuss the previous test with other observers;
(3) observers should be below deck between trials;
(4) observers should not look for the buoy until told to;
(5) observers should not be told the results of the test until after the survey;
(6) distances and angles should be over a range and not consistently a single value for all observers during a single trial.

Priority is given to the barrel and IOP trials. Trials with researchers as observers have the lowest priority. The results of the experiment are recorded on the Estimated Angle and Distance Data Record. Two examples of the protocol followed while conducting the experiment on recent cruises are presented in Appendix 3.

ESTIMATED ANGLE AND DISTANCE TRAINING EXERCISE

A training exercise is conducted on a priority basis near the beginning of the cruise to familiarise the observers with distances, angles, and the use of reticle binoculars and angle boards. The exercise uses the estimated distance and angle experiment procedures, except that several observers can make estimates at one time, and the observers are informed of the radar values in each trial. The exercise is conducted with the ship underway or stationary. The number of trials conducted is at the discretion of the Cruise leader/Senior scientist. During the cruises, there are often informal 'competitions' in which observers are asked to estimate the distance to icebergs and small pieces of ice (but not usually the angle). Estimates of the distance to the latter takes place particularly in calm weather when small pieces of ice can be more easily detected by radar. Observers are only informed of the radar measurement after they have made their estimates. Most frequently these 'competitions' were among the Front/Upper Bridge personnel but sometimes observers on all platforms were involved.

OBSERVERS CODES AND EXPERIENCE

A list of codes for observers as used on the data forms and their relevant experience has been submitted to the IWC, for each cruise since the 1993/94 cruise. An example is shown in Appendix 4.

CHANGES OVER TIME

The Estimated Angle and Distance Experiment has been conducted on each ship, on each cruise, since 1981/82 and the protocol for conducting the experiment has been essentially unchanged since the 1987/88 cruise (apart from minor logistical details). Prior to the 1987/88 cruise, the following modifications to the experimental protocol were made: (1) angle boards and reticle binoculars were used by the observers from the 1984/85 cruise; (2) the Captain and helmsman were included in the experiment from the 1984/85 cruise; (3) to improve the resemblance of the buoy to a whale

Table 6

Summary of experiments related to estimating abundance from sighting data.

Experiment	Primary aim	Seasons	References
Variable speed	Estimation of *g*(0)	1980/81; 1982/83 -84/85	Butterworth *et al.* (1982); Hiby (1986)
Density gradient	Relationship of density to distance from ice-edge	1980/81-81/82	Butterworth *et al.* (1982); Butterworth *et al.* (1984)
Parallel ship	Reaction of whales to vessel, *g*(0)	1980/81 - 84/85	Butterworth *et al.* (1982); Butterworth *et al.* (1984); Hiby (1986); Kishino (1986); Cooke (1987); IWC (1987)
Hazard rate	Collect data for use in hazard rate model	1983/84	Joyce (1984); Hiby and Thompson (1985)
Topmen behaviour	Bias in search effort	1980/81, 1985/86	Ward *et al.* (1986)
Secondary sightings	Comparison of passing and closing modes	1984/85 - 85/86	Anon. (1985)
Length estimation	Check accuracy of visual estimates	1984/85	Gordon (1985)
Dive time	Cue-counting, *g*(0)	1980/81 - 81/82, 1984/85, 1989/90 - 92/93	Hiby and Ward (1986); Ward and Hiby (1987)
Blow rate	Cue-counting; *g*(0)	1980/81- 81/82, 1984/85 - 86/87	Hiby and Ward (1986); Ward (1988); Ward and Hiby (1987)
Blow duration	*g*(0); cue-counting;	1980/81, 1982/83	Butterworth *et al.* (1982)
Radio tracking	Various incl. dive time	1986/87	Joyce (1987)
Whale reaction to the survey vessel		1986/87	
Swimming speed		1982/83	Butterworth *et al.* (1983)
Cue counting	Abundance estimation technique	1984/85 - 86/87, 1988/89	Hiby and Ward (1986); Ward and Hiby (1987)
NNSS (naval navigation satellite system) closure	Accuracy of determining position of sightings	1981/82 and 1984/85	Butterworth *et al.* (1984); Joyce (1986)
Estimated distance and angle	Abundance estimation	1981/82 to present	e.g. Butterworth *et al.* (1984)
Photographic angle measurement	Abundance estimation	1983/84 - 84/85	Thompson and Hiby (1985); Ward *et al.* (1986)

sighting, from 1984/85 a flag on the mast of the buoy was replaced with an inverted white cone (c.f. a blow); (4) an Estimated Angle and Distance Training Exercise has been conducted on each ship since the 1985/86 cruise; (5) since the 1985/86 cruise, researchers have also been included in the experiment (with the exception, for logistical reasons, of the senior scientists and Japanese researchers); (6) the number of distance and angle estimates made by each observer from each platform was initially 10, this was reduced to eight from the 1986/87 cruise; (7) the number of distance and angle estimates was further reduced (to six) from the 1987/88 cruise; (8) from the 1987/88 cruise, the experiment was conducted from the ship while it was underway at normal searching speed (prior to this, the ship was stationary while each estimate was made).

Resighting

The resighting experiment is conducted during IO mode. The resighting data provide an additional source of information for the estimation of *g*(0) and for the assessment of duplicate status. This experiment has been conducted since the 1992/93 cruise. These data have not been recorded for all IO mode sightings which have been resighted during tracking, for a variety of reasons. However, resighting data exist for a large number of sightings (322 sightings for the period 1997/98 to 2000/2001).

Biopsy

This experiment started on the 1988/89 cruise. Blue, right and humpback whales are targeted (low priority for killer and sperm whales). The following equipment was available: Japanese airguns (from 1989/90); the Paxarm system (from 1995/96); the *Larsen* gun (from 1998/99); and crossbows (1988/89 in feasibility; from 1993/94 in use). There are limits to the amount of time available for biopsying on each cruise.

Photo-identification

This experiment started on the 1987/88 cruise. Blue, right and humpback whales are targeted. Equipment includes 35mm SLR data back cameras equipped with 70-300mm lenses and motor drives, and black and white 400 ASA film (*Kodak* T-Max or *Ilford* HP5) pushed (i.e. exposed at) to 800 ASA.

SIGHTING SURVEY RECORDS

The following records for sightings survey are completed during each cruise by ship officers or researchers. Each record has undergone minor changes over the three circumpolar series of cruises. Details can be found in the Usage Notes prepared for each survey.

Weather

The Weather Record is maintained by the ship's officers and is completed every hour while in the research zone. Environmental conditions and data have been collected using consistent methodology throughout the surveys. The type of information recorded has been consistent with some minor additions such as the inclusion of swell conditions from the 1995/96 cruise.

Effort
The Effort Record is completed every day of the research programme. The Chief and Second Officers are responsible for the completion of the daily records. Research activities are identified by effort codes that are classified into four categories: On-effort; Off-effort; Experiments; and Navigation. These codes indicate the initiation or termination of full-effort sighting survey.

Sighting record
This Sighting Record is completed by the researchers. A single record is used for each cetacean sighting, regardless of search effort mode or composition of the sighting. Thus one form is completed for each distinct aggregation of cetaceans seen, e.g. a pod of whales with dolphins around them is a single sighting. If a group of animals separates when approached, all sub-groups are to be considered part of the original sighting.

Ice-edge
The Ice-edge Record is used to record information on the position of the pack ice/open water boundary and is completed by either vessel that encounters pack ice during the survey. Data for this form can come from a variety of sources: visual; satellite; other ship observations; charts (for land boundaries); and interpolations based on these sources. The senior scientist integrates the sources for the most robust estimate of the ice-edge.

Glare
Glare has been recorded on a separate data record since the 1999/2000 cruise (previously glare was recorded, in a slightly different format, on the weather data record). A recording is made at the beginning of each on-effort period and then at any time during the research if changes in the glare are considered to be significantly affecting the sighting conditions.

Charts
Exact copies (tracings) of all charts developed during the cruises are made by the ships' officers. These very detailed charts show the tracklines, waypoints, the positions of all sightings (all species) the positions of all effort mode changes (such as closing and returning to trackline), and details of the ice-edge etc. Copies of the charts (for all vessels and all cruises from the start of the programme) are sent, with the cruise data, to the IWC Secretariat.

RESULTS

The cruises have been conducted successfully for over 23 years (including the 1984/85 experiment cruise) with all six IWC management Areas investigated twice, and five of the Areas sampled thrice (Table 7). Each cruise has utilised a standard methodology, which has contained minor modifications in the procedures dictated by the results from the previous cruises.

Searching effort and ship-days
A total searching distance covered in primary search mode was 70,340 n.miles with 6,027 primary Antarctic minke whale sightings during 2,448 ship-days in the Antarctic.

International researchers
A total of 69 international researchers from 14 nations selected by the IWC have been involved in this programme. The cruise leaders have usually participated for many years. There was an additional researcher (total of four on each

Table 7

Summary of the cruises from 1978/79 to 2000/01 (effort, sightings and abundance). [a]From cruise reports. [b]From 1978/79 to 1997/98: Branch and Butterworth (2001), from 1998/99 to 2000/01: Ensor *et al.* (1999, 2000 and 2001). [c]Branch and Butterworth (2001). Numbers in parentheses are those agreed at the 1990 IWC Scientific Committee meeting.

			Searching distance (n.mile)[a]			Antarctic minke whale					
CP	Cruise	Area	Closing	IO	Total	Primary schools seen[b]	D (whales/ 100n.m^2)	P[c] (ind)	CV[c]	(P)	(CV)
CP I	1978/79	IV	7,764.1	-	7,764.1	498.3	26.6	113,569	0.218	-	-
	1979/80	III	6,966.3	-	6,966.3	419	25.0	123,714	0.242	-	-
	1980/81	V	5,299.9	-	5,299.9	545	33.7	161,695	0.264	-	-
	1981/82	II	6,581.8	-	6,581.8	447	11.5	45,580	0.262	-	-
	1982/83	I	4,823.3	-	4,823.3	576	17.2	63,932	0.254	(73,302	0.254)
	1983/84	VI	4,190.6	-	4,190.6	190	13.8	99,786	0.277	(106,901	0.277)
	1984/85	IV	-	-	-	-	-	-	-	-	-
	1985/86	V	3,485.3	4,227.9	7,713.2	1,056	31.1	299,793	0.231	(294,610	0.138)
	1986/87	II	3,329.6	3,650.7	6,980.3	781	26.5	131,177	0.256	(122,156	0.190)
CP II	1987/88	III	2,069.5	3,329.6	5,399.1	300.4	28.8	138,022	0.543	(88,735	0.273)
	1988/89	IV	2,067.2	2,378.5	4,445.7	422.7	10.1	58,170	0.375	(74,692	0.257)
	1989/90	I	2,430.2	2,980.9	5,411.1	487.5	14.9	63,972	0.258	-	-
	1990/91	VI	1,453.4	2,159.5	3,612.9	146.6	10.2	56,807	0.399	-	-
CP III	1991/92	V	1,702.8	2,029.0	3,731.8	535.9	22.2	98,682	0.200	-	-
	1992/93	III W	2,540.9	2,748.6	5,289.5	325.6	5.7	25,363	0.183	-	-
	1993/94	I	2,362.1	2,477.4	4,839.5	224.3	5.6	37,479	0.220	-	-
	1994/95	III E, IV W	2,052.3	2,248.0	4,300.3	216.1	7.4	31,620	0.210	-	-
	1995/96	VI W	1,647.4	1,733.8	3,381.2	174	8.5	37,839	0.223	-	-
	1996/97	II E	1,568.6	1,769.4	3,338.0	131.2	6.3	28,158	0.241	-	-
	1997/98	II W	1,377.2	1,688.1	3,065.3	114	5.0	15,434	0.325	-	-
	1998/99	IV	1,734.8	2,098.4	3,833.2	390	-	-	-	-	-
	1999/00	I E, II W	1,022.8	790.9	1,813.7	108	-	-	-	-	-
	2000/01	VI E, I W	1,629.6	1,556.5	3,186.1	614	-	-	-	-	-

ship) on the 1998/99 and 1999/2000 cruises. The additional researcher was an acoustics expert and did not take part in sighting activities.

Crewmembers
A total of 1,093 crewmembers (217 Soviet and 876 Japanese) have been engaged in this programme. The survey experience of Japanese crewmembers on each cruise is shown in Table 8. Younger, less experienced primary observers have mainly participated from the 1992/93 cruise. Since the 1998/99 cruise, an additional two topmen who have been inexperienced observers have been present on both the SM1 and SM2 (increasing the crew complement to 19). These additional observers have been on board to meet a need for crew training. While the numbers of observers in the platforms were unchanged, experienced observers were always present; inexperienced observers were either in the top barrel (under the tutelage of an experienced observer), or on the front/upper bridge. The inexperienced observers (beginner; the first year for the survey) have not been assigned to the IOP.

Table 8

The number of primary observers in each rank of experience for Japanese vessels between 1978/79 and 1999/2000 cruise. Survey experience included Antarctic commercial whaling and JARPA (Japanese Whale Research Program under special permit in the Antarctic). Data from Kyodo Senpaku, Kaisha, Ltd.

Cruise	Experience		
	1-5 years	6-9 years	10+ years
1978/79	0	1	11
1979/80	0	0	12
1980/81	0	0	12
1981/82	0	2	10
1982/83	0	0	12
1983/84	0	0	18
1984/85	1	0	18
1985/86	0	0	18
1986/87	0	0	18
1987/88	0	0	12
1988/89	0	0	12
1989/90	0	0	12
1990/91	0	0	12
1991/92	1	0	11
1992/93	4	1	7
1993/94	5	0	7
1994/95	5	0	7
1995/96	6	1	5
1996/97	6	0	6
1997/98	5	0	7
1998/99	8	2	5
1999/00	4	5	5

Discovery marking
Discovery marking was conducted during the 1978/79 to 1983/84 cruises, with 2,716 minke whales, 25 sperm whales and 7 humpback whales successfully marked. Details of this experiment were reported by Joyce *et al.,* (1988).

Surveyed Area (*A*)
Fig. 5 shows the comparison, by strata, of the research area surveyed (*A*, n.miles^2) in each cruise by Area from 1978/79 to 1997/98. In Areas I, II and III, the area of the northern stratum is larger in the 3rd circumpolar cruise. Although comparable data are still being calculated for Area IV, and for the 2000/01 cruise in Area VI), it appears the same tendency is to be expected.

Searching distance (*L*)
Fig. 6 shows for each cruise the comparison of the distance searched on primary effort (*L*, n.miles) by survey mode (Closing mode: black; IO mode: white) from 1978/79 to 2000/01. In Areas I, II, III and VI, the northern stratum component of *L* is higher in the 3rd circumpolar cruise with the expansion of the research area in the northern stratum. The northern part of *L* was decreased in Area IV in the 3rd circumpolar cruise.

Number of primary sightings of minke whales (n_s)
Fig. 7 shows the comparison of the number of the primary sightings of minke (code 04+91) whales (n_s) in each cruise by survey mode (Closing mode: black; IO mode: white) from 1978/79 to 2000/01. In Areas III and VI, n_s for the northern stratum component is higher in CPIII (with the expansion of survey effort in the northern stratum). However, n_s for the northern part is lower in Areas I, II and IV in CPIII (despite of the expansion of survey effort).

Encounter rate of the primary school of minke whales (*n*/*L*)
Fig. 8 shows the comparison of the number of primary sightings of minke whales (*n*/*L*; schools/100 n.miles) with CV in each cruise by survey mode (Closing mode: black; IO mode: white) from 1978/79 to 1997/98 (from Branch and Butterworth, 2001b).

Effective search half width of minke whales (ESW)
Effective search half widths of the primary minke whale schools (as analysed by Branch and Butterworth, 2001b) are shown, with the coefficient variation (CV), in Fig. 9.

Estimated mean school size of minke whales (E(*s*))
The estimated mean school size of minke whales (E(*s*)) of the primary minke whale schools (from Branch and Butterworth, 2001b) are shown, with the coefficient variation (CV), in Fig. 10.

Number of primary sightings of 'like minke'
The identification category 'Like minke' was first used during the 1985/86 cruise in Area V. Fig. 11 shows the comparison of the number of the primary sighting of the 'like minke' in each cruise by survey mode (Closing mode: black; IO mode: white) from 1978/79 to 2000/01. The number of sightings identified as 'like minke' has increased in Areas IV, V and VI through the circumpolar series. More 'like minke' sightings tended to be recorded during IO mode.

Sighting compositions of each Area
Fig. 12 shows the species compositions of the primary sightings (schools) in each circumpolar set by Area, except for the 1984/85 experiment cruise (from DESS − Strindberg and Burt, 2000; and cruise reports − Ensor *et al.,* 1999; 2000; 2001).

For CPIII, two cruises are combined in Area I (1993/94 + 1999/2000), Area II (1996/97 + 1997/98), Area III (1992/93 + 1994/95), Area VI (1995/96 + 2000/01). Although Area V has already been surveyed in the third set, the coverage of the far north of the northern strata was inadequate.

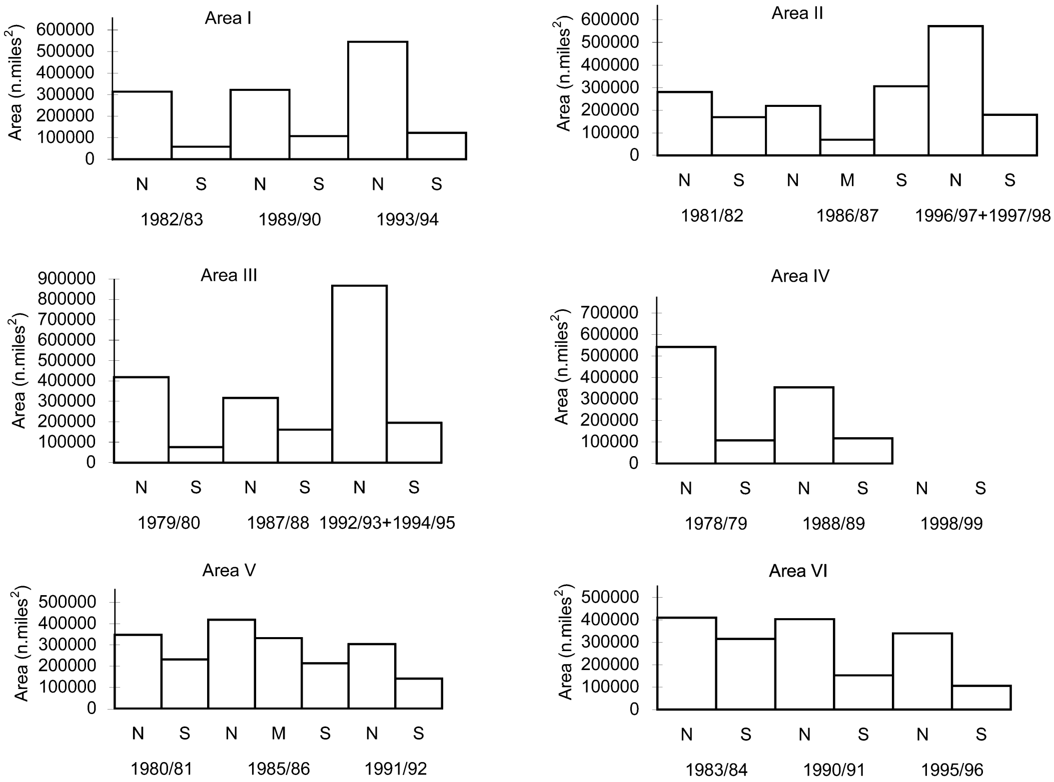

Fig. 5. Comparison of the research area surveyed (A, n.miles^2) in each cruise by Area from 1978/79 to 1997/98. In Areas I, II and III, the northern part of the area surveyed are increased in 3rd circumpolar cruise. Although Areas IV and VI (2000/01) are still calculating, it seemed that they expected same tendency. N: northern strata, M; middle strata, S; southern strata. Each stratum was established in different latitude by each circumpolar cruise.

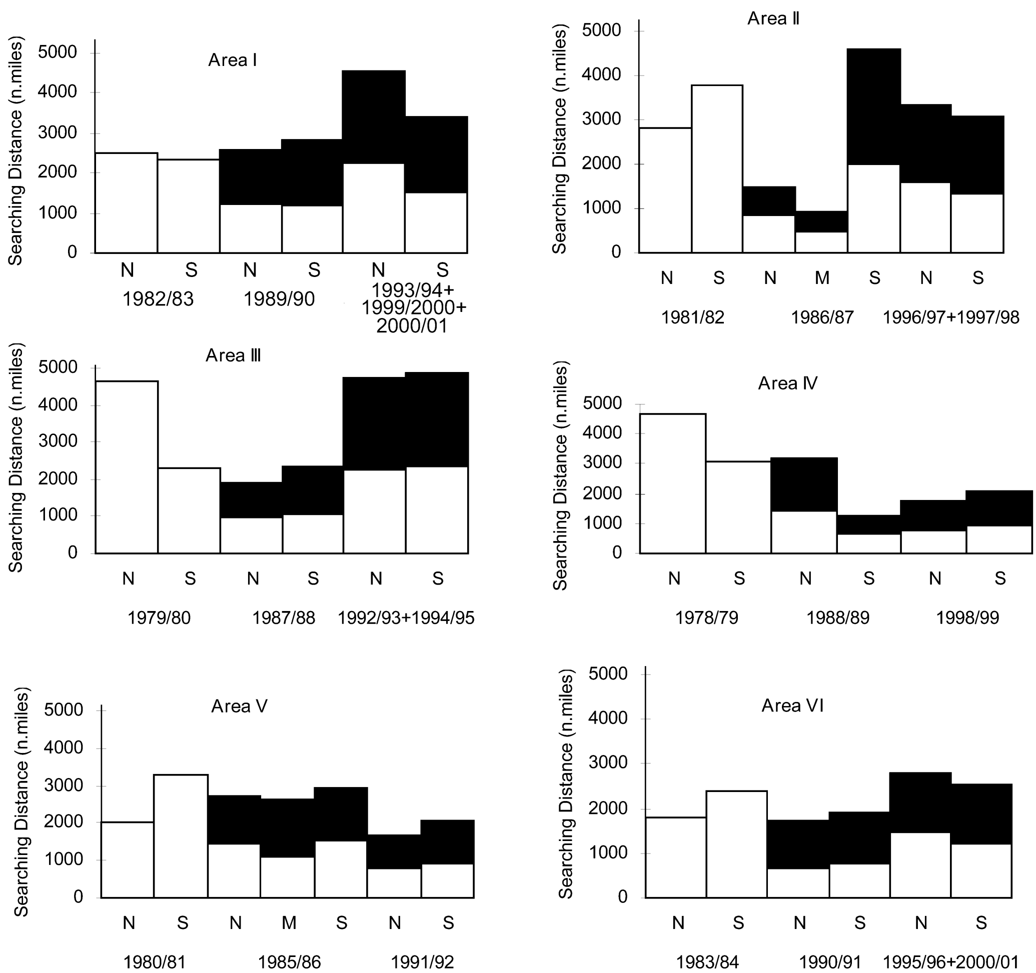

Fig. 6. Comparison of the Searching distance (L, n.miles) in each cruise by survey mode (Closing mode; white and IO mode; black) from 1978/79 to 2000/01. In Areas I, II, III and VI, the northern part of the L are increased in 3rd circumpolar cruise with the expanding of research area in northern stratum. N: northern strata, M; middle strata, S; southern strata. Each stratum was established in different latitude by each circumpolar cruise.

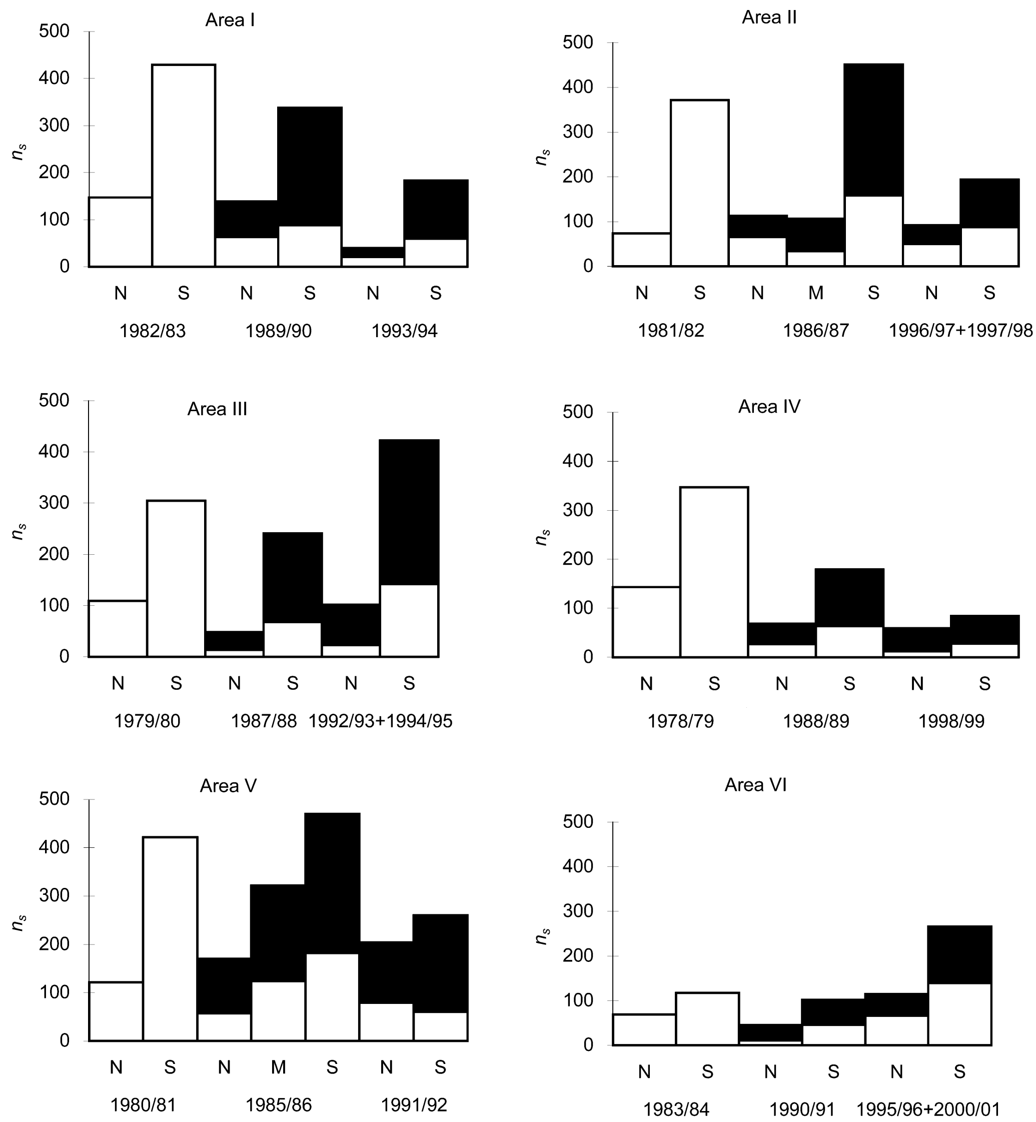

Fig. 7. Comparison of the number of the primary sighting of minke whale schools sighted (n_s) in each cruise by survey mode (Closing mode; white and IO mode; black) from 1978/79 to 2000/01. N: northern strata, M; middle strata, S; southern strata. Each stratum was established in different latitude by each circumpolar cruise (see Fig. 2a-2f).

The proportion of minke whale schools is consistent in Areas II, III and V, but it decreases (with a corresponding increase in humpback and fin whales) in Areas I and IV, over the three circumpolar cruise series. The reverse is true for Area VI. The proportion of humpback whales has increased in Areas I and IV, whilst that of fin whales has increased in Areas I, II, IV and VI.

Ziphiid (code 11) and unidentified whales tended to decrease in proportion from the second circumpolar set after whale identification standards were established. Unidentified whales include code 09 (unidentified whale); 64 (unidentified large baleen whales); 73 (unidentified large whale); 63 (unidentified small whale); and 76 (unidentified small cetacean).

DISCUSSION

Overview of data collection

It is concluded that the programme has conducted sightings surveys in a consistent way whilst developing standard procedures that are the best possible compromise between statistical needs and logistic feasibility. The experience gained over the cruises has also improved the precision of whale identification standards in the Antarctic and Southern Ocean.

Noting changes over time

Change of survey priority

After much discussion (IWC, 1986), the programme was modified from a Discovery marking cruise (for data analysis and evaluation, see Buckland and Duff, 1989) to a rigidly structured sightings cruise after CPI. With this as a turning point, rigid sighting survey procedures (especially strata design and cruise track design) and strict whale identification standards were established for the line transect abundance estimation.

Change of coverage of the northern stratum

For CPIII, the survey design was further modified to ensure complete coverage south of 60°S. The latitudinal coverage (from the ice-edge to 60°S) has taken precedence over the longitudinal coverage (this is especially the case in Areas I, II and III, compared with CPI and CPII). The width of the southern stratum has also been expanded compared to the previous cruises (Fig. 2a-f). An outcome of this change is that the distribution of effort within the overall research area

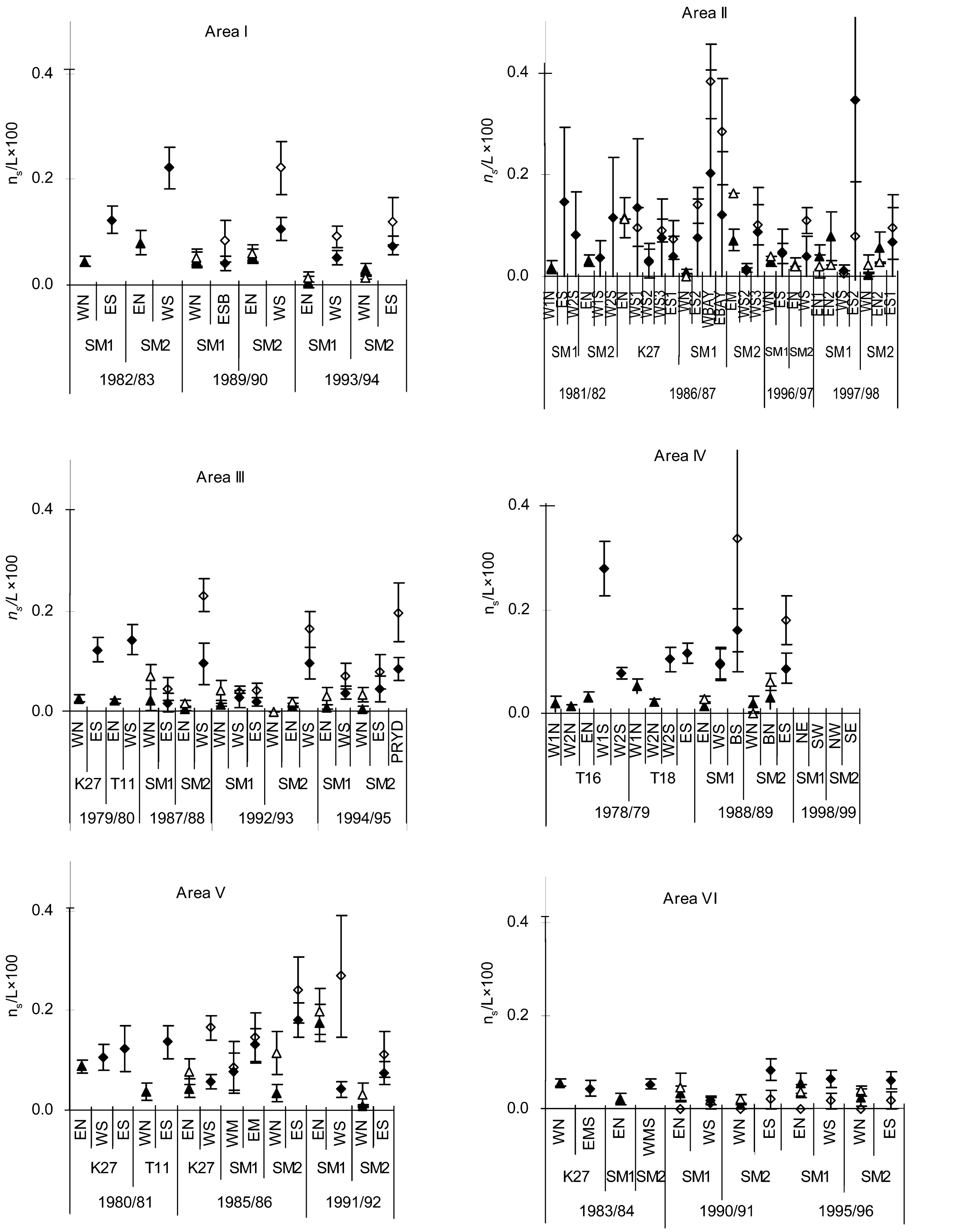

Fig. 8. Comparison of the number of the primary sighting of minke whale (*n*/*L*; schools / 100 n.miles) with the ±1 STD error in each cruise by survey mode (Closing mode; black and IO mode; white) from 1978/79 to 1997/98 (data from Branch and Butterworth, 2001b). N: northern, M; middle, S; southern. Each stratum was established in different latitude by each circumpolar cruise (see Fig. 2a-2f).

has not been consistent, not only in the south (where minke density is expected to be the higher) but also in the north (Fig. 2a-f and 3). As a result, the distance searched on primary effort in the northern stratum has increased by over 30-50% in Areas I, II, III and VI (Fig. 6). These effects possibly led to a decrease in the encounter rate in the northern stratum in CPIII (Fig. 8).

Change of whale identification standard

Systematic sighting procedures were developed and strict rules for identification of Antarctic minke, like minke, Southern bottlenose and Ziphiid whales were established from the 1985/86 cruise, along with increasing expertise of observers and researchers in identification of the species previously grouped as 'akabo'. As a result of this progress,

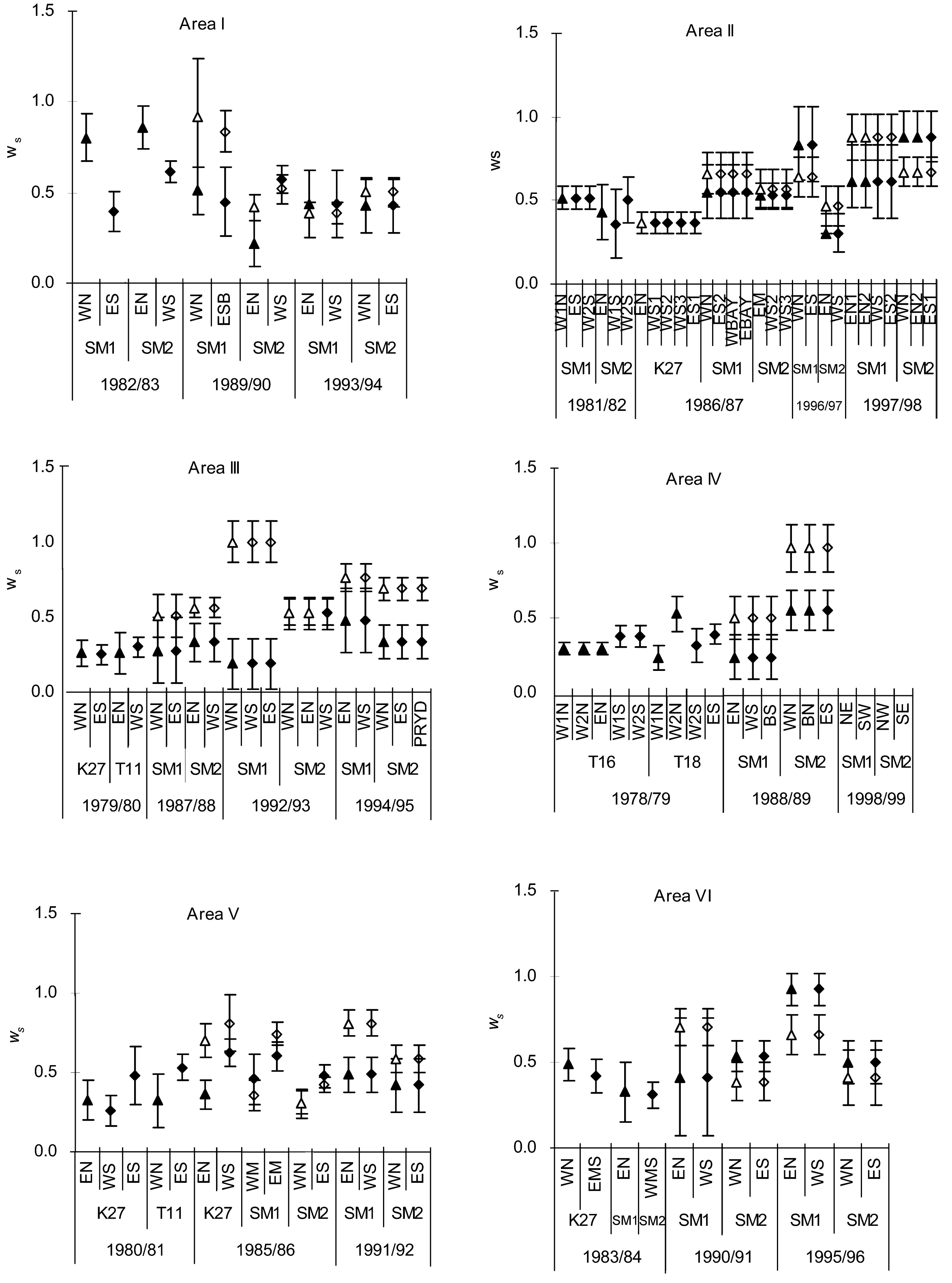

Fig. 9.The effective search half width (ESW) of the primary minke whale schools with the ±1 STD error (data from Branch and Butterworth, 2001b). The ESW were pooled by each vessel in 3rd circumpolar series. Northern stratum; triangle, southern stratum; circle. Closing mode; closed, IO mode; empty

the number of schools of 'unidentified whale (code 09)' and 'unid. Ziphiid' have decreased while 'like minke' and 'southern bottlenose' whales have increased in Areas II, III and IV (Figs 11 and 12). In relation to the standardisation of identification and research procedures, there is no single clear reason to account for the change in proportion, across years, of minke identifications and 'like minke' identifications. Plausible explanations may include the following.

(1) Changes in the distribution of survey coverage (northwards) may have increased the likelihood of encountering smaller group sizes of minke whales, particularly solitary animals (an increase in solitary animals would lead to a decrease in the success rate of closures and identification in closing mode and increased difficulty tracking and identification in IO mode). There may also have been changes to the clustering pattern of minke whales (towards a more

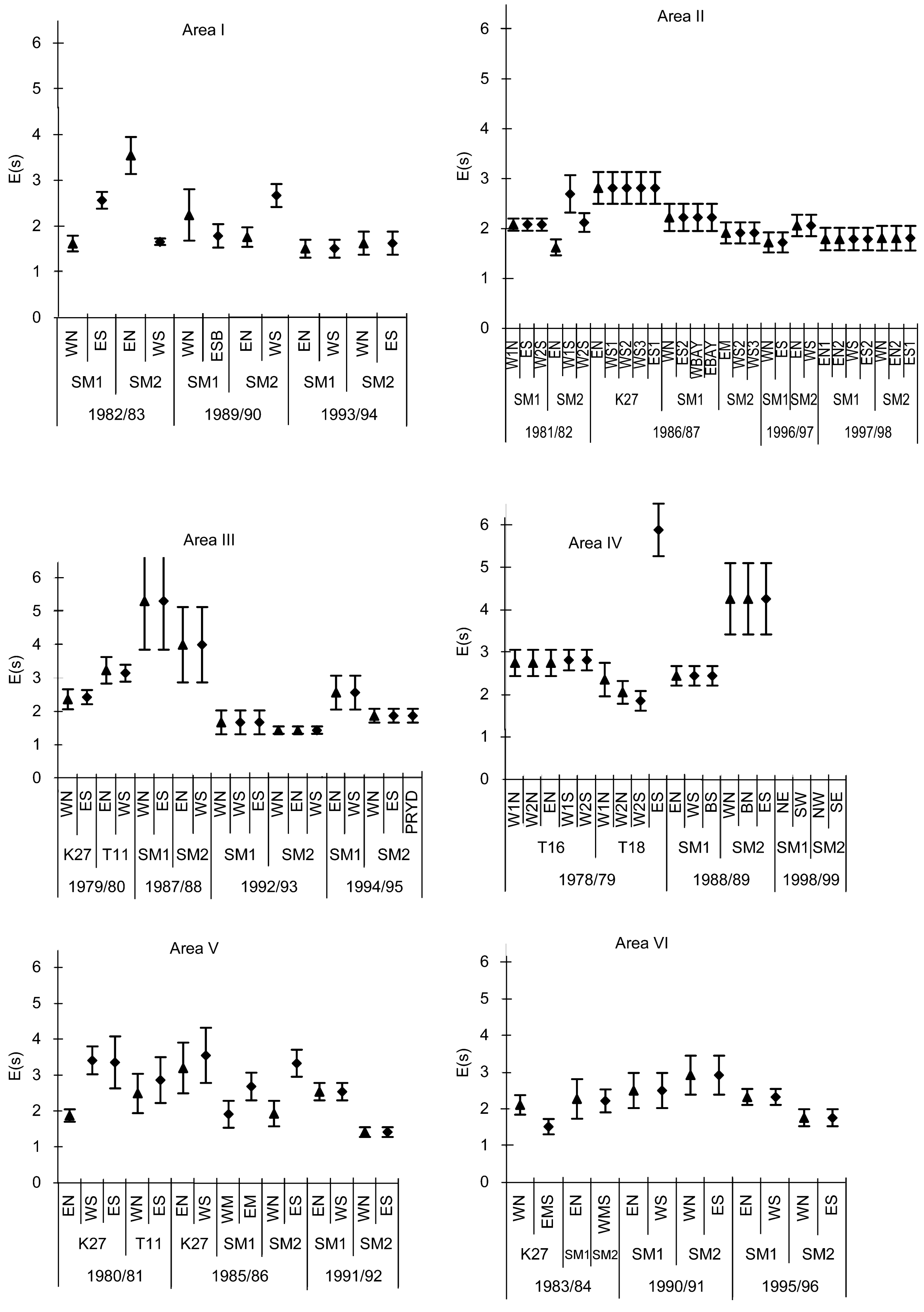

Fig. 10. The estimated mean school size of minke whales (*E(s)*) of the primary minke whale schools with the ±1 STD error (data from Branch and Butterworth, 2001b). The *E(s)* were also pooled by each vessel in 3rd circumpolar series. Northern stratum; triangle, southern stratum; circle.

dispersed distribution) or a change in age structure (smaller animals are generally more difficult to identify) or change in school size or distribution of prey species (*Euphausia*).

(2) Areas of higher sighting rate of minke whales may have been encountered in some years and not in other years. In both survey modes (and particularly in IO mode), when the sighting rate is high there is greater likelihood

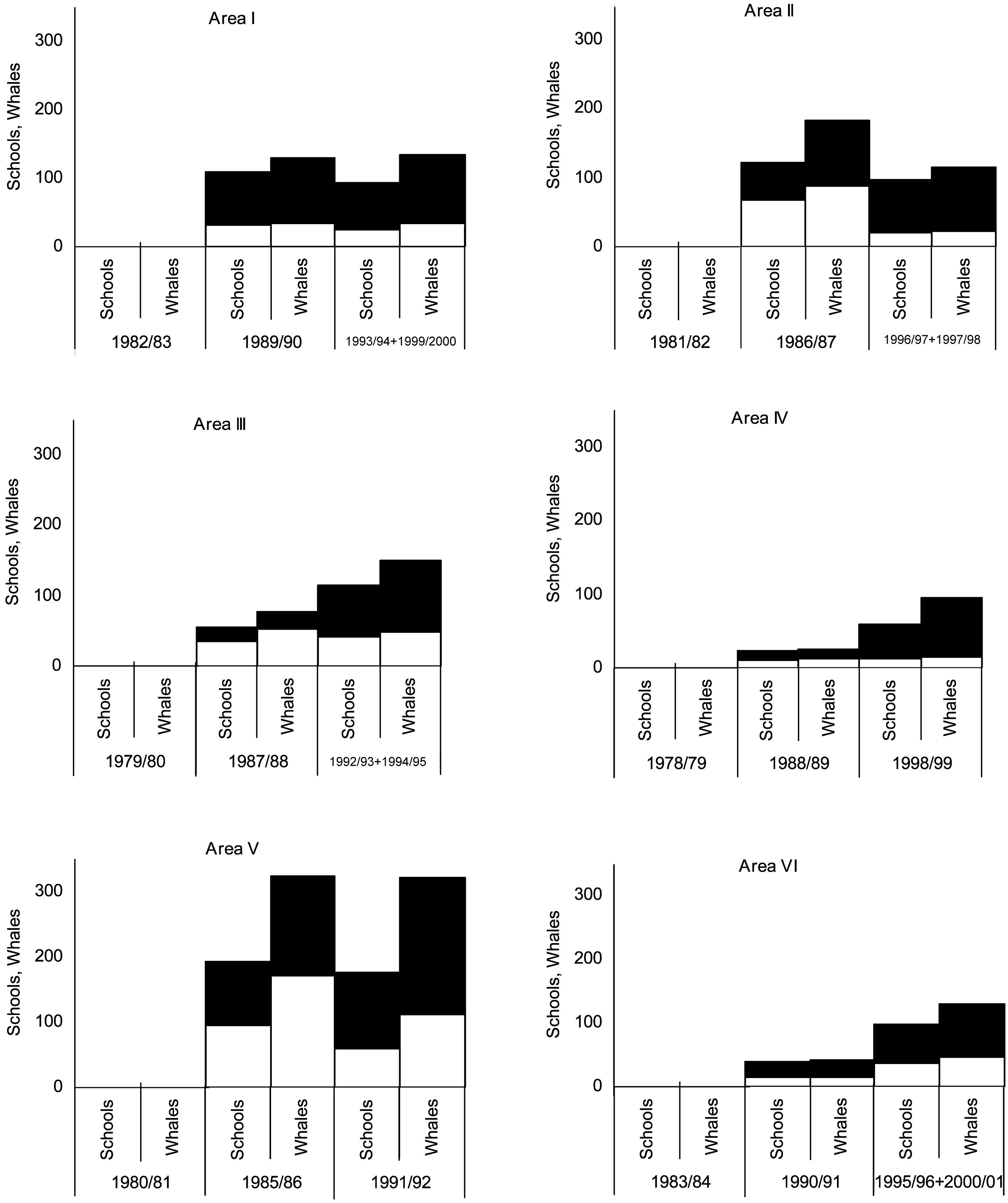

Fig. 11. Comparison of the number 'like minke' (primary schools and whales) by each Area during 1978/79 to 2000/01 cruises (Closing mode; lower, IO mode; upper). More 'like minke' sightings tended to be recorded during IO mode.

that the increased time spent assessing duplicate status means that not all groups will be tracked and identified.

(3) The introduction of younger, less experienced observers into the programme.

(4) Researchers may have had different levels of strictness, across years, in assigning identifications.

Change of research schedule

The two- to three-week delay in the schedule for the cruises since the 1994/95 cruise may have had some subtle effects on the results of the sighting survey. Prior to, and after the changes to the schedule there was a significant difference in effective half width between the ships. Consistently on all recent cruises, the SM1 has had a significantly greater effective half width, than SM2, (Borchers, 1993; Burt and Borchers, 1996; Burt and Borchers, 1999), except for the 1992/93 cruise (when SM2 went to the Southern Stratum first (Borchers and Cameron, 1995) and excluding the 1997/98 cruise results when strata were pooled (Burt and Stahl, 2000).

It is possible to speculate that there may be a difference in minke whale sightability between the strata from early-season to late-season. The methods and equipment

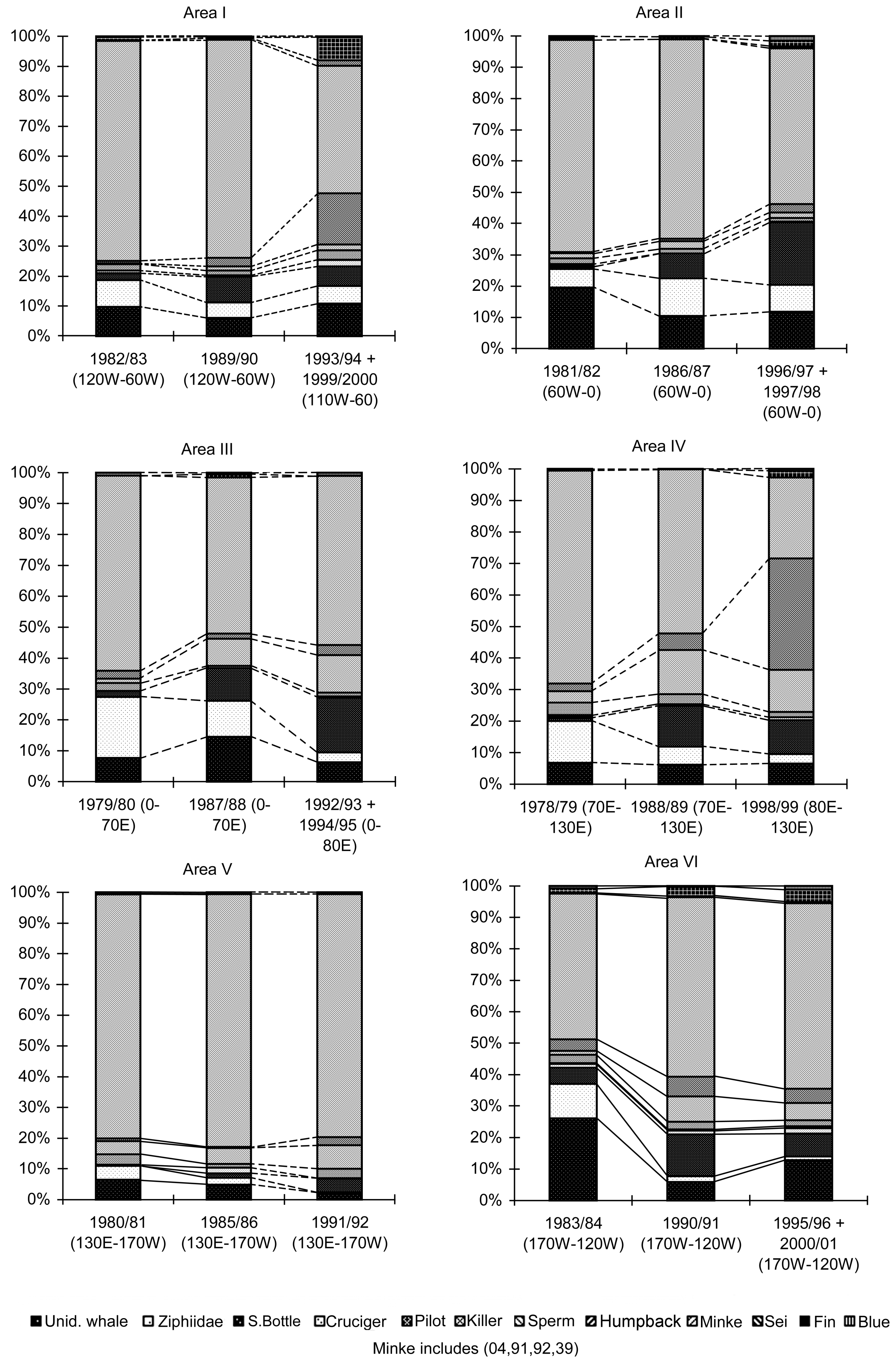

Fig. 12. Compositions of the primary school sightings in each circumpolar set by Area, during 1978/79 to 2000/01. Blue, fin, sei, minke, humpback, sperm, killer, pilot, cruciger, southern bottlenose, Ziphiidae and unidentified whales are analysed. Minke whale includes codes '04; Minke', '91; Undetermined minke', '92; like Antarctic form' and '90; like Dwarf form' and '39; like minke'.

used for distance estimation are the same between the ships; the sighting ability of the crews should not differ significantly as the crews are rostered 'randomly' to the ships for each cruise. The standards used for acceptable sighting conditions should also be the same on each ship. Factors affecting sightability may be the result of differences in weather conditions (in sightability conditions) or differences in group size, behaviour, body size (and related cue size). For example, a proportion of the 'larger?, behaviourally more obvious?' animals (for which closing/tracking are completed more easily, thereby aiding identification) may change their clustering pattern and/or behaviour during the season, or move further south into the pack ice and be inaccessible for survey. This may also have implications for the identification of species, particularly the change in proportion of minke and 'like minke' identifications.

Change of research hours

The reduction in research hours from 16 hours per day for the earlier cruises, to the current 12 hours per day may have had an impact on the sighting efficiency of observers. Although the observers have always had scheduled 'rest' periods, they have always had additional ship maintenance and management tasks to complete. The reduction in working hours would have reduced the fatigue of the observers and it is possible there has been a related increase in their sighting efficiency, while total distance searched during a cruise had decreased. In this regard, Branch and Butterworth (2001a) indicate that the shape of the detection function for minke whales (and humpback and sperm whales) has changed over the three circumpolar series, with broadening of the shoulder (see Branch and Butterworth, 2001a; fig. 2) implying sightings of these whales are now made at greater distances.

Distance estimation across years

The Estimated Angle and Distance Experiment protocol has been described here in detail. Since it has been conducted in a consistent manner using the same equipment for many cruises, and because several observers have taken part on several different cruises, it may be possible to test if there has been any trend in distance estimation over time. This may also help explain the change in the shape of the detection function for minke whales as indicated in Branch and Butterworth, (2000a; b).

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Appendix 1

SPECIFICATIONS OF THE JAPANESE RESEARCH VESSEL IN IWC/IDCR AND SOWER CRUISES

Note: a list of all crew members and researchers for each cruise can be found at
http://www.iwcoffice.org/publications/additions.htm

	Shonan-Maru	*Shonan-Maru No.2*	*Kyo-Maru No.27*	*Toshi-Maru No.11*	*Toshi-Maru No.18*	*Toshi-Maru No.16*
Call sign	JFBW	JFCF	JBOT	JNOL	JPMQ	JPLG
Register length (m)	64.80	64.80	63.50	63.20	63.20	63.20
Molded breadth (m)	10.20	10.20	9.90	9.90	9.90	9.90
Gross register tonnage	709	710	729.55	740.37	758.33	758.33
Barrel height (m)	20	20	17	17	17	17
IOP height (m)	14	14	-	-	-	-
Upper bridge height (m)	11.8	11.8	10	10	10	10
Bow height (m)	6.5	6.5	6.5	6.2	6.2	6.2
Maximum continuous output	5,280	5,280	3,600	3,500	3,500	3500
Main sailing technique	GPS	GPS	Celestial	Celestial	Celestial	Celestial
NNSS from 1981, GPS from 1991						

Appendix 2

PHOTOGRAPHS OF RESEARCH VESSELS IN IWC/IDCR AND SOWER CRUISE BETWEEN 1978/79 AND 2000/01 (SEE TABLE 1)

Photographs opposite

Toshi Maru No. 11

Toshi Maru No. 16

Toshi Maru No. 18

Kyo Maru No. 27

Vdumchivy 34

Vderzhanny 36

Shonan Maru

Shonan Maru No. 2

Appendix 3

EXAMPLES OF THE PROTOCOL USED FOR THE ESTIMATED DISTANCE AND ANGLE EXPERIMENT

Example 1, 1998-99 IWC-SOWER Antarctic cruise *Shonan Maru*

The Estimated Angle and Distance Experiment was conducted on the *Shonan Maru* on 30 January 1998.
Selected target distances and angles were:

Distance (nmile)	Angle
2.87	P 004°
2.38	S 015°
1.73	P 034°
1.44	S 028°
0.78	P 011°
0.41	S 007°

Persons taking part in the experiment were divided into five teams (A-E). The members of the teams and their allocation to the platforms are shown in Table 1.

Table 1

IWC/SOWER Antarctic Cruise 1998-99. Estimated Angle and Distance experiment from the *Shonan Maru*.

	Top barrel	IOP	Upper bridge
A	Nitta	Kurisu	Kurogi and captain
B	Abe and Sakimukai	Nitta	Kurisu
C	Wakazuki	Abe	Sakimukai & Kleivane
D	Kurogi	Wakazuki	Abe and Doherty
E	Kurisu	Kurogi	Wakazuki

The observers undertook the Experiment only from platforms where they normally conducted sighting effort. For example, Nitta (the Boatswain) did not normally conduct sighting effort from the Upper Bridge therefore did not undertake the Experiment from that platform. Similarly, Sakimukai (a young sailor with no previous Antarctic sighting survey experience) did not conduct sighting effort from the IOP and therefore did not undertake the Experiment from the IOP. (This was the first IDCR/SOWER cruise with participation of a young sailor with no previous Antarctic sighting survey experience and it had been agreed at the Planning Meeting that the observer rotation schedules would be arranged to ensure that the least experienced crewman would not be assigned to the IOP).

The teams were selected for the angle and distance estimates in a random order. The order of selection of teams and the target angles and distances for each trial are shown in Table 2.

Note, as shown in Table 2, that the tested angle and distance usually differ from the target angle and distance.

Table 2

IWC/SOWER Antarctic cruise 1998-99. Estimated Angle and Distance experiment from the *Shonan Maru*.

Trial no.	Team	Target dist./angle	Time	Compass	Radar angle	Radar distance
1	A	2.87 P 004°	132514	089	P003	2.70
2	C	2.38 S 015°	132827	068	S018	2.16
3	E	1.73 P 034°	133144	118	P035	1.60
4	B	1.44 S 028°	133445	057	P028	1.16
5	D	0.78 P 011°	133801	093	P014	0.62
6	A	0.41 S 007°	134002	068	S007	0.28
7	E	2.87 P 004°	135448	078	P004	2.72
8	B	2.38 S 015°	135803	059	S015	2.13
9	C	1.73 P 034°	140032	110	P036	1.73
10	A	1.44 S 028°	140257	047	S027	1.34
11	E	0.78 P 011°	140543	085	P013	0.87
12	B	0.41 S 007°	140749	061	S005	0.48
13	D	2.87 P 004°	142207	096	P006	2.71
14	A	2.38 S 015°	142451	074	S015	2.25
15	B	1.73 P 034°	142723	125	P035	1.77
16	D	1.44 S 028°	143011	065	S025	1.28
17	C	0.78 P 011°	143200	099	P011	0.74
18	E	0.41 S 007°	143445	080	S006	0.43
19	B	2.87 P 004°	144939	095	P006	2.81
20	D	2.38 S 015°	145204	073	S014	2.34
21	A	1.73 P 034°	145510	118	P035	1.82
22	C	1.44 S 028°	145734	048	S033	1.41
23	B	0.78 P 011°	150136	096	P012	0.67
24	D	0.41 S 007°	150343	068	S011	0.26
25	C	2.87 P 004°	151820	088	P003	2.76
26	E	2.38 S 015°	152055	070	S015	2.32
27	D	1.73 P 034°	152413	118	P035	1.70
28	E	1.44 S 028°	152626	049	S031	1.30
29	A	0.78 P 011°	152939	092	P009	0.71
30	C	0.41 S 007°	153134	069	S012	0.33

Example 2, 2000-2001 IWC/SOWER Circumpolar Cruise, *Shonan Maru*

The Estimated Angle and Distance Experiment was conducted on the *Shonan Maru* on 25 January 2001
Selected target distances and angles were:

Distance (nmile)	Angle
2.67	P 009°
2.25	P 001°
1.63	S 027°
0.71	S 018°
0.32	P 014°
0.24	S 058°

Persons taking part in the experiment were divided into six teams (A-F). The members of the teams and their allocation to the platforms are shown in Table 3.

Table 3

Estimated Angle and Distance experiment from the *Shonan Maru* IWC-SOWER circumpolar cruise 2000-2001

	Barrel	IOP	Front bridge
A	Suzuki	Nakato	Captain Sakai
B	Nishi	Suzuki	Nakato
C	Nakamura	Nishi	Van Waerebeek & Fukitome
D	Kawaragi	Nakamura	Takada
E	Fukitome and Takada	Kawaragi	Nakamura
F	Nakato	-	Kawaragi

Table 4

IWC/SOWER circumpolar cruise 2000-2001. Estimated Angle and Distance experiment from the *Shonan Maru*.

Trial no.	Team	Target dist./angle	Time	Compass	Radar angle	Radar distance	Ship GPS position	Ship GPS position
BUOY	XXX	XXX		XXX	XXX	0.00	6811.42S	12846.05W
1	A	2.67 P 009°	08:25	293	S010	2.65	6812.70S	12840.43W
2	E	2.25 P 001°	08:30	309	P002	2.04	6812.36S	12842.05W
3	C	1.63 S 027°	08:37	278	S025	1.56	6812.01S	12843.11W
4	F	0.71 S 018°	08:43	300	S018	0.71	6811.66S	12845.19W
5	D	0.32 P 014°	08:50	336	P014	0.32	6811.36S	12845.93W
6	B	0.24 S 058°	08:58	299	S061	0.24	6811.29S	12846.48W
BUOY	XXX	XXX	09:01	XXX	XXX	0.00	6811.05S	12846.66W

For all trials, (on both ships), the GPS position of the ship was recorded simultaneously with each trial of observers' estimates. Also on both ships, the GPS position of the buoy was recorded at the end of each set of six trials when the ship passed within a few meters of the buoy (thus the set and drift of the buoy could be determined). The aim of this was to provide verification of the GPS distances calculated from the results of the GPS Experiment.

Note that observers undertook the Experiment only from platforms where they normally conducted sighting effort. For example, Suzuki (the Boatswain) did not normally conduct sighting effort from the Upper Bridge therefore did not undertake the Experiment from that platform. Similarly, Takada and Fukutome (observers with no previous Antarctic sighting survey experience) did not conduct sighting effort from the IOP and therefore did not undertake the Experiment from the IOP.

The teams were selected for the angle and distance estimates in a random order. The sample of order of selection of teams and the target angles and distances for each trial are shown in Table 4.

Appendix 4

EXAMPLE OF LIST OF OBSERVER CODES AND DETAILS OF PREVIOUS IDCR/SOWER EXPERIENCE, IWC-SOWER CIRCUMPOLAR CRUISE 2000-2001

For the purposes of data validation the codes used to identify observers on the data records are listed below.

Table 1

Example lists of observer codes and details of previous IDCR/SOWER experience.

Code	Name	Experience (years) IDCR/SOWER	Experience (years) JARPA/JARPN
Shonan Maru			
1	Suzuki	4	8/5
2	Nishi	2	6/4
3	Nakamura	3	3/4
4	Kawaragi	2	2/2
5	Nakato	1	1/1
6	Takada	1	0/0
7	Fukutome	1	0/0
8	Captain Sakai	5	5/3
C	Crew (and when no researchers present)		
E	Ensor		
M	Murase		
K	Van Waerebeek		
Shonan Maru No.2			
1	Nitta	7	7/7
2	Hirai	3	6/6
3	Maeda	3	3/3
4	Sawabe	1	3/2
5	Sakimukai	2	2/1
6	Nagai	1	2/2
7	Yamaguchi	1	0/0
C	Captain Miura	4	5/3
S	Crew (and when no researchers present)		
M	Matsuoka		
P	Pitman		
F	Marques		