Abundance estimates of minke whales by 10° longitudinal sectors from IDCR-SOWER surveys

ML BURT
RUWPA, University of St Andrews, The Observatory, Buchanan Gardens, St Andrews, KY16 9LZ, UK
louise@mcs.st-and.ac.uk

ABSTRACT
The Antarctic has been divided into thirty-six 10° longitudinal sectors. For each IDCR-SOWER survey the sighting rate, school size, school density, whale density and whale abundance have been estimated for each sector. Estimates of whale density are presented here.

INTRODUCTION
IWC IDCR-SOWER surveys have now completed three circumpolar (CP) sets of surveys and previous analyses (Branch and Butterworth, 2001) have indicated an appreciable decline in minke whale abundance between CP II and CP III. One factor not taken account of in previous analyses has been an increase in sea ice coverage from CP II to CP III and this may reflect a greater proportion of minke whales in the pack ice which will not have been included in these abundance estimates. Of interest is the comparison of minke whale abundance estimates and sea ice extent changes and to further this work, abundance estimates are required for each 10° longitudinal sector around Antarctica (IWC, 2006). Sightings rates, densities and abundances of minke whales have been calculated for each sector using standard line transect methodology. These estimates are available from the author. This document presents density estimates and describes the data and analysis used to obtain these estimates.

SURVEY DATA
The Antarctic has been divided into thirty-six 10° longitudinal sectors (Table 1). Sightings and effort data for each sector have been extracted from the 'standard' dataset (Burt, 2004) which contains all surveys from 1978/79 to 2003/04. The IWC-SOWER survey in 2004/05 which completes CP III was extracted from DESS (Strindberg and Burt, 2000).

In addition to the data selection options used to obtain the standard dataset, only schools recorded as minke (code 04), undetermined minke (91) and minke, like Antarctic (92), have been included in the present analysis. Sightings classed as definite duplicates of previous sightings have been removed. Search effort legs that straddled two sectors were allocated to the sector that contained the majority of the effort. Search mode was classified as either closing mode or independent observer (IO) mode.

METHODOLOGY
The analysis was based on the standard line transect methodology described by Branch and Butterworth (2001). Sightings rates were calculated for each sector using sightings seen within a perpendicular distance of 1.5 nm of the trackline. Each longitudinal sector generally contained sections from both the northern and southern strata which were defined when the survey was designed. These pre-determined strata have been ignored in estimating sighting rates and only the longitude of the sightings has been taken into account.

Due to small sample sizes in some sectors, pooling was necessary for reliable estimation of the detection function. Branch and Butterworth (2001) recommended pooling only if there were fewer than 15 sightings in a stratum. However, nearly all surveys had at least one sector with fewer than 15 sightings. Therefore, all sightings from a survey were pooled to obtain a single effective strip half-width (esw) for closing mode and another for IO mode. The hazard rate model with no adjustment terms was used to obtain the detection function. Sighting angles and radial distances were smeared using smearing parameters obtained for each circumpolar set of sightings (Table 2).

Estimates of mean school size were obtained from sightings seen in closing mode with confirmed school sizes only and these estimates were used to convert estimates of school density to estimates of whale density for both closing and IO mode data. The log(*size*) *vs*. $g(x)$ regression method of Buckland *et al*. (2001) was used to estimate mean school size. The detection probability was obtained using the same level of pooling as for the esw and a single mean school size for each survey was obtained. In 1990/91 and 2000/01, the correlation of the log(*size*) *vs*. $g(x)$ was positive. When this occurs the usual practice is to replace the regression estimate by the average school size of sightings within 0.5 nm of the trackline. However, in 2000/01, this average school size was higher than the size bias regression estimate and so the average school size of confirmed sightings within 1.5 nm of the trackline was used.

The size of the sectors were obtained using the strata boundaries extending from the ice edge to the most northerly stratum boundary, which was generally at 60° N (for examples see Figure 1). Note that the size of sectors for surveys in CP I have not been calculated due to the nature of the survey design where one vessel closely followed the ice edge and the difficulty in dividing the southern strata into 10° sectors (see Branch and Butterworth, 2001, for details).

RESULTS

Sighting rate, school size, school density, whale density and whale abundance have been estimated by sector for each survey. These results are not presented here but are available from the author. Note that abundance estimates for CP I have not been calculated (see above). There are some differences between the total numbers of sightings and total search effort for each survey in this analysis and those reported in Branch and Butterworth (2001), however, these differences are generally small (within 5%).

The detection functions fitted to each survey are shown in Figures 2-4. Generally the detection functions are a good fit to the data. For some surveys, particularly in CP I, the distributions of perpendicular distributions have a high proportion of very small distances which makes it difficulty to fit a robust model. Smearing, however, helped to alleviate this problem.

Whale density estimates for each sector are given in Table 3. Some sectors have been covered more than once within a CP set (mainly in CP III) and so in these cases, the average whale density weighted by search effort for each sector was obtained. These densities are plotted by longitude in Figure 5. This clearly shows that there were differences in the densities around Antarctica. In general the highest densities in CP I were Areas I, III and IV and in CP II the highest density Areas were II and III. The range of densities is much narrower in CP III and the densities are lower than for the earlier CP sets (Table 4).

REFERENCES

Branch TA and Butterworth DS (2001) Southern Hemisphere minke whales: standardised abundance estimates from the 1978/79 to 1997/98 IDCR-SOWER surveys. *J cetacean Res Manage* 3(2):143-174.

Buckland ST, Anderson DR, Burnham KP, Laake JL, Borchers DL and Thomas L (2001) *Introduction to Distance Sampling: Estimating Abundance of Biological Populations*. Oxford University Press, Oxford.

Burt ML (2004) Overview of the standard dataset of IDCR/SOWER data. Unpublished paper *SC/56/IA2* presented to the IWC SC, Sorrento.

IWC (2006) Annex G, Report of the Sub-Committee on In-depth Assessment from IWC SC meeting 2006, St Kitts and Nevis.

Strindberg S and Burt ML (2000) \IWC Database-Estimation Software System (DESS) User Manual, May 2000. RUWPA, University of St Andrews

Table 1 IWC Management Areas divided into 10° longitudinal sectors. Sighting and effort records were included in the sector if their longitude was greater than or equal to the start longitude and less than the end longitude.

Area	Sector Number	Longitude ≥ start	Longitude < end	East/West
V	-18	-180	-170	West
VI	-17	-170	-160	
	-16	-160	-150	
	-15	-150	-140	
	-14	-140	-130	
	-13	-130	-120	
I	-12	-120	-110	
	-11	-110	-100	
	-10	-100	-90	
	-9	-90	-80	
	-8	-80	-70	
	-7	-70	-60	
II	-6	-60	-50	
	-5	-50	-40	
	-4	-40	-30	
	-3	-30	-20	
	-2	-20	-10	
	-1	-10	0	
III	1	0	10	East
	2	10	20	
	3	20	30	
	4	30	40	
	5	40	50	
	6	50	60	
	7	60	70	
IV	8	70	80	
	9	80	90	
	10	90	100	
	11	100	110	
	12	110	120	
	13	120	130	
V	14	130	140	
	15	140	150	
	16	150	160	
	17	160	170	
	18	170	180	

Table 2 Smearing parameters obtained for each CP set of surveys.

CP	Closing mode		IO mode	
	Angle	Radial distance	Angle	Radial distance
I	6.64	0.34		
II	5.32	0.24	3.86	0.22
III	3.40	0.15	2.62	0.14

Table 3 Whale density estimates, $\hat{D}_w$, and coefficient of variation, *cv*, for each sector by search mode and CP set.

	Closing mode						IO mode			
	CP I		CP II		CP III		CP II		CP III	
Sector	$\hat{D}_w$	*cv*	$\hat{D}_w$	*cv*	$\hat{D}_w$	*cv*	$\hat{D}_w$	*cv*	$\hat{D}_w$	*cv*
-18	0.3336	25.4	0.3197	36.9	0.1070	24.5	0.3062	20.35	0.2106	17.0
-17	0.2749	42.9	0.1352	33.9	0.1097	34.0	0.3535	39.35	0.1266	24.2
-16	0.1126	23.3	0.0405	46.6	0.0852	29.1	0.1078	53.55	0.0893	25.9
-15	0.1604	19.9	0.1388	79.8	0.0507	41.0	0.0929	38.14	0.0676	49.2
-14	0.0859	36.4	0.1459	26.2	0.1988	36.0	0.1246	40.98	0.1822	48.8
-13	0.0241	53.6	0.2672	56.8	0.1058	51.0	0.1488	129.29	0.1421	44.0
-12	0.2156	30.1	0.1523	22.1	0.0402	49.0	0.2821	59.22	0.0671	47.9
-11	0.2175	23.0	0.1481	54.1	0.0740	44.2	0.2507	32.26	0.1332	39.1
-10	0.4631	34.7	0.1701	29.1	0.0121	39.5	0.2066	56.76	0.0220	25.2
-9	0.2973	33.7	0.1204	26.8	0.0450	69.1	0.2037	29.84	0.0858	85.5
-8	0.1819	25.3	0.1734	19.5	0.0486	64.3	0.0758	30.99	0.0840	51.1
-7	0.1359	33.2	0.0364	34.5	0.0806	41.1	0.0700	111.10	0.0860	35.1
-6	0.0982	35.5	0.4356	37.4	0.0067	162.2	0.1453	53.42	0.0103	70.1
-5	0.1008	42.0	0.0376	41.1	0.0194	66.5	0.0530	42.95	0.0212	41.5
-4	0.1842	22.4	0.0709	53.2	0.0897	46.9	0.1097	69.37	0.0948	59.0
-3	0.1553	30.3	0.3051	26.3	0.1110	39.5	0.4620	21.31	0.1079	41.7
-2	0.1655	40.7	0.2246	21.3	0.0939	50.5	0.2685	22.32	0.0665	40.0
-1	0.2022	39.0	0.1855	51.2	0.0380	58.1	0.1708	33.60	0.0422	56.3
1	0.3409	55.8	0.5874	112.31	0.0694	51.1	0.7219	36.52	0.0864	47.7
2	0.3862	42.0	0.2881	44.8	0.1121	29.2	0.5101	47.62	0.1727	30.8
3	0.4274	43.4	0.2439	53.5	0.0209	52.1	0.5278	28.39	0.0502	39.9
4	0.1923	35.8	0.1117	89.1	0.0164	32.2	0.1083	39.47	0.0116	51.3
5	0.4054	55.2	0.0141	86.8	0.0394	75.1	0.0989	69.35	0.0410	31.2
6	0.3211	34.1	0.1406	139.8	0.0766	46.7	0.1803	68.55	0.1165	47.0
7	0.3687	41.6	0.0502	68.9	0.0841	82.7	0.0326	45.13	0.0916	44.8
8	0.4008	29.0	0.2494	41.8	0.1119	46.6	0.2281	50.44	0.0948	41.4
9	0.3324	27.4	0.2064	67.5	0.0141	105.0	0.0585	106.93	0.0460	77.2
10	0.2118	24.1	0.0610	86.7	0.0045	77.0	0.0262	112.61	0.0186	70.5
11	0.3235	38.4	0.1523	65.6	0.0043	53.1	0.1636	72.79	0.0239	35.5
12	0.3228	33.5	0.1193	42.2	0.0114	33.1	0.1830	69.18	0.0196	39.2
13	0.3797	23.1	0.3351	85.3	0.0268	49.7	0.1044	31.05	0.0349	35.1
14	0.1049	69.4	0.0587	53.1	0.0514	65.9	*		0.1312	72.1
15	0.2291	35.3	0.1464	24.9	0.0481	66.4	0.3141	25.03	0.1704	37.5
16	0.2761	38.3	0.1114	47.1	0.1675	33.2	0.3505	32.58	0.1691	25.1
17	0.2085	22.6	0.1597	38.4	0.2178	36.6	0.2569	27.20	0.0808	27.4
18	0.4247	19.8	0.2797	24.6	0.2038	22.0	0.3641	36.24	0.2367	17.4

* There were only 4 nm of search effort conducted in IO mode in this sector.

Table 4 Mean whale density for each CP set of surveys. Standard deviations are given in parentheses.

CP set	Search mode	Density
I	Closing	0.252 (0.115)
II	Closing	0.178 (0.120)
	IO	0.219 (0.158)
III	Closing	0.068 (0.055)
	IO	0.090 (0.059)

Figure 1 Example of survey regions divided into 10° longitudinal sectors. The sectors are bounded by the ice-edge in the south and by the most northerly stratum boundary.

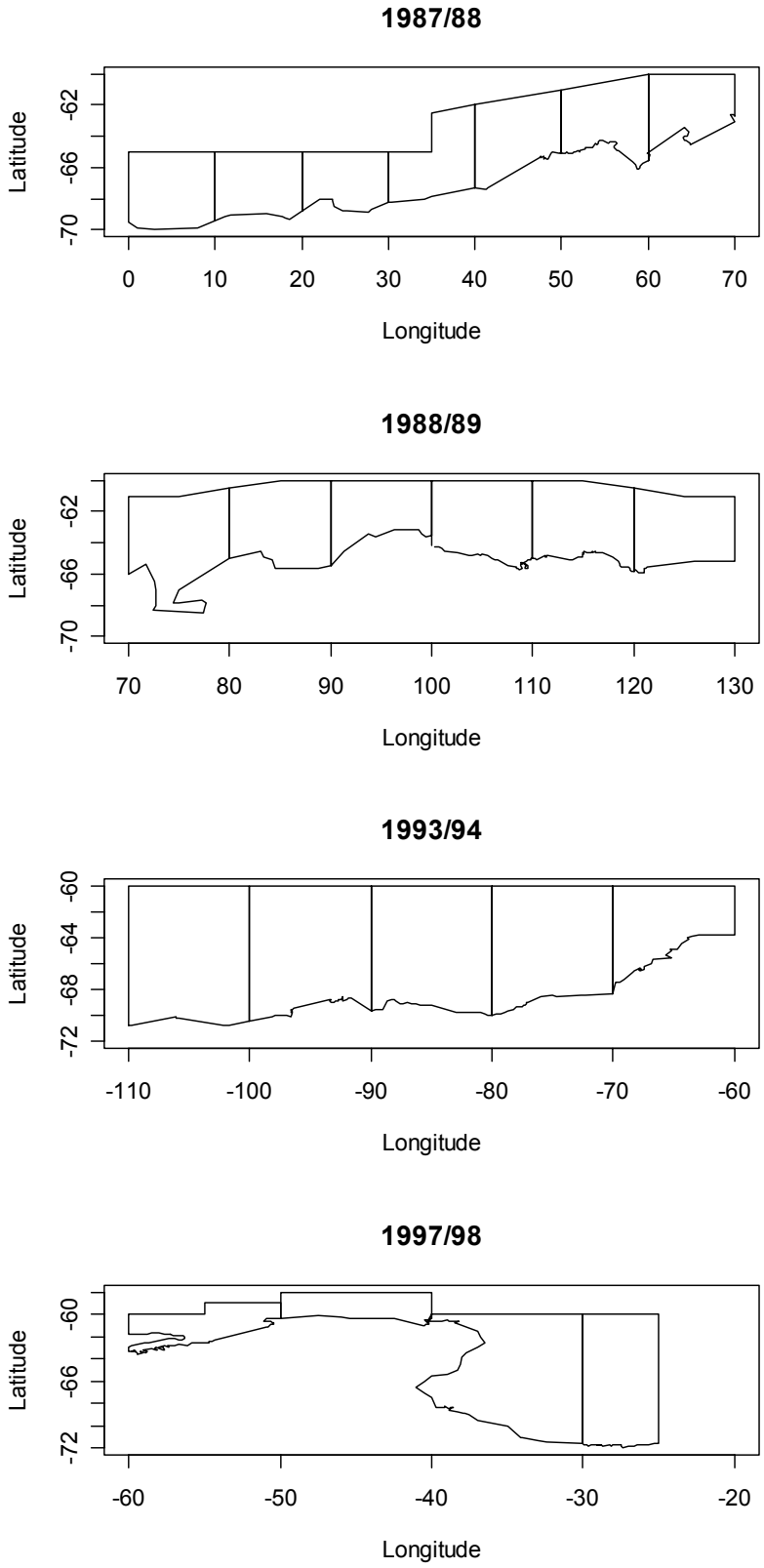


Figure 2 Perpendicular distance distributions and fitted hazard rate models for CP I closing mode. Surveys are identified by the second year i.e. 1979 for the 1978/79 survey.

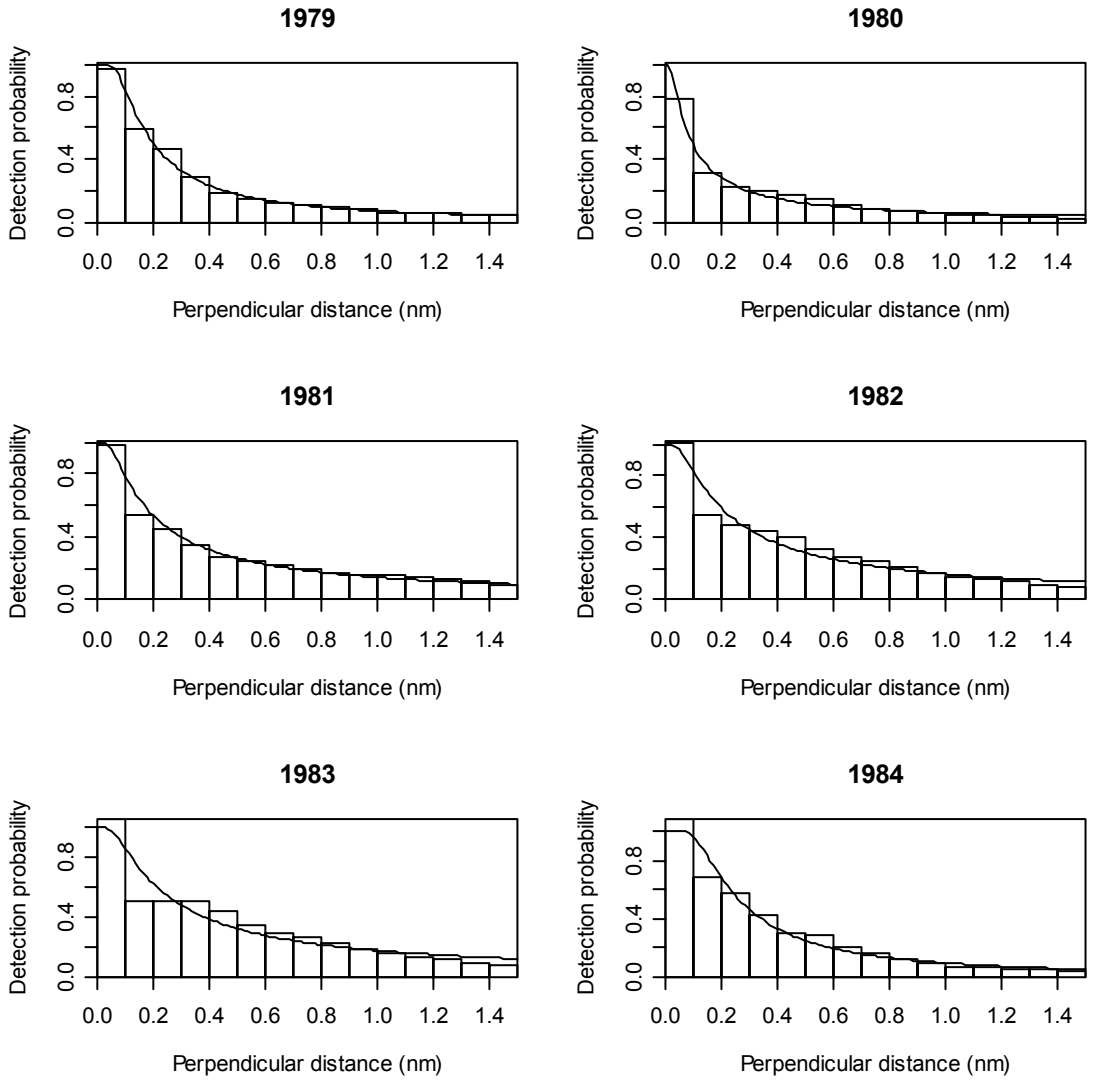
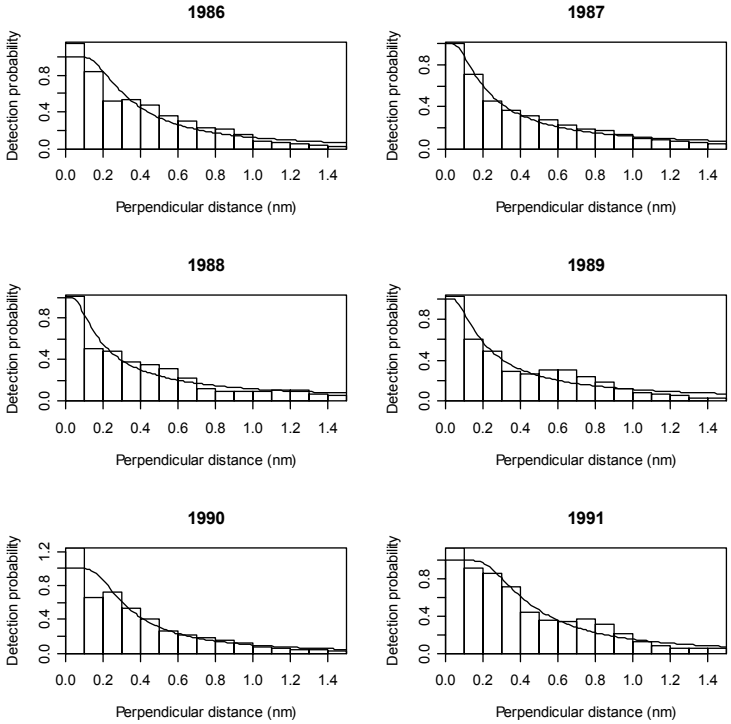


Figure 3 Perpendicular distance distributions and fitted hazard rate models for CP II: a) closing mode and b) IO mode. Surveys are identified by the second year i.e. 1979 for the 1978/79 survey.

a)



b)

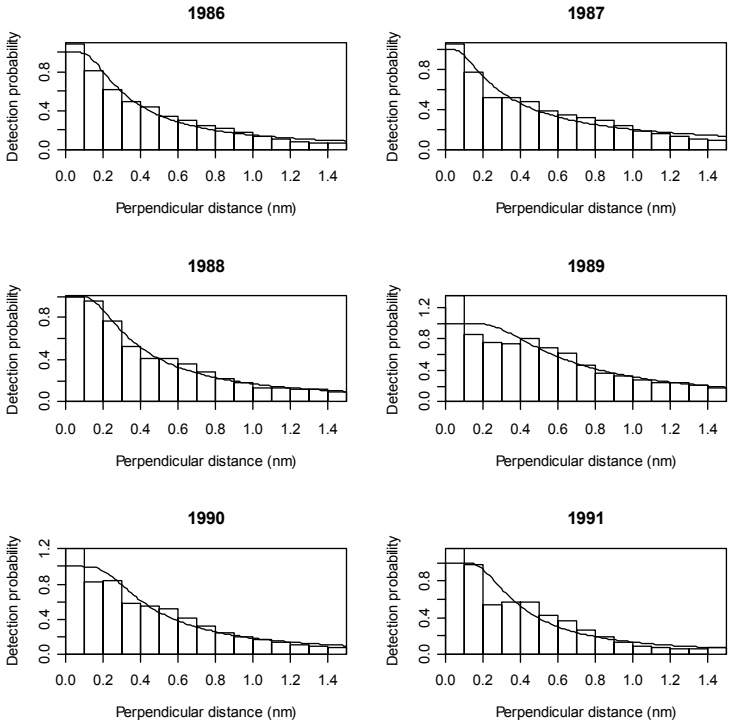


Figure 4a Perpendicular distance distributions and fitted hazard rate models for CP III closing mode. Surveys are identified by the second year i.e. 1979 for the 1978/79 survey.

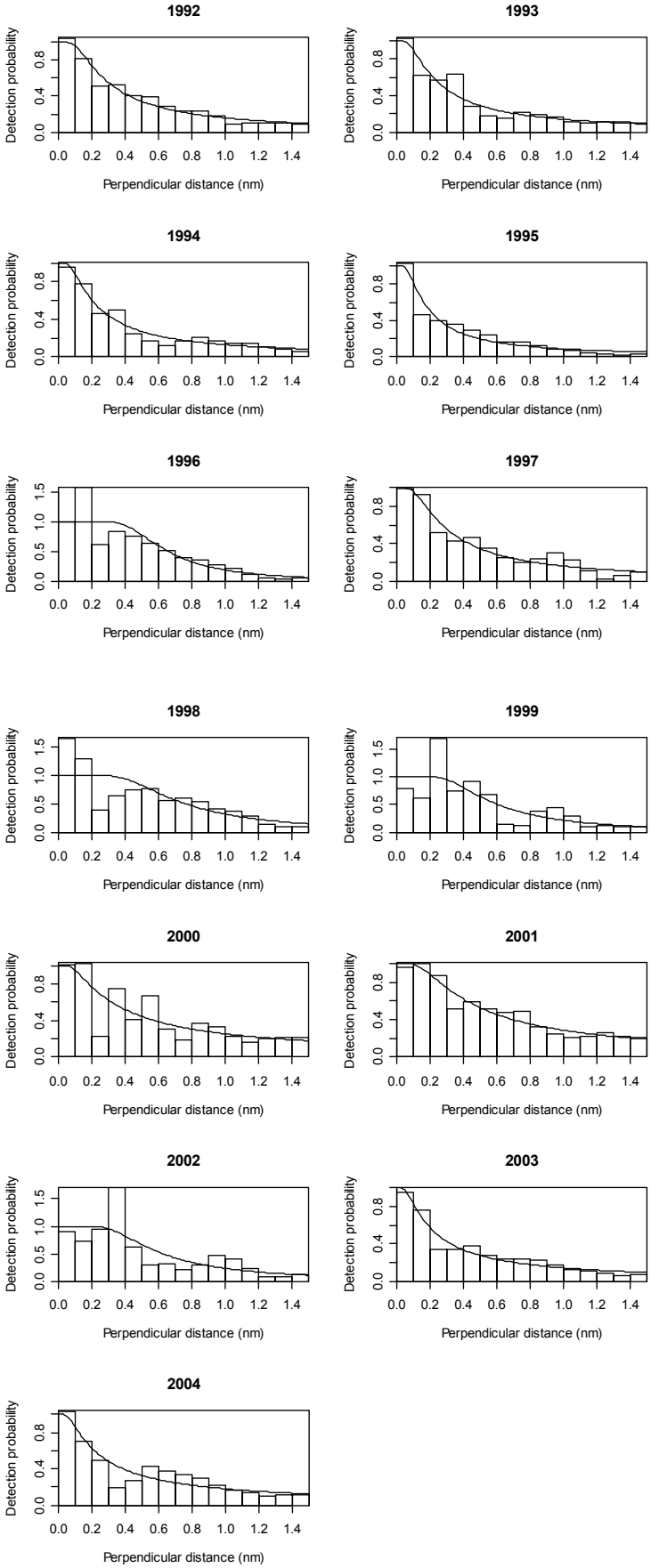


Figure 4b Perpendicular distance distributions and fitted hazard rate models for CP III IO mode. Surveys are identified by the second year i.e. 1979 for the 1978/79 survey.

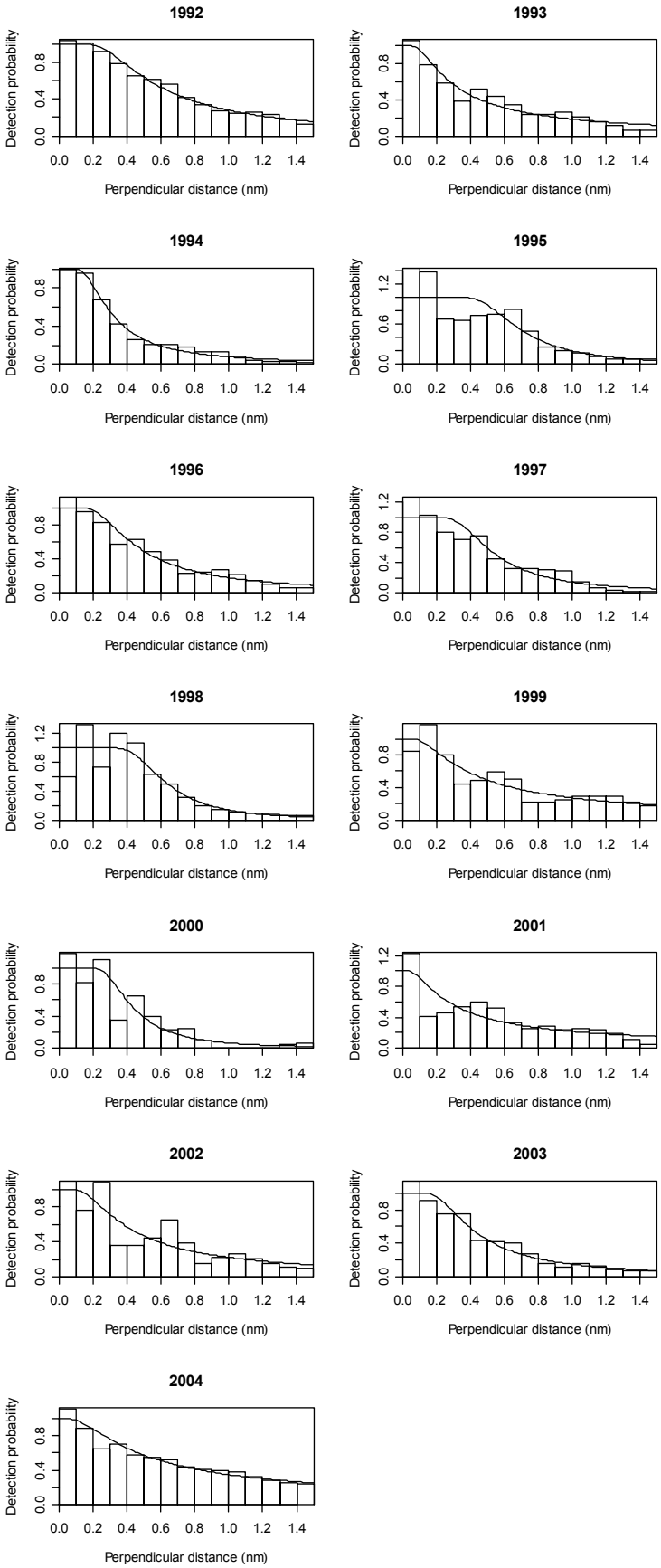
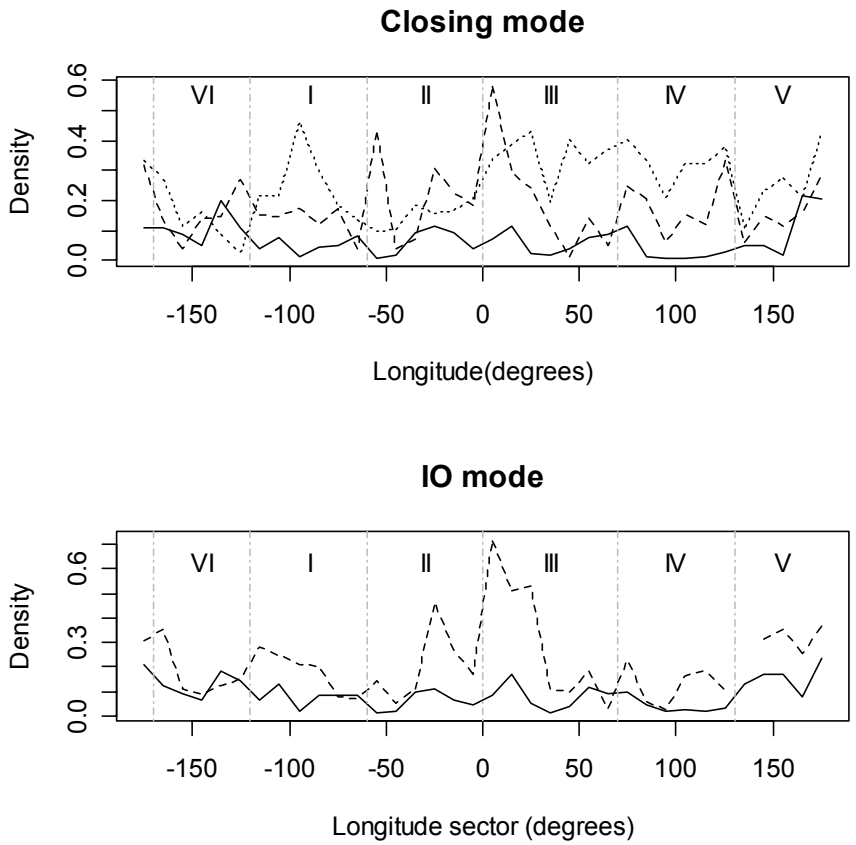



Figure 5 Plot of minke whale density (whales/nm^2) by midpoint of longitudinal sector (see table 1) for each CP set: CP I dotted line, CP II dashed line and CP III solid line. The numbers along the top of the figures are the IWC Mangement Areas and the paler vertical lines indicate the boundaries between the Areas.