ESTIMATING THE ADUNDANCE OF COMMON DOLPHINS ON THE SOUTHERN COAST OF SOUTH AFRICA

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Abstract

Sightings made on an aerial survey in December 1982 and on a ship-based survey in January/February 1983 have been used to assess the size of the population of common dolphins (*Delphinus capensis*) occurring over the continental shelf south of South Africa. Thirteen sightings (12 primary) were made in 2,445.7 n. miles flown on the aerial survey and 10 sightings (6 primary) in 1,772.2 n. miles steamed on the ship-based survey. Sightings and effort in both surveys have been stratified by water depth (0-100 m, 100-200 m) and geographical region (west coast, south coast). Because of difficulties in accurately estimating the size of schools in this highly gregarious species, numbers of individuals were counted in composite aerial photographs taken of the school. Radial distance and angle estimates to sightings from the ship were smeared to allow for estimation errors. Assuming $g(0) = 1.0$, both data sets resulted in roughly similar estimates of the number of schools (52-58 for aerial, 40-59 for ship-based across a range of sensitivity tests), but mean school size estimates differed significantly (454 SE 90 for aerial, 159 SE 27 for ship-based). As the aerial estimates were based on counts of animals in composite vertical photographs, they are considered more reliable than the ship-based estimates that were made from a lower vantage point and at a greater angle. Given the small number of primary sightings on each survey, it was considered preferable to produce a combined estimate using school density estimates from both surveys weighted by their inverse variances but applying the mean school size from the aircraft. The resultant population estimate of 49 schools (CV = 0.29) and 22200 individuals (CV = 0.35) is discussed in relation to known or estimated incidental mortalities in South African waters.

INTRODUCTION

In December 1982 an aerial survey was carried out over the putative range of the South African inshore stock of Bryde's whales, as a precursor for a shipboard survey for the same species over the same range in January/February 1983 (Best *et al.*, 1984). Several sightings of common dolphins were made both during the aerial survey and the subsequent shipboard cruise, and these are used here in an attempt to establish the abundance of these dolphins in the area.

Although there is still some uncertainty over the number and identity of common dolphin species in southern African waters, it is generally accepted that the form that occurs close inshore on the southern African coast most closely resembles the long-beaked species (Samaai *et al*., 2005), and the type locality for *Delphinus capensis* is the Cape of Good Hope (Gray, 1828). Six specimens were collected on the cruise and all proved to conform morphologically to the long-beaked form. The estimates in this paper are therefore assumed to refer to the species *D. capensis.*

MATERIAL AND METHODS

A high-wing, twin-engined aircraft (Partenavia P62B) was chartered to fly a series of onshore/offshore transects from the coast to the 200 m isobath, and between the latitude of 31^{o}S on the west coast and the longitude of 27^{o}E on the south coast (Fig. 1). This flight path was designed to cover the known summer range of the inshore stock of Bryde's whales, but also included most of the observed summer range of common dolphins inshore. All transects were flown at a height of 1,000 ft (304.8 m) above sea level and at an average speed of 110 knots (ranging between 95 and 130 knots, depending on wind speed and direction). Two pilots sat up front with two observers (PBB and MAM) behind them: all four acted as spotters but the two observers also took clinometer readings and recorded all weather, effort and sighting data. For each sighting the aircraft maintained its original flight path until the sighting was perpendicular to it, when a clinometer reading of the angle of the sighting from the vertical would be taken. The sighting would then be approached and circled to establish the species and number present (minimum, maximum, best estimate). At this time schools of *Delphinus* would be photographed through the open rear luggage door from as near vertical a position as possible, using a handheld Hasselblad ELM with 250 mm lens and Ektachrome 200 ASA film, and a series of overlapping frames would be taken of each school. After finishing with the sighting, the aircraft would return to the trackline.

In total, 4,529 km of trackline were covered on effort during 32 h 15 min of flying over seven days between 2 and 16 December 1982. Following similar treatment of the shipboard survey for Bryde's whales (Best *et al.*, 1984), this effort was separated into four strata: from the coast to the 100 m isobath, between the 100 m – 200 m isobaths, and to the west and east of Cape Point (or on the west and south coasts respectively). This stratification attempted to acknowledge likely density differences, both onshore-offshore and on west and south coasts. All sightings made when the aircraft was on the survey trackline were categorised as primary sightings and all those made when the aircraft was engaged in other activities (including investigating another sighting) were categorised as secondary.

Perpendicular distances from the trackline (d) were obtained from the trigonometric function

$$d = h*\text{cotan}(\theta)$$

where h = altitude of aircraft above sea level and θ = clinometer reading.

In the laboratory, the images of each school were projected onto a translucent paper screen in a darkened room and the position of each dolphin marked. Objects sub surface that could have been dolphins were marked with a query. After all images of a school had been examined, the marked sheets were superimposed to determine the degree of overlap between images (Fig. 2). In this, small distinct subgroups of dolphins, and especially groups of escorting seabirds, were useful as "landmarks". After the best possible fit had been obtained between images, duplicate individuals and groups were ignored and a composite count obtained. Doubtful individuals were recorded separately. These determinations were all made independently of the field count.

The Japanese scouting vessel *Kyo Maru no. 27* carried out a sighting survey for Bryde's whales over the continental shelf of southern Africa between 21 January and 14 February 1983 (Fig. 3). A masthead lookout for cetaceans by two trained observers was maintained during daylight hours, weather permitting, and supplemented by observations made on a less systematic basis from the top of the upper bridge. Estimates of the radial distance and angle of each sighting from the trackline were made as soon as possible after the sighting was made: details of the protocol used in calibrating these estimates have been previously published (Best *et al.*, 1984). The vessel would then usually leave the trackline to verify the species identity and to establish ("confirm") the group's size. Groups seen while the vessel was on the survey trackline in searching mode were termed primary sightings, and those seen at other times secondary sightings.

Abundance estimation was effected by application of the DISTANCE program version 5.0 release 2 to determine an estimate of the number of schools (*N*) in a stratum from the formula:

$$N = \frac{nA}{2Lw}$$

where *n* is the number of primary sightings of schools,
L is the primary effort,
A is the area of the stratum, and
w is the effective search half-width.

This assumes that all schools on the trackline will be seen ($g(0) = 1$). Variance of the sighting rate (*n/L*) was determined from inter-transect variability with each stratum, with weighting proportional to transect length.

Estimates of abundance of individuals (*P*) were determined by multiplying *N* by estimates of mean school size:

$$P = N.E(s)$$

RESULTS

Aerial survey

Thirteen sightings of an estimated total (best estimate) of 4,708 common dolphins were made during the aerial survey; all but one were primary sightings (Table 1).

Counts from photographs of 11 primary sightings indicated a range of confirmed totals from 127-1,100 individuals with a mean of 454 (SE 90). Agreement with field counts was surprisingly reasonable, with an AIC-based selection amongst regressions through the origin suggesting no bias (non-significant point estimate of -4%) and a standard derivation of the relative error of field counts compared to photographic of 47%.

If the doubtful animals are included in the counts, the mean school size increases to 484 (SE100).

Calf proportions in the school (using confirmed numbers only) ranged from 0 to 2.5%: excluding schools with zero calves (as being either inappropriate social groupings or too poorly photographed) leaves a range of 0.4-2.5% with a mean of 1.4% (n = 9). Given the difficulty of identifying this reproductive class from the air, this proportion is almost certainly an underestimate.

Cockcroft and Peddemors (1990) list estimates of school size for 57 sightings of *Delphinus* during opportunistic aerial surveys off south-east South Africa. These range from 50 to 10,000 with a mean of 1,193, but only the smallest schools (about 50 animals or fewer) were actually counted, with the others being estimated by visual subsampling and extrapolation: the authors comment on the difficulty of enumerating the larger schools in this way. There is a suggestion of rounding off of numbers (at 100, 200, 500, 750, 1000 and 1500, for example – Fig. 4).

Furthermore, most of these sightings were made in autumn and winter and often in association with the sardine run, when seasonal aggregations may occur for the purposes of cooperative predation (Peschak, 2005). Hence it would not be unrealistic to expect that the Cockcroft and Peddemors sample would include much larger schools of *Delphinus* than those photographed here, and for the purposes of this analysis we have used the mean school size photographically determined from the December 1982 survey itself.

Estimates of the perpendicular distance of schools of *Delphinus* from the trackline were available for all 12 primary sightings, and ranged from 685 to 4,983 m with a mean of 2,290 (SE 335) m (Table 1). The relatively small number of primary sightings and their distribution away from the trackline complicates the fitting of an appropriate function for estimating effective search half-width (see below).

There was no significant relationship between estimated school sizes (s) and the perpendicular distance at which they were seen, irrespective of whether the sizes used were the field estimates ($r^2 = <0.0005$) or those arising from photographic counts, with or without doubtful animals included ($r^2 = <0.0005$, and $r^2 = <0.0001$).

Ship-board survey

Ten sightings of 1,585 (best estimate) common dolphins were made by the *Kyo Maru no. 27*, of which six were primary sightings (Table 2).

All but one of the sightings were recorded as status 1, that is both species and school size were considered “confirmed”; the exception was a school of status 2, where the species was reliably determined but not the school size. The sizes of the nine confirmed schools ranged from a minimum of 50 to a maximum of 300 (mean 159 SE 27), so that all fell below the average size of the schools whose size was determined from aerial photographs, and the distribution of schools sizes estimated from the ship is significantly different from that of the photographically determined schools (Mann-Whitney U test, two-tailed $p = 0.017$).

Abundance estimates

Given the small number of primary sightings in the aerial (12) and ship-board (6) surveys, these obviously had to be pooled over the spatial strata in each case to estimate effective strip half-width *w*. Because of the precision of height and angle measurements no smearing was implemented for the aerial survey. However for the ship-board survey, estimates of the DISTANCE smearing parameters *ø* = 23.6° and *s* = 0.9 were obtained respectively from the analysis of the estimated angle and distance experiment repeated in Best *et al*. (1984), and application of the same method for estimated compared to radar radial distances.

As for Bryde's whales in Best *et al*. (1984), a half-normal model without truncation at large perpendicular distances was used to estimate *w*. Given the small numbers of sightings, it is not reasonable to attempt to estimate more than one parameter for the detection function. The data and fits of this model are shown in Fig. 5. For the aerial survey the data indicate a clear paucity of sightings close to the trackline, most likely as a result of sighting difficulties from the aircraft at inclinometer readings near to 90°. To correct for this bias, the analysis ignored a strip of 0.5 n mi either side of the trackline and the one primary sighting that occurred within the strip, thus effectively adjusting perpendicular distance estimates to the extent to which they exceeded 0.5 n mi, an approach that probably introduces some negative bias as some schools at a distance of $y = 0.5$ n mi might be missed.

The resultant estimates of the number of schools by stratum are shown in Table 3 for both surveys. The proportion of the total number that is on the west coast is minimal or zero. Table 4 shows the results of sensitivities to various alternatives to the baseline approach for estimating *w*: making use of the hazard rate instead of the half-normal model for the detection function, a truncation distance of $y < W$, alternative widths for the exclusion strip about the trackline for the aerial survey, and different extents of smearing for the ship-board survey. Aerial survey estimates show little sensitivity to these changes. For the ship-board survey, the large CV for *w* when the hazard-rate functional form is used shows the inappropriateness of attempting use of a detection function form with more than one estimable parameter. Lessening the truncation distance *W*, or decreasing the extent of smearing of the radial distance estimates, would increase the ship-board abundance estimates by up to some 25%; however this remains appreciably less than the standard errors associated with these results.

In converting the estimated number of schools to estimated number of dolphins, it was decided to use the aerial photographic counts of school size for both surveys. Discussion above indicates that these are probably the more reliable, and the significantly lower values obtained during the ship-board survey almost certainly reflect the under-counting that is to be expected from the poorer vantage point that a vessel provides compared to an aircraft. In the absence of any indication of relationship with perpendicular distance, a straightforward average of the 11 primary aerial sightings for which counts were available was used for E(*s*) for trackline estimates.

Results for the baseline estimate of the number of dolphins, together with some sensitivities, are given in Table 5. Since the two surveys were close in time and covered virtually identical areas (except for the west coast stratum for which abundance is minimal), it seems appropriate to combine the two estimates by weighting each by the inverse variance of the number of schools estimated so as to provide improved overall precision. This yields a school number estimate of 49 (CV = 0.29) and a population estimate of 22200 (CV = 0.35) dolphins.

DISCUSSION

The only previous attempt to assess abundance for this population used aerial strip-transect surveys of the coast between Port Elizabeth and Durban on the southeast coast of South Africa in 1988/89 (Cockcroft and Peddemors, 1990). Although these surveys extended well beyond the eastern limit of the survey described here, 89.5% of those on which common dolphins were seen were carried out in the period March to August, that includes the annual sardine run in which large numbers of predators migrate up the east coast. Cockcroft and Peddemors (1990) comment that while common dolphins could be found year-round in the coastal sector between Port Elizabeth and East London, sightings further north were confined to the period March to September with peak densities in July. Consequently there is no reason to suppose that a sizable proportion of the common dolphin population would be outside the area searched during the December 1982 survey.

Cockcroft and Peddemors (1990) estimated from the densities of dolphins seen on days when continuous good weather flights were made that there were about 9,000-12,000 common dolphins between Port Elizabeth and Durban in May and September, while maximum counts on days in which flights continued to the north of Durban (both in July) suggested as many as 13,000-15,000 dolphins might occur between Port Elizabeth and Richards Bay. Given that no allowance had been made for schools missed within visual range, or for schools occurring to the west of Port Elizabeth at the time of the survey, they concluded that the total population might be as high as 15,000-20,000 animals. The current estimate is certainly consistent with that conclusion.

Common dolphins feature as incidental or by-catch in a number of fisheries or fisheries-related activities round the South African coast. Between 1968 and 1986, 13 common dolphins are known to have died as a result of some form of fisheries interaction in the Western Cape – nine from purse seine nets, two from mid-water trawls, one from a beach seine and one from an unknown fishery. If these figures are considered as a rough guide to the degree of interaction with a particular fishery, then the purse seine fishery for pelagic fish (pilchard, anchovy and round herring) is likely to be the most important source of mortality. Although there is no systematic collection of by-catch statistics, Best and Ross (1977) estimated that the annual take of all dolphin species in this fishery might be as high as 100 a year, the majority of which were likely to be long-beaked common dolphins.

The best-documented incidental mortalities of common dolphins in southern African waters are those associated with the nets set to protect bathing beaches from sharks on the coast of KwaZulu-Natal. Between 1980 and 2000 a total of 1,074 common dolphins is estimated to have been taken in these nets (or an average of 37 a year), 3.2% of which were released alive. Catches have fallen noticeably from 2006, to an average of 5 a year, probably as a result of a combination of poor sardine runs (that attract the species into the area) and improved management measures taken by the Natal Sharks Board (that include lifting the nets in anticipation of the sardine run and leaving them out longer, and (in 2007) the replacement of 50% of the nets on one stretch of the coast with drumlines) (S. Dudley, pers. comm.).

The Potential Biological Removal (PBR) of this population can be calculated using the formulation developed by Wade (1998), where

$$\mathrm{PBR} = N_{min}\,(0.5(R_{max})F_r)$$

with N_{min} = the minimum population estimate (taken to be the lower 20th percentile), $0.5(R_{max})$ = half the maximum theoretical net productivity rate of the population at a small population size, and F_r = a recovery factor between 0.1 and 1. Using the default value of 0.04 for R_{max} for cetaceans, and setting F_r at 0.5 to ensure robustness against bias in the data, the PBR for this population can be assessed as 16700 (0.01) = 167. It seems unlikely that any one of the known sources of incidental mortality in South African waters would exceed this amount, although in combination they might approach or surpass it. However for a more reliable assessment of risk, much better estimates of fisheries by catch, especially in the purse seine fishery, are needed.

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References

Best, P.B., Butterworth, D.S. and Rickett, L.H. 1984. An assessment cruise for the South African inshore stock of Bryde's whale (*Balaenoptera edeni*). *Rep. int. Whal. Commn* 34: 403-423.

Best, P.B., and Ross, G.J.B. 1977. Exploitation of small cetaceans off southern Africa. *Rep. int. Whal. Commn* 27: 494-497.

Cockcroft, V.G., and Peddemors, V.M. 1990. Seasonal distribution and density of common dolphins *Delphinus delphis* off the south-east coast of southern Africa. *S. Afr. J. mar. Sci.* 9: 371-377.

Gray, J. E. 1828. Original figures and short systematic descriptions of new and unfigured animals. Spicilegia Zoologica Part 1: 1,2

Peschak, T. 2005. The sardine run: the greatest shoal on earth. In: *Currents of Contrast: Life in southern Africa's two oceans*. Struik Publishers, Cape Town. 200 pp.

Samaai, T., Best, P.B., and Gibbons, M.J. 2005. The taxonomic status of common dolphins *Delphinus* spp. in South African waters. *African Journal of Marine Science* 27 (2): 449-458.

Wade, P.R. 1998. Calculating limits to the allowable human-caused mortality of cetaceans and pinnipeds. *Marine Mammal Science* 14(1): 1-37.

Table 1: Schools of common dolphins seen and photographed from the air off South Africa, December 1982

Date sighted	Type of sighting	Est. school size	Perp. dist. (m)	Photographic count, total		Photographic count, cow-calf pairs	
				Confirmed	Doubtful	Confirmed	Doubtful
2 Dec	Primary	500	4983	408	18	10	0
3 Dec	Primary	250	1099	149	25	2	1
3 Dec	Primary	400	1568	409	95	8	2
3 Dec	Primary	500	1729	1100	146	7	2
3 Dec	Secondary	8		7	2	0	0
3 Dec	Primary	300	2482	314	0	0	0
5 Dec	Primary	600	3484	637	44	5	0
12 Dec	Primary	300	685	235	0	5	0
12 Dec	Primary	150	2675	127	1	3	0
12 Dec	Primary	100	2482	267	8	1	2
12 Dec	Primary	500	1821	817	0	4	0
12 Dec	Primary	1000	1568	532	0	0	0
12 Dec	Primary	100	2900	n/a			
Total		4708		5002	339	45	7

Table 2: Schools of common dolphins seen on ship-board survey off South Africa, January/February 1983 (status 1 = school size confirmed, 2 = unconfirmed)

Date	Type	Position		School size estimate			Status	Est angle from course	Perp. dist. from course (n mi)
		Latitude (ºS)	Longitude (ºE)	Max	Min	Best			
23-Jan	Primary	34.63	24.63	60	50	50	1	65	2.27
25-Jan	Secondary	33.77	26.65	60	60	60	1	30	0.40
26-Jan	Primary	33.83	25.93	150	100	120	1	2	0.05
27-Jan	Primary	34.25	24.88	250	200	230	1	23	0.59
29-Jan	Secondary	34.77	22.80	100	100	100	1	30	0.40
29-Jan	Primary	34.88	22.78	250	250	250	1	30	0.50
09-Feb	Primary	34.20	18.30	125	50	100	1	35	0.75
12-Feb	Secondary	34.73	19.07	200	80	200	1	30	0.50
13-Feb	Primary	34.87	20.48	300	300	300	1	90	0.80
13-Feb	Secondary	34.83	20.38	200	150	175	2	45	0.92

Table3: Contributing factors (see text for details) and resultant line transect estimates of the number of *Delphinus* schools (*N*) for a) aerial and b) ship-board surveys off South Africa in 1982/3. The numbers in parentheses are CVs. For the aerial survey, the total number of primary sightings is less than the 12 listed in Table 1 because the abundance estimation procedure adopted excludes sightings within a perpendicular distance of 0.5 n mi from the trackline.

a) Aerial Survey

		Cape Point to East London		Orange River to Cape Point		Total
Stratum		0-100 m SI	100-200 m SO	0-100 m WI	100-200 m WO	
Primary sightings	*n*	8	2	0	0	10
Primary effort (*n mi*)	*L*	985.92	992.64	171.08	296.02	2445.66
Sighting rate (sch/100 *n mi*)	*n/L*	0.0081 (0.26)	0.0020 (0.56)	0	0	
Effective search half width (*n mi*)	*w*	1.26 (0.29)	1.26 (0.29)	-	-	
Area $(n\ mi)^2$	*A*	11279	17732	1796	5117	35924
No. schools	*N*	37 (0.35)	14 (0.60)	0	0	50 (0.34)

b) Ship-board survey

		Cape Point to East London		Orange River to Cape Point		Total
Stratum		0-100 m SI	100-200 m SO	0-100 m WI	100-200 m WO	
Primary sightings	*n*	2	3	1	0	6
Primary effort (*n mi*)	*L*	522.30	583.10	300.10	366.70	1772.20
Sighting rate (sch/100 *n mi*)	*n/L*	0.0038 (0.51)	0.0051 (0.52)	0.0033 (0.67)	0	
Effective search half width (*n mi*)	*w*	1.77 (0.32)	1.77 (0.32)	1.77 (0.32)	-	
Area $(n\ mi)^2$	*A*	11279	17732	2862	14318	46191
No. schools	*N*	12 (0.60)	26 (0.61)	3 (0.74)	0	41 (0.48)

Table 4: Sensitivity of estimates of the number of *Delphinus* schools off South Africa given in Table 4 to alternative prescriptions for estimating the effective search half width *w*. *W* is the value of *y* at which the data are truncated in the analyses. The number of sightings considered in each analysis is indicated by *n*. This number may be less than the number of primary sightings listed in Tables 1 or 2 because the analyses truncate sightings near to or far from the trackline.

	Approach	No. schools(CV)
Aerial	Baseline ($W \to \infty$, $y > 0.5$, $n = 10$)	50 (0.34)
	Truncations	
	$W = 3.5$ ($n = 10$)	50 (0.34)
	$W = 2.5$ ($n = 10$)	48 (0.35)
	Adjusted distances	
	$y > 0.3$ ($n = 11$)	49 (0.34)
	$y > 0.4$ ($n = 10$)	47 (0.35)
	$y > 0.6$ ($n = 9$)	47 (0.34)
	Hazard-rate ($n = 10$)	44 (0.35)
Ship-board	Baseline ($W \to \infty$, $\o = 23.6°$, $s = 0.9$, $n = 6$)	41 (0.48)
	Truncations	
	$W = 3.5$ ($n = 6$)	46 (0.48)
	$W = 2.5$ ($n = 6$)	53 (0.50)
	Smearing	
	$\o = 0.01°$, $s = 0.9$ ($n = 6$)	40 (0.48)
	$\o = 23.6°$, $s = 0.6$ ($n = 6$)	46 (0.49)
	$\o = 23.6°$, $s = 0.3$ ($n = 6$)	50 (0.50)
	$\o = 23.6°$, $s = 0.01$ ($n = 6$)	49 (0.49)
	$\o = 0°$, $s = 0$ ($n = 6$)	49 (0.50)
	Hazard-rate ($n = 6$)	59 (1.54)

Table 5: Estimates for the number of *Delphinus* off South Africa for the surveys separately and combined. Baseline estimates use confirmed photographic counts from the aerial survey for E(*s*).

	Approach	No. schools (CV) N	School size (CV) E(s)	No. dolphins (CV) [95% C.I.]
Aerial	Baseline	50 (0.34)	454 (0.20)	22700 (0.40) [11400, 45400]
	E(s) includes doubtful	50 (0.34)	484 (0.21)	24200 (0.40) [12100, 48400]
Ship-board	Baseline	41 (0.48)	454 (0.20)	18600 (0.52) [6810, 48600]
	E(s) from ship-board	41 (0.48)	129.17 (0.20)	5300 (0.52) [1940, 1380]
Combined	Baseline	46 (0.28)	454 (0.20)	20900 (0.34) [10800, 40200]

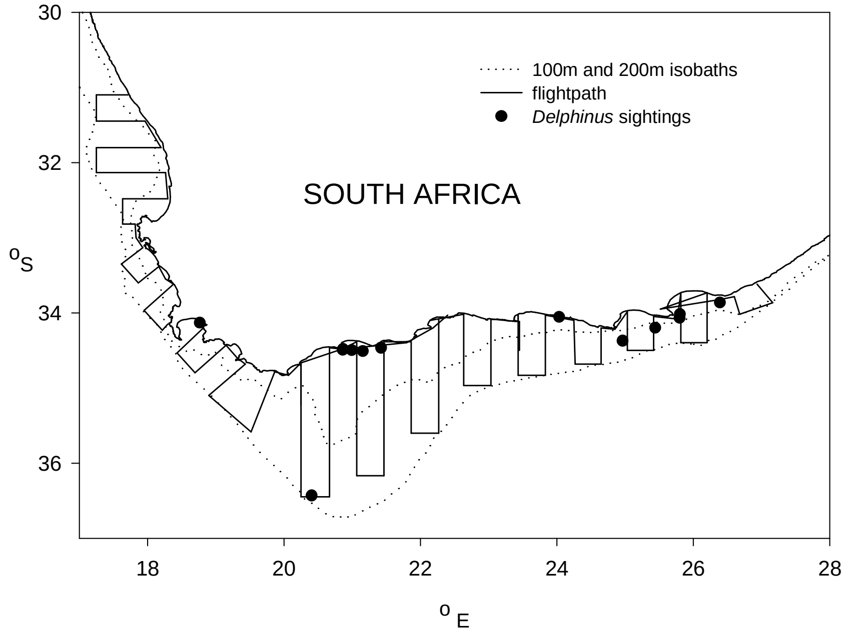


Fig. 1: Aerial survey and sightings of *Delphinus* off South Africa, December 1982

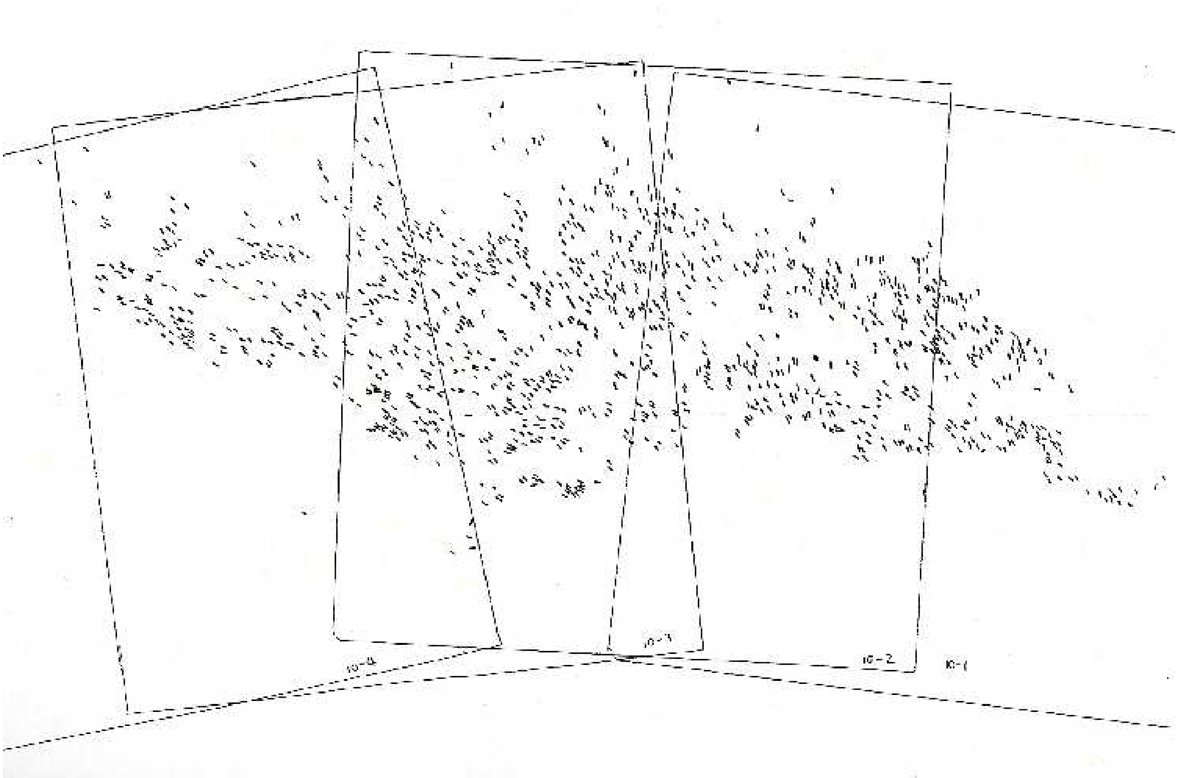


Fig. 2: Compilation of *Delphinus* school from aerial photographs, South Africa, 12 December 1982

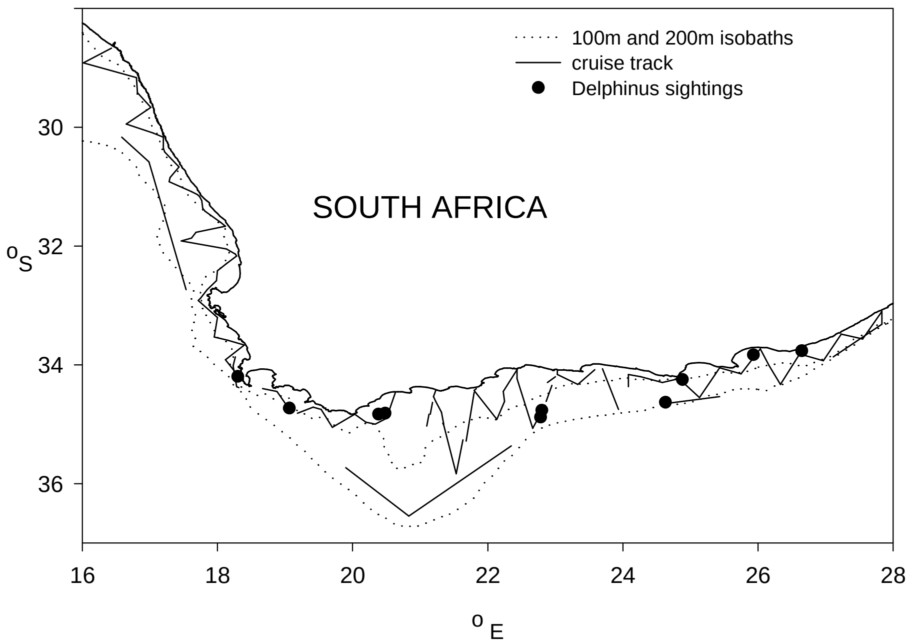


Fig. 3: Cruise track of *Kyomaru no. 27* and sightings of *Delphinus* off South Africa, January/February 1983

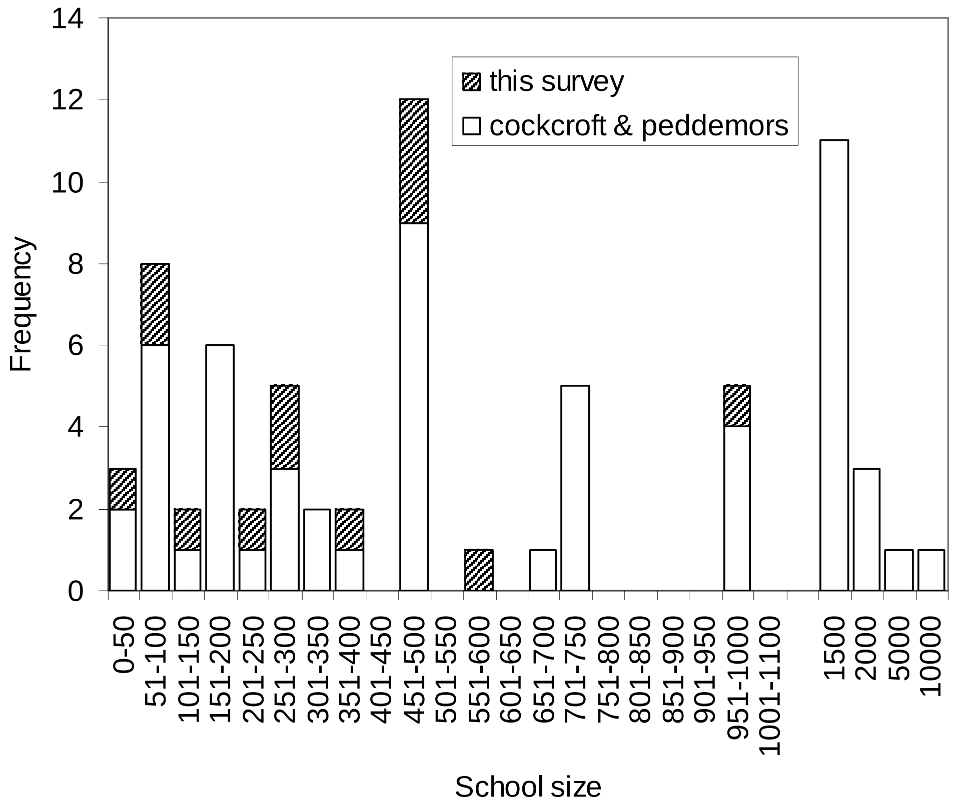
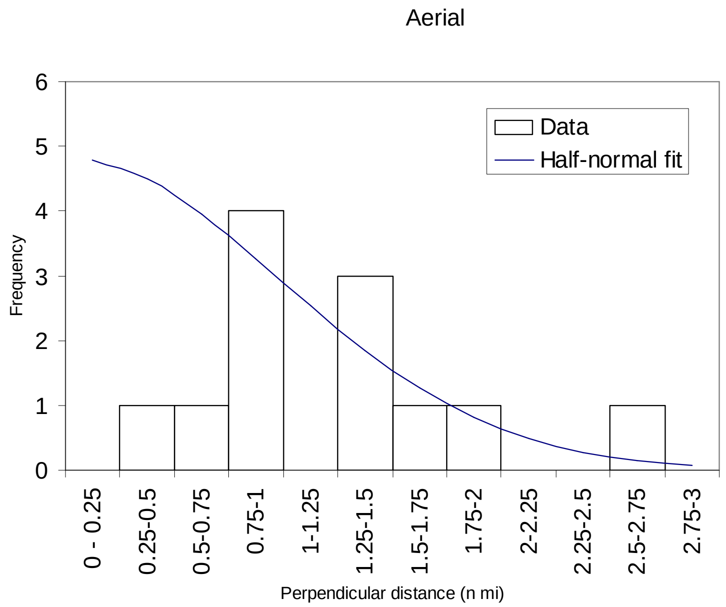


Fig. 4: Aerial estimates of school size for *Delphinus* on the south-east coast of South Africa (from Cockcroft and Peddemors, 1990) and over the Agulhas Bank region of South Africa, December 1982



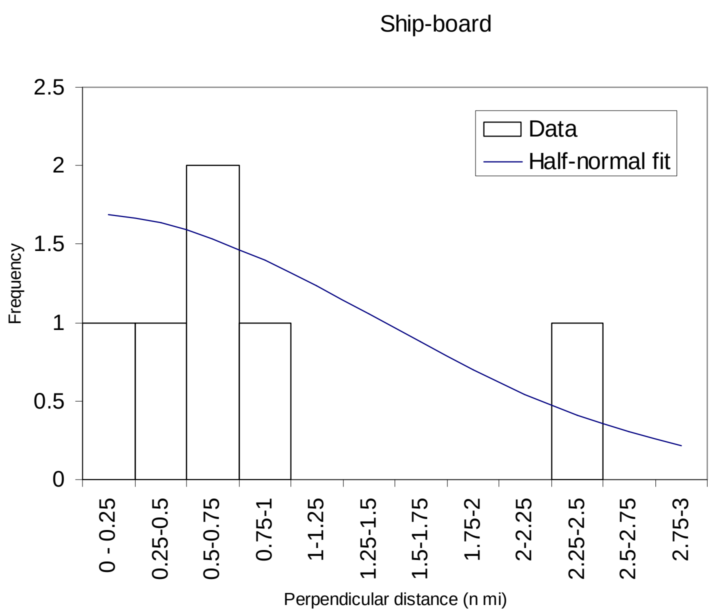


Fig 5: Distribution of perpendicular distances of *Delphinus* sightings from the trackline on a) an aerial survey in 1982 and b) a ship-board survey in 1983 off South Africa. The curves shown are the fits of the half-normal detection function to these data. Note that for the aerial survey, this fit is only for distances greater than 0.5 n mi (see text for reasons). The data in b) have been smeared to account for imprecision in distance and angle estimates.