The estimation of the detection function and $g(0)$ for short-beaked common dolphins (*Delphinus delphis*), using double-platform data collected during the NASS-95 Faroese survey

A. CAÑADAS*, G. DESPORTES† AND D. BORCHERS‡

Contact e-mail: alnitak.ana@cetaceos.com

ABSTRACT

This paper examines the data for common dolphins collected during a general double-platform line transect cetacean survey carried out in waters around the Faroe Islands in 1995 (from southeastern Iceland to western Ireland) in order to determine the extent to which a correction factor can be estimated to account for animals missed on the trackline and for responsive movement towards the vessel. A major assumption of conventional distance-based methods is that all objects at zero distance from the line are detected (i.e. $g(0)=1$). If this assumption is violated the estimated density and hence abundance will be negatively biased. It also assumes that animals do not respond to the survey vessel before they are detected by the observers. If the animals are attracted to the vessel, for example, this will result in a positively biassed estimate. The $g(0)$ estimate was obtained using the method of Borchers *et al.* (1998). Visual inspection of the data suggested that the dolphins were attracted to the vessel and this was accounted for following the Buckland and Turnock (1992) approach. Coefficients of variation (CVs) and confidence intervals (CIs) were estimated using a non-parametric bootstrap procedure. During the survey, almost 1,700 n.miles were sailed on primary research effort. There were 153 common dolphin sightings including 52 duplicates. The chosen model for the detection function incorporated perpendicular distance, group size and Beaufort sea state. The resulting estimate of $g(0)$ was 0.7961 (CV=0.14). Density estimates obtained under an assumption of no responsive movement are almost six times higher than when it is taken into account, highlighting the importance of collecting appropriate data to allow analysis of this potential problem in cetacean surveys.

KEYWORDS: ABUNDANCE ESTIMATE; $g(0)$; SURVEY-VESSEL; COMMON DOLPHIN; ATLANTIC OCEAN; EUROPE

INTRODUCTION

The short-beaked common dolphin (*Delphinus delphis*, common dolphin hereafter) is widespread in the northeastern Atlantic. Although typically found in oceanic and shelf-edge waters, it can also be seen in neritic waters (e.g. Forcada *et al*., 1990; Carlisle *et al*., 2001; Harwood and Wilson, 2001; Hammond *et al*., 2002; Lopez, 2003; Silva and Sequeira, 2003). In recent years, concern has been expressed over its conservation status in these waters, largely due to large bycatches of the species in certain fisheries (e.g. Goujon *et al*., 1993; 1994; Tregenza and Collet, 1998; Morizur *et al*., 1999; Lopez *et al*., 2003; Silva and Sequeira, 2003). However, quantitative knowledge of the abundance and stock structure of the species in this area is sparse and this, combined with a lack of reliable estimates of bycatch levels and population dynamics, make a good evaluation of conservation status problematic (e.g. see Hall and Donovan, 2002).

Of primary importance in understanding the status of a population is knowledge of its abundance. The most commonly used method for estimating abundance of cetaceans is distance-based line-transect sampling, in which the visual observer(s) travels along a pre-determined trackline recording 'sightings' (individuals or clusters of individuals) and estimating the perpendicular distances to the trackline. These data (together with covariates that may be affecting the detection of the targets), can be used to estimate the effective strip width of the survey and ultimately density and abundance estimates (Buckland *et al*., 2001).

For reliable estimates to be obtained, a number of assumptions must either be met or violations corrected for. One major assumption is that all animals on the trackline are detected, commonly expressed as $g(0)=1$[1]. In practice, this is unlikely to be fully met for cetaceans, as for example, it is probable that some animals will be missed because they are submerged. If this assumption is indeed violated, and no correction is made, the estimated density and abundance will be negatively biased to some degree (Buckland *et al*., 2001; Hammond, 2001).

A number of methods to attempt to estimate $g(0)$ have been developed over the last two decades. These generally involve double-platform surveys where two visually and acoustically independent teams of observers (usually located one above the other on the same vessel) survey the same area (e.g. Barlow, 1988; Butterworth and Borchers, 1988; Buckland *et al*., 1993). Analyses combine distance sampling and mark-recapture methodology (Borchers *et al*., 1998; 2002). The process can be seen as an experiment in which each sighting corresponds to a trial with four possible outcomes: detection by platform 1, detection by platform 2, detection by both platforms (a duplicate sighting) or detection by neither of the platforms. A set of covariates, one of which would typically be perpendicular distance of the sighting to the transect, is associated with each trial. The probability that a group is detected by a platform is modelled as a logistic function of the detection covariates. Each trial represents a capture event, and duplicate sightings represent 'recaptures'. The proportion of duplicate sightings is then used to estimate $g(0)$ (Borchers *et al*., 1998; 2002; Buckland *et al*., 2001).

In recent years, more robust methods have been developed which incorporate corrections for responsive movement and for groups missed on the transect line

[1] $g(y)$ is the probability that an object at distance y from the line is detected.

* *Alnitak. Nalón 16, 28240 Hoyo de Manzanares, Madrid, Spain.*
† *Fjord & Bælt, Margrethes Plads 1, DK-5300 Denmark.*
‡ *RUWPA, The Observatory, University of St Andrews, Fife, KY16 9LZ, Scotland.*

(Buckland and Turnock, 1992; Borchers *et al*., 1998). In these, one of the independent observation platforms searches further ahead of the vessel than the other (e.g. using high-powered binoculars), ideally detecting the animals before they respond to the approaching vessel. The observers then track the sightings until they are detected by the other (primary) platform or have passed abeam.

A further assumption of line-transect methods is that animals do not respond to the survey vessel before they are detected by the observer; again, if violated and not corrected for, this will result in either an overestimate (if animals are attracted to the vessel) or an underestimate (if animals move away from the vessel). Different approaches have been used to account for responsive movement (e.g. Palka and Hammond, 2001; Mullin and Fulling, 2003). Common dolphins are known to be attracted to vessels, although the extent of this behaviour is unknown.

This paper examines the data from the first double-platform survey with sufficient duplicate sightings of common dolphins to allow an estimation of $g(0)$. The data (Desportes *et al*., 1995; 1996) were obtained by the Faroese vessel that took part in the third multinational NASS (North Atlantic Sighting Surveys) survey held in summer 1995 and co-ordinated by the North Atlantic Marine Mammal Commission (NAMMCO, 1997). Earlier NASS surveys took place in 1987 (Gunnlaugsson and Sigurjónsson, 1990) and 1989 (Sigurjónsson *et al*., 1991). The present analysis estimates $g(0)$ for common dolphins for the first time incorporating a correction for both animals missed on the trackline and responsive movement. Resultant abundance estimates and a discussion of the distribution of common dolphins as revealed by the full series of NASS surveys is given in Cañadas *et al*. (In press).

METHODS

Survey design and data collection

The primary target species of the Faroese vessel in 1995 was the long-finned pilot whale (*Globicephala melas*) and this was reflected in the survey design (in terms of survey area and methodology). However, data were collected on all species encountered.

The survey area for the Faroese vessel comprised the area between southeastern Iceland and western Ireland (see Fig. 1). The area was divided into two blocks, an Eastern block (between 5ºW-18ºW and 52ºN-62ºN) and a Western block, added to cover an area extended to the west, (between 18ºW-28ºW and 52ºN-57º30'N). The Eastern block (Block E hereafter) had an area of 232,858 n.miles^2 (798,708km^2), and the Western block (Block W hereafter) an area of 108,325 n.miles^2 (371,557km^2). The total area was surveyed between 8 July and 6 August 1995.

Given the limited amount of vessel time available and the unpredictability of the weather, two cruise tracks were planned: primary and secondary (solid and dashed lines respectively, Fig. 1). The primary cruise track (1,841 n.miles) was designed to fulfil the necessary statistical requirements for line transect surveys and be expected to result in a reliable estimate. Effort was allocated to each block depending on their areas and the encounter rates observed in 1989 (Sigurjónsson *et al*., 1991). The secondary cruise tracks were planned to enhance coverage if time and weather permitted, once the primary track was covered.

The research vessel was a 36m modified long-liner, *Miðvingur*, equipped with two observation platforms. The cruising speed was about 9.5 knots.

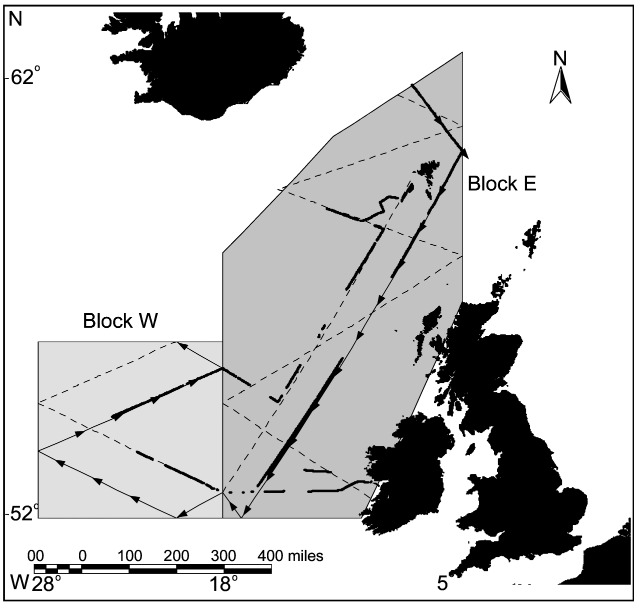

Fig. 1. Survey area showing blocks W and E, planned cruise tracks (solid thin line with arrows = primary cruise track; dashed line = secondary cruise track) and tracks realised on effort (thick solid line).

The double-platform method used in this survey (hereafter BT mode), was based on that developed for the 1994 SCANS[2] survey (Hammond *et al*., 1995; 2002) following Buckland and Turnock (1992); only one-way independence between the platforms is required.

The primary platform (PP) was situated on the forward mast with an eye height of 11.5m. It was visually and acoustically independent from the tracking platform. The PP housed two observers searching with naked eyes (binoculars were only used for species identification), concentrating on the surface within the 1,000m of the vessel and 90° either side of the trackline. Distances to sightings were estimated by eye and angles were measured with mounted angleboards.

The tracking platform (TP) was situated above the navigation bridge, with an eye height of 9.35m. Two observers and one duplicate identifier (DI) were present. The TP observers used 7 × 50 reticule binoculars to search an area ahead of the primary searching area of the PP observers (>1,000m). One TP observer concentrated on a band 60° on either side of the trackline whilst the other searched a wider band 90° either side of the trackline. It was hoped that this search area was sufficiently wide and far ahead of the vessel to ensure that animals were detected prior to any responsive movement to the ship. Once sighted by the TP, animals were tracked until either being detected by the primary platform or passing abeam of the vessel.

The DI received information from both the TP observers and the PP observers (by telephone) as soon as a sighting was made; it was the DI's responsibility to determine if duplicate sightings were made and to record effort data and sighting conditions onto a computer in real time. GPS positions were recorded automatically every 30s. Data on effort and sighting conditions were recorded every 15 minutes or whenever changes occurred (including observers on watch, sea state (Beaufort), swell height and angle, glare width and strength, horizontal and vertical angle of the sun, wind direction and weather type). The following data were

[2] Small Cetacean Abundance in the North Sea.

recorded for each sighting or re-sighting: time, platform, estimated distance, angle, observer, cue, behaviour, aspect, species, group size, calves, duplicate class (definite, likely, probable) and comments.

A total of 10 experienced observers rotated in two hours shifts (two hours on duty and two hours off). The observers remained assigned to the same platform during most of the cruise. Research was not conducted if visibility was less than 1,000m, if it was raining or if sea state exceeded Beaufort 4.

Data analysis

Organisation of the data

Several legs (transects) were defined within each block: two for block W and 10 for block E, and effort was calculated for each leg. In addition, each leg was divided into segments of approximately 20 n.miles each (except for 1 leg in block E which contained one single segment) for bootstrapping purposes (non-parametric bootstrap). Sections of transect were considered different segments when there was more than one hour off effort between them (e.g. due to bad weather conditions or night) even if they had a length of less than 20 n.miles. A total of 106 segments were thus defined, of which 22 were in block W.

Estimation methods

The estimation of the detection function and $g(0)$ followed the methods of Borchers *et al.* (1998), implemented in S-Plus. The estimation functions and associated documentation are available on request (email: *dlb@mcs.st-and.ac.uk*). The essentials of the method (described in detail in Borchers *et al.*, 1998) are as follows:

(1) Only the PP detection function is estimated.
(2) TP sightings provide binary trials for estimation of the PP detection function, in which detection by the PP constitutes a ‘success’. Binary regression on these data, using generalized linear model (GLM) methods and a ‘logit’ link function provides estimates of the PP detection function (details below).
(3) Abundance of animals within the searched strip (N_w) is estimated using only PP sightings in a Horvitz-Thompson-like estimator in which the detection probability of the *i*th sighting is estimated by evaluating the logistic detection function estimated in (2) above, using the explanatory variables associated with the *i*th sighting (details below).
(4) Density is estimated by dividing the estimate of N_w by the area of the searched strips.

The form of the detection function, with *r* explanatory variables in addition to perpendicular distance (*x*), is:

$$g(x,\underline{z}) = \frac{\exp[\beta_0 + \beta_x x + \sum_{k=1}^{r} \beta_k \underline{z}_k]}{1+\exp[\beta_0 + \beta_x x + \sum_{k=1}^{r} \beta_k \underline{z}_k]} \quad (1)$$

where: $g(x,z)$ is the detection probability as a function of the available explanatory variables (x = perpendicular distance and $z_1,...,\underline{z}_k$ = k other explanatory variables), β_0 is an intercept parameter, β_x is a parameter relating to the effect of distance and the β_ks are parameters relating to the effects of other explanatory variables. All these parameters are estimated.

The explanatory variables considered were perpendicular distance and any of the variables (animal or environment related) recorded during the sightings: group size, cue, behaviour, aspect, sea state, glare width and intensity, swell height and angle, sun angle horizontal and vertical and wind direction. Model selection was done manually using the Akaike Information Criterion (AIC). Following Borchers *et al.* (1998), $g(0)$ is estimated as:

$$\hat{g}(0) = \hat{E}_z[g(0,\underline{z})] = \sum_{j=1}^{n} \frac{\hat{g}(0,\underline{z}_j)}{\hat{g}(\underline{z}_j)\hat{N}_w} \quad (2)$$

where:

$$\hat{g}(\underline{z}_j) = \int_0^w \hat{g}(x,\underline{z}_j)\frac{1}{w}\,dx \quad (3)$$

Coefficients of variation (CVs) for $g(0)$ were estimated using a non-parametric bootstrap procedure (1000 iterations), in which segments were the sampling units. Resampling was performed separately within each block. Confidence intervals (CIs) were estimated using a simple percentile method.

Visual inspection of the data suggested substantial movement of the animals towards the ship between the detection from the tracking and the primary platform (probably due to attractive responsive movement): see Figs 2, 3 and 4. These plots should not be over-interpreted; more duplicate detections of animals moving in toward the trackline after being seen by the TP would be expected, even if there is random, non-responsive movement, because animals that move in are more likely to be seen by PP. However, estimation of the expected fraction of duplicate detections that show movement towards the trackline is not simple and the apparent movement in the plots is enough to suggest that it would be wise to use a method which accommodates responsive movement. If the TP detects animals before they respond, the BT method is able to do this. The version of this method which is described in detail in Borchers *et al.* (1998) was implemented in the set of Splus functions mentioned above.

Abundance within the searched strip of half-width *w* about the trackline was estimated by :

$$\hat{N}_w = \sum_{j=1}^{n} \frac{s_j}{\hat{g}(\underline{z}_j)} \quad (4)$$

where s_j is the group size of the j^{th} detected school and the sum is over all PP detections. The density of dolphins in the survey area, *D*, is estimated as follows:

$$\hat{D} = \frac{\hat{N}_w}{2Lw} \quad (5)$$

where *L* is the total length of all lines and *w* is the chosen truncation distance.

RESULTS

Data collection

Bad weather conditions meant that only 43% of the available research time could be spent on effort. This prevented even completion of the primary cruise track and a number of modifications to the tracklines had to be made during the survey itself.

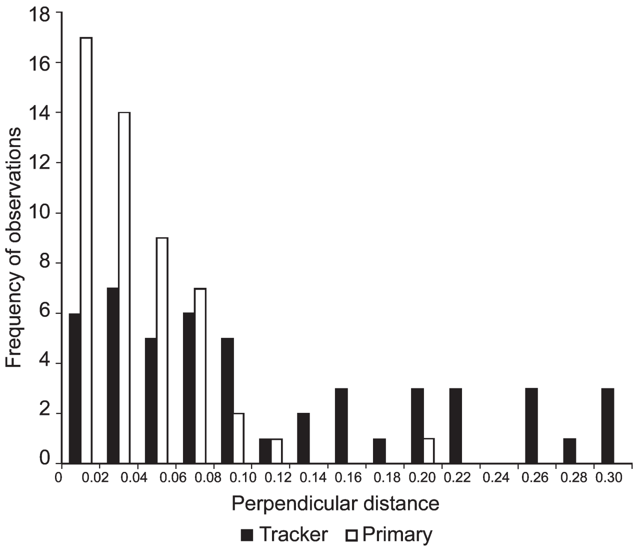

Fig. 2. Frequency of observations at different perpendicular distances (in nautical miles) for duplicate sightings, both from the tracker and primary platforms.

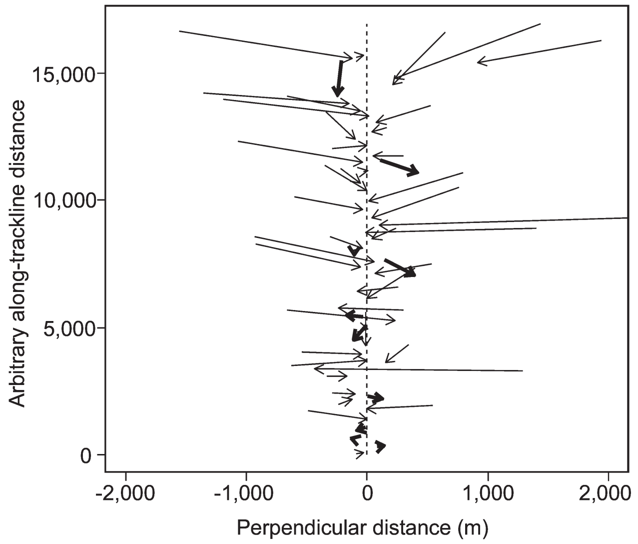

Fig. 4. Perpendicular distance movement of duplicates. Arrows represent the movement of duplicates from the time they were detected by the tracker until the time they were detected by the primary observers. All positions are relative to the survey vessel. Each detection has been shifted by 300m along the trackline relative to the previous detection in order to separate the arrows. The single arrow extending beyond the right edge of the box originated at 4,000m. All arrows corresponding to movement away from the trackline appear in bold.

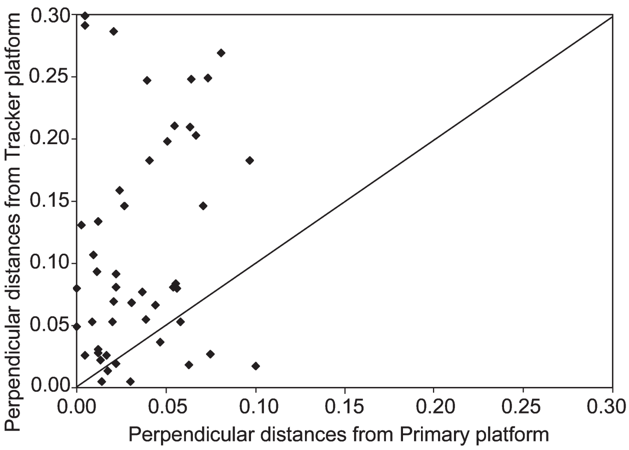

Fig. 3. Scatterplot of perpendicular distances measured both from tracker and primary platforms. Each dot represents a duplicate sighting.

Table 1

Numbers of schools of common dolphins detected on effort from primary (PP) and tracker (TP) platforms, together with the number of duplicates (D), for each block and in total.

Species	PP	TP	D
Block W	49	46	29
Block E	27	31	23
Total	76	77	52

Shelter from forecast extended bad weather was sought in the city of Galway on the west coast of Ireland. The tracks to and from Galway, conducted in searching effort, were added to the original cruise track. In contrast, some additional time was available at the end of the survey and thus some searching effort was conducted on the western edge of the Faeroe Bank following part of the secondary trackline. The final tracks performed under effort are shown in Fig. 1 (solid thick line). However, these changes to the original design give rise to some concern over the representativeness of the survey, especially in block E (see below).

In total, 1,672.8 n.miles were sailed on effort, of which 1,321.8 n.miles were in block E and 351 n.miles in block W. About 64% of the effort was in Beaufort 3 or 4 and only 4% was in Beaufort 0 or 1. Of the 471 cetacean sightings recorded, 153 (including 52 duplicates) were of common dolphins (i.e. n=101). Sightings by block and platform are given in Table 1 and the position of the sightings is given in Fig. 5.

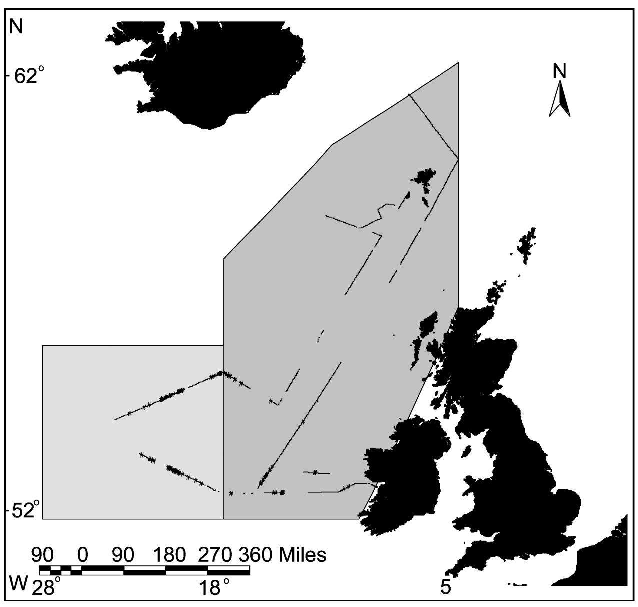

Fig. 5. Sightings of common dolphins on effort.

Data analysis

Estimation of g(0)

For the estimation of $g(0)$, data from both blocks were pooled to increase sample size, since no differences in detectability were expected between them (same vessel, observers and similar environmental conditions). A truncation distance of 0.3 n.miles was chosen given (1) the distribution of the data, with most sightings very close to the trackline and (2) that for estimating $g(0)$, sightings of primary interest are those relatively close to the trackline. With this truncation distance, only 2.5 % of the data was discarded.

Fig. 6 shows the frequency distributions of the perpendicular distances of primary detections (detections from the PP), trials (detections from the TP) and duplicates, together with the proportion of duplicates within the truncation distance. Within this distance, no trend in the proportion of duplicates is apparent (i.e. the proportion of duplicates was not influenced by distance from the trackline; bottom right plot of Fig. 6). The fact that the PP perpendicular distance distribution of detections falls off and the duplicate proportion does not, may reflect either: (a) unmodelled heterogeneity which increases as distance increases (in which case the duplicate detection function is a biased estimate of the detection function – it should fall off more); (b) that the PP perpendicular distance distribution is a biased estimate of the shape of the PP detection function, because animals have moved towards the trackline by the time they are detected, making the distribution too peaked near distance zero; or (c) some combination; in this application (b) appears the most likely (see below).

Several combinations of the potential explanatory variables listed in 'Methods' were considered for modelling the detection function. The two models with the lowest AICs (differing by only 0.008) were a model using perpendicular distance and group size (AIC = 62.925; and see Fig. 7) and a model with the same two variables plus sea state (AIC = 62.917; and see Fig. 8). Although the first is more parsimonious, the second seems more appropriate given that external information shows that sea state is very likely to be affecting detectability, even if in this case sample size is inadequate to detect this. In addition, this model gives a more plausible detection function shape. The coefficients of the final model and their standard error and *t* value are shown in Table 2.

Table 2

Coefficients of the variables included in the chosen model of the detection function, with their standard error (SE), *t* values and approximate *p*-values.

	Coefficients	CE	*t* value	*p*-value
Intercept	1.895	1.348	1.41	0.16
Perpendicular distance	-1.063	4.592	-0.231	0.82
Group size	0.121	0.077	1.56	0.12
Beaufort	-0.453	0.345	-1.31	0.19

Group size was selected by AIC as an important explanatory variable for the detection function. In addition the detection function parameter associated with group size has a positive sign (Table 2). This implies that the effect of increasing group size in the model is to increase detection probability, and that detection probability at any given distance (and at distance zero in particular) is greater for large groups than small groups. The fitted model implies that larger groups have greater $g(0)$ values than smaller groups, as one might expect.

The resulting overall estimate of $g(0)$ was 0.796 for the whole area. Non-parametric bootstrapping with 1,000 resamples gave a CV of 0.13 (CI: lower 95%=0.577, upper 95%=0.961). Results by block are given in Table 3.

Estimation of density

When applying the Horwitz-Thompson estimator to the fitted values obtained from the logistic regression (i.e. incorporating responsive movement), an estimated density of 2.52 animals n.mile^{-2} (0.74 animals km^{-2}) for block W was obtained. The mean value obtained by bootstrapping with 1000 resamples was similar − 2.58 with a CV of 0.13. Results for the whole area and for each block are shown in Table 3. Although results can be obtained for both blocks, the actual tracks carried out in block E (see Fig. 1) most of which lie in the middle of the stratum and roughly parallel to depth contours, combined with the small sample size in that area give rise to concern as to its reliability. In effect, given the coverage, the density estimate obtained, even for block W, applies to the east of this block. This is considered further in Cañadas *et al*. (In press).

To compare the density estimates incorporating and ignoring the effects of responsive movement, an estimate was also obtained using the DISTANCE program (Thomas *et al*., 2002) under the assumption that animals were uniformly distributed with respect to distance from the transect at the time they were detectable by the primary platform. Although the same covariates used in the BT method (group size and sea state) were considered when modelling the detection function, the best model fit to the data was a hazard-rate key function with hermite polynomial series expansion and no covariates other than perpendicular distance. The $g(0)$ estimate for the whole area given above was incorporated as a multiplier. Results are shown in Table 3. The detection function for the primary platform (with a right truncation distance of 0.07 n.miles, discarding 8% of the data) is shown in Fig. 9. The density estimate obtained, 14.74 animals n.miles^{-2}, was 5.9 times higher than that obtained using the BT method[3].

DISCUSSION

There have been relatively few double platform shipboard surveys in Europe. Perhaps the best example is the summer 1994 SCANS survey conducted in the North Sea (Hammond *et al*., 2002). Estimates of $g(0)$ were obtained for the three most abundant species in the area: the harbour porpoise (*Phocoena phocoena*), minke whales (*Balaenoptera acutorostrata*) and whitebeaked dolphins (*Lagenorhyncus albirostris*), as well as for a fourth group: *Lagenorhyncus* sp. The small duplicate sample size for common dolphins (which were found almost exclusively in the Celtic Sea) precluded estimation of $g(0)$ for that species; the estimate of abundance presented assumed that $g(0)$=1.

The $g(0)$ estimate obtained here for common dolphins (0.80, CV=0.13) is relatively high compared to those obtained for other small cetacean species in the North Sea during SCANS (Hammond *et al*., 1995): 0.31 (CV=0.15) for the harbour porpoise, 0.57 (CV=1.41) for white-beaked dolphins, 0.54 (CV=0.27) for the group *Lagenorhyncus* sp.

Common dolphins are usually sociable and conspicuous animals, with frequent surface and aerial behaviour. In addition, the mean school size in this study was 8.3,

[3] This difference is larger than that reported in Buckland *et al*. (2004). This is due to an error in their analysis which was discovered after publication.

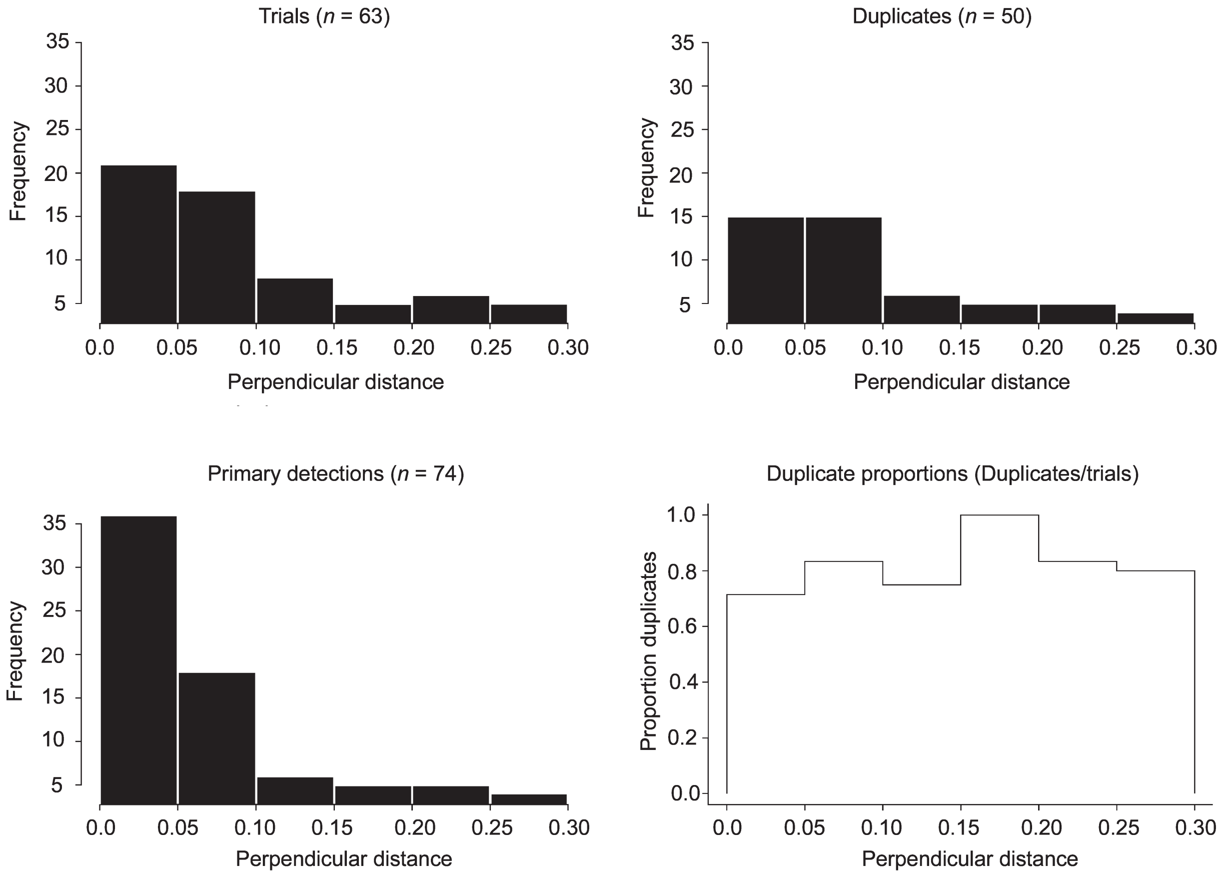

Fig. 6. Frequency distributions of the perpendicular distances of primary detections (detections from the primary platform), trials (detections from the tracker platform) and duplicates, and proportion of duplicates within truncation distance from the trackline.

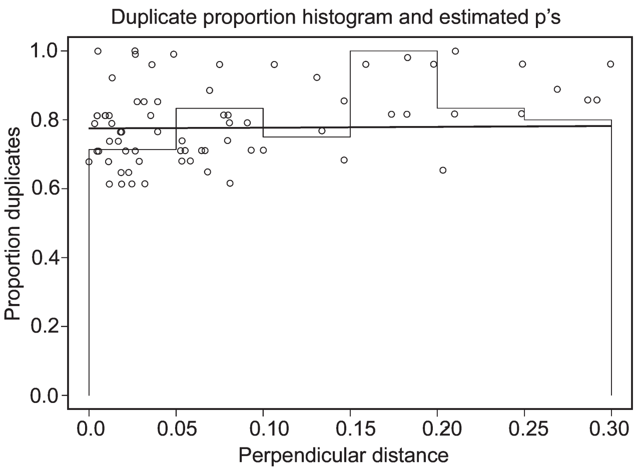

Fig. 7. Histogram of proportion of duplicates against perpendicular distance. The detection function obtained from including perpendicular distance and group size in the model is shown as a solid line. The dots represent the predicted detection probability for individual detections.

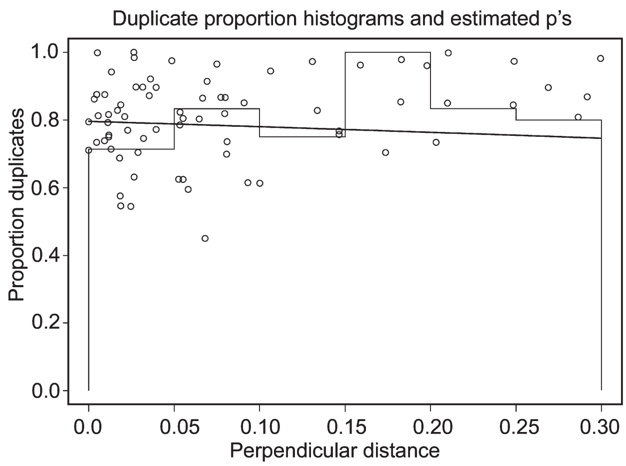

Fig. 8. Histogram of proportion of duplicates against perpendicular distance. The detection function obtained from including perpendicular distance, group size and Beaufort sea state in the model is shown as a solid line. The dots represent the predicted detection probability for individual detections.

considerably larger than for the species considered in the SCANS survey: 1.5 for harbour porpoise, 3.8 for white-beaked dolphins, and 4.3 for *Lagenorhyncus* sp. Taking this into account, it does not seem very surprising that the $g(0)$ value for common dolphins in this paper is higher, even though the adverse weather conditions on this survey would tend to reduce $g(0)$.

Estimates of $g(0)$, of course, take into account other factors than the behaviour and school size of the target species. In particular they take into account characteristics of a specific survey such as the type and speed of the vessel, height of the platforms, individual observers, predominant environmental conditions (e.g. sea state and visibility) etc. This makes it problematic to consider using $g(0)$ values across surveys. Despite this, the present results suggest that relatively little negative bias may occur if an assumption of $g(0)=1$ is made for common dolphins for surveys where $g(0)$ cannot be estimated (such as SCANS).

By contrast, the present study has revealed that potential responsive movement of common dolphins to the vessel must be taken into account when estimating their abundance from vessel surveys. In this regard it should be noted that

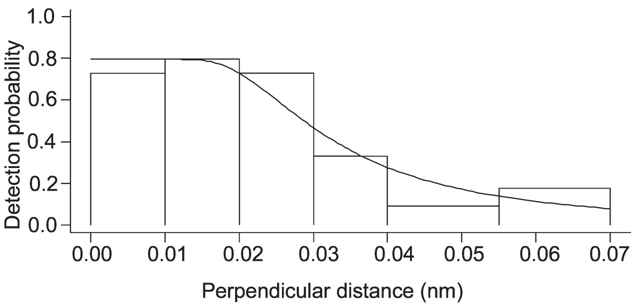

Fig. 9. Perpendicular distance distribution of detections by the primary platform. The line is the detection function fitted with DISTANCE software to data truncated at 0.07 n.miles. The histogram and fitted line have been scaled to give the line an intercept equal to the estimated $g(0)$. The estimated effective strip width was 0.038 n.miles.

Table 3

Estimates of $g(0)$, encounter rate (n/L), group size (E[s]), density of schools (Dschool) and animals (Dindiv) and abundance of schools (Nschool) and animals (Nindiv) for the whole area and stratified for blocks. Mean ($Mean_{bs}$) and coefficients of variation (CV_{bs}) after 1000 resampling bootstrap are given, together with the 95% confidence intervals (CI). Area and densities are given in $n.miles^2$, length and encounter rates are given in n.miles. Truncation distance was 0.3 n.miles. Estimates from DISTANCE for block W are also shown, calculated from PP data and with a truncation distance of 0.07 n.miles.

	n	Dschool	Dindiv	g(0)
Total area				
Estimate	74	0.124	1.028	0.796
$Mean_{bs}$	74	0.133	1.052	0.788
CV_{bs}	0.21	0.32	0.24	0.13
Lower 95% $_{bs}$	47	0.072	0.618	0.577
Upper 95% $_{bs}$	105	0.226	1.583	0.961
Block E				
Estimate	25	0.040	0.333	0.807
$Mean_{bs}$	25	0.042	0.34	0.799
CV_{bs}	0.36	0.51	0.43	0.14
Lower 95%$_{bs}$	10	0.017	0.109	0.556
Upper 95% $_{bs}$	44	0.078	0.661	0.985
Block W				
Estimate	49	0.304	2.522	0.791
$Mean_{bs}$	49	0.329	2.578	0.785
CV_{bs}	0.25	0.37	0.26	0.13
Lower 95% $_{bs}$	27	0.159	1.416	0.542
Upper 95% $_{bs}$	73	0.592	4.017	0.957
Distance (W)				
Estimate	45	2.145	14.737	0.796
CV		0.35	0.38	
Lower 95%		1.069	7.052	
Upper 95%		4.303	30.798	

there is no guarantee that even the 7x binoculars allow detection before responsive movement occurs, especially for small groups in rough sea states. It is thus not inconceivable that the effect of responsive movement is greater than calculated here. It is clear that if surveys aim to estimate the abundance of common dolphins, data should be collected in such a way that attempts to allow most sightings to be detected before responsive movement occurs and that allows responsive movement to be accommodated in analysis, should it occur.

It is beyond the scope of this paper to provide a detailed comparison of density estimates for common dolphins obtained from this study with estimates from other parts of the North Atlantic or to develop an abundance estimate; this is covered in Cañadas *et al*. (In press).

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