Journal of Marine Animals and Their Ecology

Vol 1, No1, 2008
Printed in Canada

Winter abundance estimates for the common dolphin (Delphinus delphis) in the western approaches of the English Channel and the effect of responsive movement

De Boer, M.N.[1], Leaper, R.[2], Keith, S.[1], Simmonds, M.P.[1]
[1] The Whale and Dolphin Conservation Society (WDCS) Chippenham, Wiltshire, UK
[2] International Fund for Animal Welfare, London, UK

Abstract
A survey using line-transect techniques was conducted during two winters providing the first estimates of common dolphin, *Delphinus delphis,* abundance (number of dolphins) on winter pelagic trawl fishing grounds in the English Channel. Independent teams of observers searched with binoculars or naked eye. These methods were intended to allow for the calculation of a correction factor for both animals missed on the trackline and for responsive movement. Results indicated that the naked eye observers missed 7% of the dolphins on the trackline, but that there was a strong responsive movement towards the vessel. Comparing initial locations of animals detected by the two independent teams showed that just using naked eye observations would result in apparent densities that were 1.5 times larger than the dual platform analysis. Using these factors the mean corrected winter density of common dolphins in the study area across both years was 0.74 dolphins/km^2 (CV = 0.39) giving a mean abundance of 3,055 dolphins (95% CI = 1,425-6,544). However, these estimates are most likely positively biased due to responsive movement not being fully accounted for. Nevertheless, the relative index for abundance (number of schools per 100km effort, mean school size 5.1) was the highest recorded from comparable surveys in the North Atlantic and shows that the Channel is a very important winter habitat for common dolphins. [JMATE. 2008;1(1):15-21]

Key Words: *Delphinus delphis*; line-transect survey, mark recapture distance sampling

Introduction

The English Channel constitutes a relatively narrow link between the Atlantic Ocean and North Sea that appears to have had variable use by common dolphins over time (15). Fish stocks in the Channel are heavily exploited here with pelagic fisheries operating during the winter months from October to May. In recent years, several hundred corpses of short-beaked common dolphins (*Delphinus delphis*) have washed ashore in south west England each winter, many clearly diagnosed as having died through capture in fishing nets. In the case of many of the common dolphin corpses, the external damage is consistent with death in small-meshed mobile gear (i.e. trawl netting) (18). The conservation status of the common dolphin has therefore become of great concern (20, 14, 17). In recent years the UK has conducted monitoring of the winter sea bass fishery, which has been found to be responsible for a high rate of cetacean bycatch (6). However, there are still no estimates of total annual bycatch for this species in all fisheries combined (10).

Only a few studies to date have reported the abundance of the short-beaked common dolphin in the NE Atlantic or supplied an estimate or index of density and abundance (8, 5, 4,13). However, these surveys differ in distribution of effort, vessel-type, survey methodology and the season in which they were carried out.

This study utilised a commonly used method for estimating animal abundance, distance sampling, and highlights the consequences of responsive movement of dolphins towards the survey vessel. Line-transect surveys were conducted in two subsequent winters (2004 and 2005) to estimate the first winter abundance of common dolphins in an area of the Western Approaches of the English Channel.

Material and Methods

Survey design

The survey was conducted from the *MV Esperanza*, a 72.3m research vessel which traveled at either a 'fast' average speed of 8.6 knots or a 'slow' average speed of 5.3 knots. All data used for density estimation were collected in 'passing mode', where the vessel did not deviate from the track-line in response to sightings of the target species.

The two surveys were conducted during the winter months, between 21 January and 8 March 2004 and between 17 February and 26 March 2005 in the Western Approaches of the English Channel. The study area was divided into different survey strata and lay between 49°20'N-50°20'N and 3°26'W-6°10'W (Fig. 1). The western stratum (Stratum W) extended to the west and covered 4,743km^2 and the eastern stratum (Stratum E) covered 4,129km^2. Both strata coincided with an area where trawlers operate during winter.

The survey track followed a saw tooth (zig-zag) pattern inside a rectangle (survey stratum). The zig-zags (transects) were designed such that the offshore boundary of the stratum was drawn parallel to the major axis of the coastline. Each point within the specified survey stratum had an equal probability of being on a line. The overall orientation of the transect lines was also designed such that they were placed approximately across likely density contours.

Data collection

To facilitate systematic data collection, the data-logging program *Logger 2000* (developed by IFAW to promote benign, non-invasive research) ran continuously throughout the survey on a laptop computer which was linked to the ship's Global Position System (GPS, a Furuno GP-80 satellite navigation system) through an NMEA (National Marine Electronics Association) interface. This program automatically recorded the ship's location every 15 seconds and provided a continuous visual display of the vessel's track on a map of the area. Data concerning sightings and the environment were entered manually.

Received October 24, 2007; Accepted March 07, 2008.
Correspondance: Marijke de Boer, Consultant to WDCS, Gruttershof 33
3514 AW Utrecht, The Netherlands E mail: Marijke.deboer@yahoo.co.uk
Mobile (NL): +31 611411056

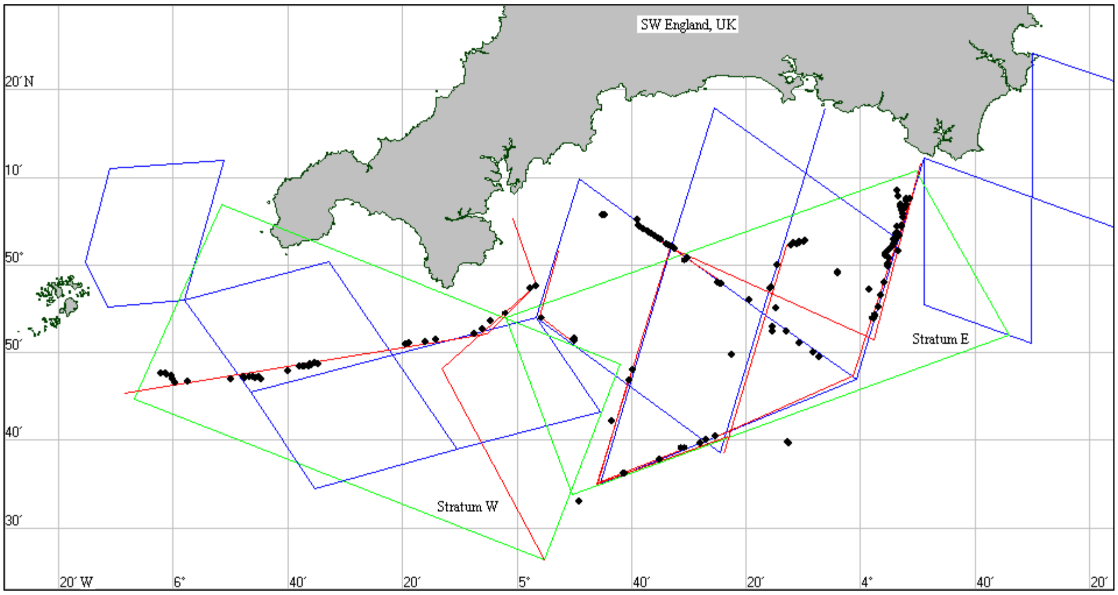


Figure 1. Map showing the transect layout (blue lines) with achieved effort (in red lines) and survey strata (green boxes). Sightings of common dolphins are plotted as black dots.

The Primary platform

During both the 2004 and 2005 surveys, observations were conducted from a Primary platform. This was located on the outer bridge wings with an approximate eye height of 11.3m and was visually and acoustically independent from the secondary (tracking) platform. The two Primary observers scanned a 90 degrees sector (on port and starboard), forming an approximately 180 degrees combined survey area in front of the ship. Scanning was done with the naked eye. A third person acted as the data recorder, entering sighting information and environmental details. The observers were rotated every hour to avoid fatigue.

Once a sighting was made, Nikon 7X50 marine binoculars with in-built reticule scales were used to measure the vertical angle from the horizon to the sighting in order to estimate distance. The bearing to the sighted animals and the animal(s) headings were determined by using 'angle-boards' which were fixed to the ship's railings. These were aligned parallel to the ship's bow and the alignment checked and corrected throughout the survey.

Sightings data recorded from the Primary platform included the time, GPS position, bearing, distance, species identification (and degree of certainty ranging from definite-100%, probable-75% to possible-50%), presence of calf and/or juveniles, school size (maximum, minimum and best estimate), animal's heading, travel mode, group composition and behaviour.

The following environmental data were collected every hour, and when conditions changed: ship's position, heading and speed; wind speed and direction (using an OBSERMET Wind meter *OMC 939*); cloud coverage and glare conditions (in degrees); visibility; swell height; and sea state. Water depths were obtained using a Furuno Navigational Echosounder (FE-700).

The secondary (Tracker) platform

During the 2005 survey, observations were also conducted from a second platform. This Tracker platform was situated in the ship's crow's-nest, with an approximate eye height of 19.5m, housing one observer ('Tracker'). The crow's nest contained two window frames which interrupted the view but allowed searching an uninterrupted combined area of at least 60 degrees (30 degrees on either side of the trackline with a free view beyond both frames to 120 degrees on either side) using Nikon 7X50 reticule marine binoculars mounted on a tripod. A digital voice recorder with a built-in digital camera (Olympus W-10) was attached to the binoculars and was used to record the following sightings data: time, reticules, heading, species ID and school size. The camera was facing down when photographing the bearing to the sighting to obtain images of reference lines on the deck. These lines were used to calculate the bearing to the sighting relative to the ship's heading using the methods of Leaper and Gordon (12). The Tracker concentrated on searching at ranges beyond 1,000m ahead of the vessel (prioritising sightings >1,500m), trying to detect animals before they had responded to the approaching vessel, and recording re-sightings (tracking) until the animals had passed abeam.

The Tracker platform was not in operation throughout the survey. However, it was used whenever possible and when the ship was going at 'fast' speed and in a straight line.

Data analysis

Only data collected from both platforms during 'fast' speed were used for conventional distance sampling analysis, whereas the Primary platform data collected during slow and fast speeds was used to study the effect of responsive movement.

The line transect method is based on certain assumptions. One of them is that all objects at zero perpendicular distance from the trackline are detected, that is '$g(0)$' equals one, where '$g(y)$' is the probability that an object at a perpendicular distance y from the line is detected. In practice, however, this is likely to not be a valid assumption for cetaceans as they can be missed for a number of reasons. This is the main reason why during line-transect surveys two independent data sets are often collected, because it allows for the calculation of a parameter, $g(0)$, to account for animals missed on the trackline. If no correction is made for $g(0)$ then this is a source of negative bias (3). Another potential problem is that of a 'responsive

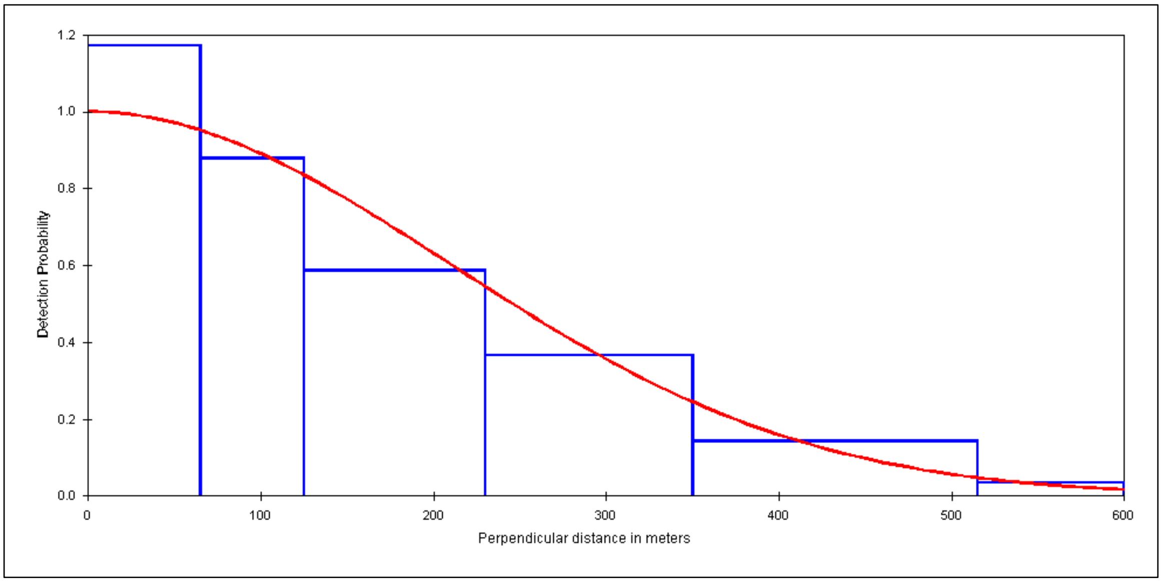


Figure 2. Histogram of perpendicular primary sighting distances and their fitted detection functions for common dolphins (n=108).

movement' of the animals to the presence of the survey vessel, since another assumption is that animals do not respond to the surveyor before detection. Common dolphins are known to be strongly attracted to vessels and frequently approach to investigate and 'bow-ride'. If animals approach the vessel before detection, this would positively bias the density estimate.

In the 2005 survey, the methodology followed the Mark Recapture Distance Sampling method first described by Buckland and Turnock (2). This method uses two sets of observation from the independent platforms to estimate a combined correction factor for *g(0)* and the effects of responsive movement. The underlying assumptions are that animals are detected by the Tracker platform before any responsive movement has taken place. In addition, the Tracker needs to search a sufficiently wide sector that animals should not be able to approach to within the field of view of the Primary platform without some chance of being detected by the Tracker.

Data from the Primary platform during double platform effort (predetermined transects and straight lines) were used to estimate the encounter rate (number of detections per km^2), while data from the secondary platform allowed the effective width of search from the Primary platform to be estimated.

Duplicate sightings (sightings seen by both platforms) were identified on the basis of time and sub-sequent re-sightings, species ID, best school size and heading of the animal(s). The eye-height for each observer was measured in order to convert radial distances calculated from the reticules and bearing data to perpendicular distance (3).

Using the program *Distance 4* (Research Unit for Wildlife Population Assessment, University of St. Andrews, UK) the conventional estimate of density (groups/km^2) was obtained by equating the number of detections from the primary platform (n_p) with the number expected. When assuming *g(0)* equals 1, the equation is:

$$\hat{D}_p = \frac{n_p \hat{f}(0)}{2L} \quad \text{(I)}$$

Where n_p is the number of primary detections, $\hat{f}(x)$ is the probability density of perpendicular distances x recorded from the primary platform and L is the length of transect (km).

The density estimate in (I) is biased if there is responsive movement in response to the platform before detection from the Primary platform or if the probability of detection on the trackline is less than unity. The estimate in the presence of both effects is then:

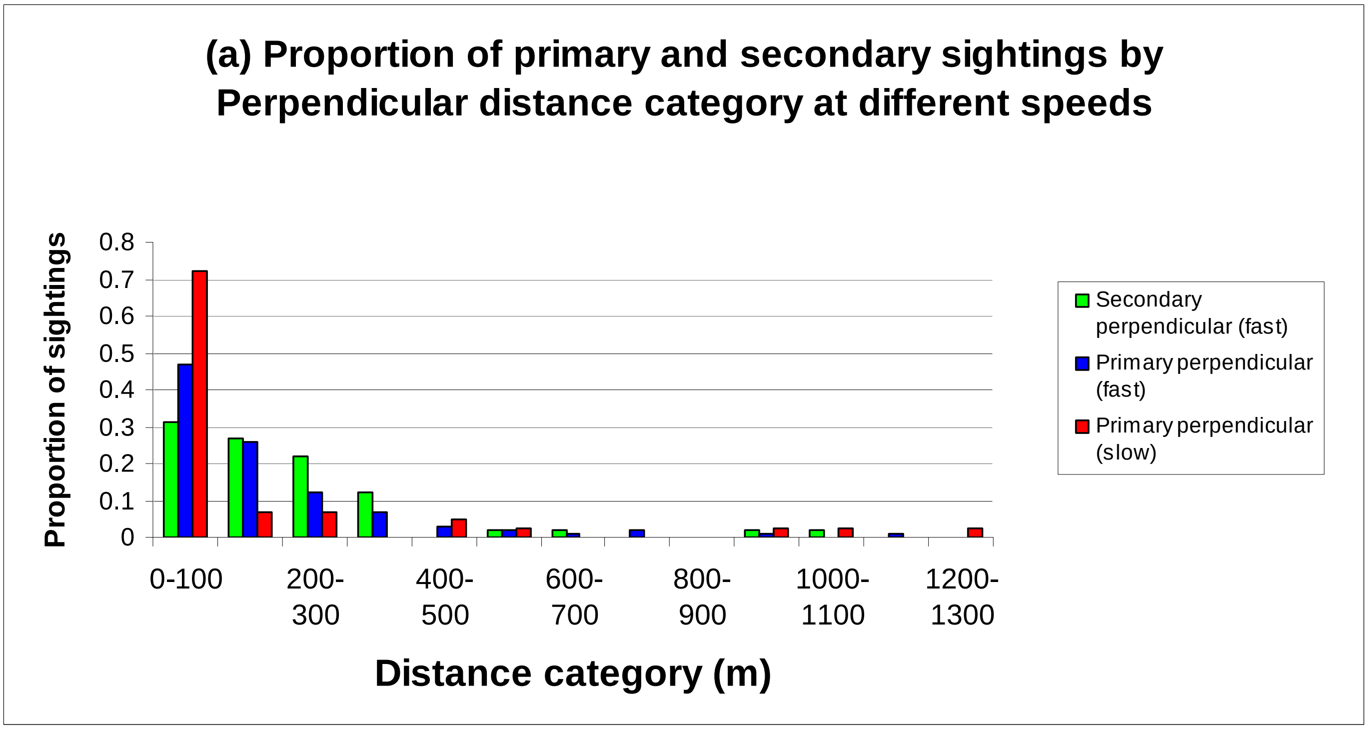
$$\hat{D}_c = \frac{n_p \hat{fp}(0)}{2L\hat{g}p(0)} \quad \text{(II)}$$

Where $\hat{fp}(x)$ is the probability density of perpendicular distances prior to responsive movement, of animals subsequently detected by the Primary platform and where $\hat{g}p(y)$ is the probability that an animal detected from the Tracker platform at perpendicular distance y from the trackline of the Primary platform is subsequently detected from the Primary platform (i.e. the detection function for the Primary platform).

If the Tracker platform is not in continuous operation, the above procedure is carried out on data collected while both platforms were in operation and a correction factor is calculated as:

$$\hat{c} = \frac{\hat{D}_c}{\hat{D}_p} \quad \text{(III)}$$

The density for the entire survey area is then estimated by cD, where D is estimated from the sightings data from the Primary platform for the full survey, calculated assuming *g(0) = 1* (using *Distance 4*). This estimate does not include any covariates and thus the assumption is that the estimate of *g(0)* for the two platform effort is the same as for Primary platform only. The corrected abundance estimate is calculated by $N_c = c\ D\ A$ and the CV of the corrected abundance estimate can be



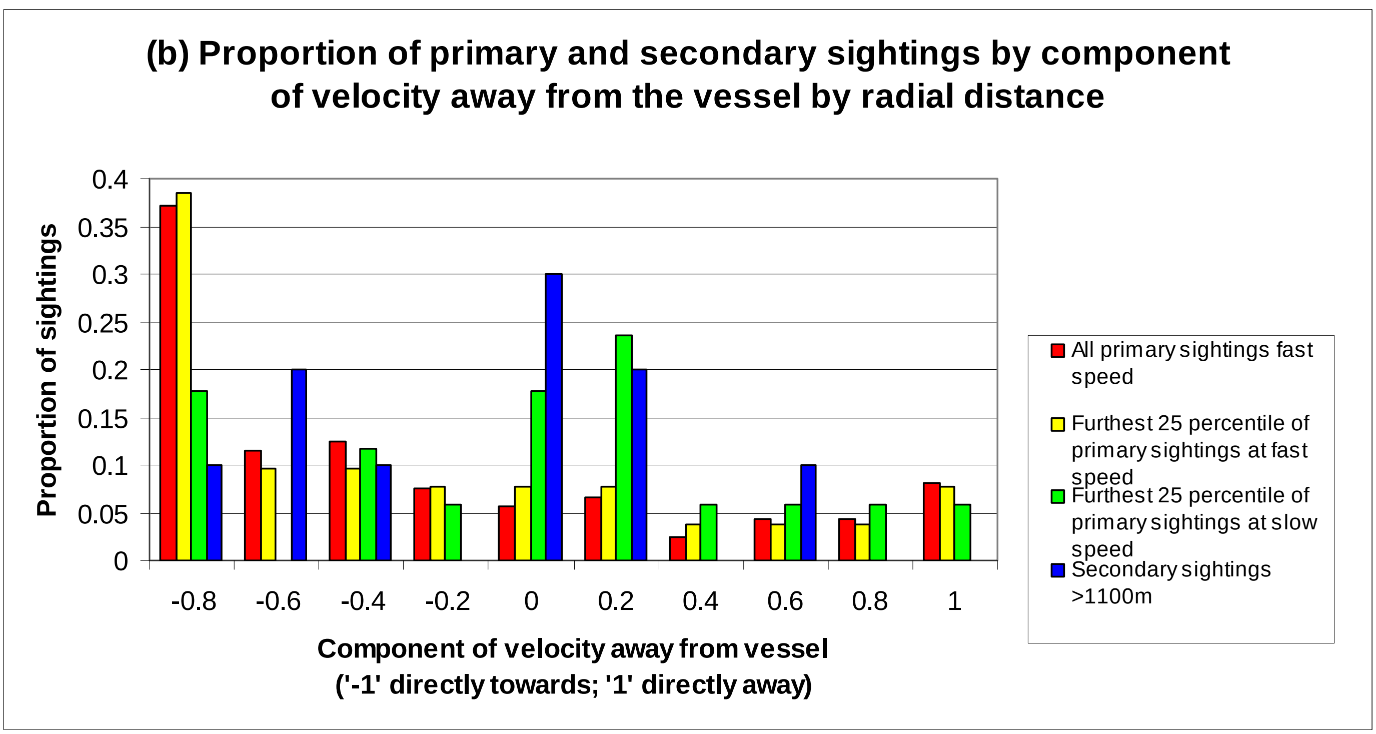


Figure 3. (a) The proportion of primary and secondary sightings by perpendicular distance category (m) at different survey speeds: 'fast' and 'slow' and (b) the proportion of primary and secondary sightings by component of velocity away from the vessel (*i.e.* the cosine of the difference between bearing and heading). Where a value of '1' indicates movement directly away from the survey vessel, '0' perpendicular and '-1' directly towards the vessel.

calculated by equations outlined in Turnock et al. (21). The upper and lower 95% confidence intervals for N_c can be calculated by using the Satterthwaite degrees of freedom procedure outlined in Buckland et al. (3).

Results

Survey effort

The line-transect survey covered 728.5km of transect and the double platform survey covered 514km. A total of 129 sightings of common dolphins of approximately 759 animals were made during the line-transect survey. Other species that were also identified during the survey were: harbour porpoise (*Phocoena phocoena*), bottlenose dolphin (*Tursiops truncatus*), Risso's dolphin (*Grampus griseus*), striped dolphin (*Stenella coeruleoalba*), fin whale (*Balaenoptera physalus*) and minke whale (*Balaenoptera acutorostrata)*.

Density and abundance

Common dolphin sightings first made aft of the beam were excluded. To ensure that only high quality data were used sightings made during Beaufort sea state >3 were removed and sightings beyond 600m were eliminated before *f(0)* estimation. Sightings made by the Primary platform were analysed for 2004, 2005 and pooled across both years.

Using the program *Distance 4*, we fitted detection functions to the perpendicular distance data to estimate the Effective half Strip Width (*ESW*) which is defined as *1/f(0),* for the different survey years*.* To reduce bias in mean school size estimates due to the potential of a positive relationship between school size and perpendicular distance *(x)*, a regression was performed to investigate the relationship between the probability detection function, *g(x),* and observed school size (3). From this regression, an expected school size was estimated. Akaike's Information Criterion (AIC) was used to select among models fitted to the data. Out of the models tested, the half-normal key with cosine adjustment was found to be the best fit for both surveys. The distribution of perpendicular distances and fitted detection function for sightings data pooled across both years is shown in Fig. 2.

Having selected a model, we reviewed the options for variance estimation. Bootstrapping was carried out which incorporates uncertainty in model fitting and model selection. Although survey effort was achieved in both strata, some concerns are given to the western stratum (covered only in 2004) where there were large differences between the designed and the realized cruise tracks as a result of heavy shipping traffic in the area (Fig. 1).

For the eastern stratum (Stratum E; 4,129km^2) the designed survey coverage was achieved so the density estimate should not be biased by non-uniform distribution of animals. The combined density estimate for both strata is more sensitive to non-uniform distribution of animals since only a relatively small proportion of the designed survey coverage was achieved in the western stratum due to heavy shipping traffic. The estimate of the density of individuals per km^2 (D) for Stratum E was calculated (Table 1) as outlined in Buckland et al. (3).

Parameter	Value/Estimate
Primary effort (L) in 2004+2005 (km)	573.9
Number of schools (n)	63
n/L	0.109
ESW (km)	0.253
Expected/mean school size (s)	5.063
Density (D) of individuals (ind/km^2)	1.097
%CV(D)	35.94

Table 1: Line-transect *primary* effort and winter density results estimated by *Distance 4* (assuming *g(0)*=1 and no responsive movement) for common dolphins for Stratum E by stratification, where *ESW* =Effective half Strip Width and *CV*=coefficient of variation.

Measuring the effect of responsive movement and survey speed

We pooled data for all initial Primary sightings of common dolphins in sea state ≤3 (to make sure that higher sea states were not affecting the data) for both fast and slow speed modes (transects/straight lines) for the different survey years. The perpendicular distance plots (Fig. 3a) show substantial peaks in the first bin (less than 100m) and this is consistent with responsive movement towards the vessel. We assume that there is no difference in observer behaviour between fast and slow vessel speeds, however, the peak at small perpendicular distances is considerably more pronounced at slow speed than at fast speed suggesting an effect related to the behaviour of the animals.

We explored responsive movement further by examining the estimated swimming directions of dolphins relative to the vessel. Taking the vector component of the dolphin's velocity away from the vessel, the results for the Primary platform are shown in Figure 3b. There is a distinct large peak close to '-1', *i.e.* the majority of sightings are of dolphins approaching the vessel. When only sightings with a distance in the 25 percentile furthest from the boat (>400m) are included in this analysis, there remain significantly more animals with headings towards the vessel than away (χ^2, p=0.001) although this effect is no longer significant for primary sightings made during slow speed mode (χ^2, p=0.8). Results from the Tracker platform also show significantly more animals heading towards the vessel (χ^2, p=0.003). Although the effect is no longer significant for sightings made at distances greater than 1,000m (χ^2, p=0.2), there were nevertheless more than double (n=7) the number of sightings with animals heading towards the vessel than away (n=3). The observed distribution of headings will be affected by the sightability of the animal at different presentation angles (16). The peak we observed was with animals heading directly towards the vessel which would be expected to show a smaller visual target. Thus these observations cannot be explained by presentation angle effects.

Estimating a correction for both g(0) and responsive movement

Using *Distance 4*, we used Tracker platform data to estimate $f_s(0)$; Primary data to estimate *f(0);* and duplicates to estimate $f_{ps}(0)$. The error for the correction factor *c* was estimated by bootstrapping on sightings data from both platforms by transect and applying the estimation procedure to each of 199 bootstrap data sets (Table 2). The *CVs* of corrected density and abundance estimates and the Satterthwaite degrees of freedom (*df*) for the corrected density and abundance estimate confidence intervals were calculated (Table 2).

Parameter	Value/Estimate
Double platform effort, DP (km)	514
Truncation distance, w (km)	0.6
Number of secondary detections, n_s	12
Number of primary detections, n_p	88
Number of primary detections after truncation at 0.600km	86
Number of duplicate detections, n_{ps}	10
ESW of secondary platform, $1/f_s(0)$	1/3.16 = 0.316
ESW for duplicates (km), $1/f_{ps}(0)$	1/3.53 = 0.283
Apparent ESW for primary platform (km), 1/f(0)	1/5.15 = 0.194
Apparent density estimate, D_p (groups/km^2)	0.431
Corrected density estimate, D_c (groups/km^2)	0.291
Primary detection probability 'near' trackline, $g_p(0)$	0.931
Correction factor, c	0.675
Standard error of c, s.e. (c)	0.113
Provisional density (ind/km^2) for Stratum E in 2004+2005	1.097
Corrected density (ind/km^2) for 2004+2005 survey (Stratum E)	0.74 (CV=39%) 95% CI [0.34-1.59]

Table 2: Summary of variables required for the calculation of a correction for movement and for animals missed on the trackline using the Double Platform Effort data, where *ESW* =Effective half Strip Width and *CV*=coefficient of variation. The corrected density estimate for Stratum E is calculated using the correction factor (*c*).

Distribution

Common dolphins were widely distributed throughout the study area in both winters. It is worth noting that the relative index for abundance (number of schools per 100km effort, mean school size 5.1) of common dolphins sighted (following pre-designed and not pre-designed transect/lines) was much lower in the French part of the Channel (south of the study area, 1.23 schools per 100km) when compared to the study area (14.23 schools per 100km). Areas of few or no sightings included waters to the east of the study area although survey effort was low. Waters to the west of the study area were not systematically surveyed due to unfavourable weather conditions.

Discussion

The obtained estimated corrected density was 0.74 individuals/km^2 (95% CI 0.34-1.59; Table 2) and the corrected abundance estimate for stratum E was 3,055 animals (95% CI=1,425-6,544). There are no other abundance estimates that are directly comparable with these winter estimates for the study area. Other estimates are from ship surveys that took place some years ago and were conducted during the summer months (7, 4, 9) and during autumn (5). The relative index for abundance, number of schools per 100km effort (mean school size 5.1), can be compared and was much higher during this winter survey (10.9) than the SCANS 1994 summer survey in the Celtic Sea (Block A: 0.94) (9) and to the NASS 1995 summer survey in the Faeroes and western British Isles (Block E: 1.02) and in the offshore Atlantic (Block W: 7.5) (4). The autumn relative index was also found to be much lower in the western Approaches of the English Channel (2.9) (5).

The double platform survey indicated that Primary observers only missed 7% of the dolphins on the trackline, *g(0)* =0.93, but that a strong responsive movement towards the boat resulted in apparent densities 1.5 times greater than based on the double platform data. Sample sizes for animals first detected at radial distances of greater than 1000m were small (n=10). Although, the number of animals heading towards the vessel was not significantly different from the number heading away, it is possible that some animals were responding to the vessel at greater distances than they were detected. Thus the true correction factor could be much greater than 1.5. In addition, we observed that the *ESW* of the Tracker platform appeared to be rather narrow (316m). It is very likely that animals could approach the vessel from outside the Tracker's view and still be detected by the Primary observers. This means that the strip width for duplicates (ESW_{ps}) will be underestimated and is possibly the reason why the obtained ratio of c^{-1} (1.5) is small. By comparison, Cañadas et al. (4) estimated a correction factor of around six for a similar double platform survey using naked eye and 7x50 binoculars.

This study found that survey speed affected cetacean responsiveness to the survey vessel. In fact, it appeared that there were two effects when comparing the two survey speeds (fast *versus* slow). One is a 'movement' effect and the other is a 'sightability' effect. The perpendicular distance data show a more pronounced effect at slow speed which contrasts with a more pronounced effect at fast speed indicated by the heading data. The heading data for the fast speed mode indicated that there was still significant evidence of responsive movement even for the further 25 percentile of naked eye radial detection distances. For the slow speed data, however, the further 25 percentile of radial distances show no significant responsive movement. We conclude that this is probably due to an availability/detectability effect (*e.g.* surfacing behaviour changes the observer's ability to sight an animal). Indeed, it could well be that dolphins that are approaching a fast moving vessel are more likely to surface in the 'middle class' of distances (around 200-300m).

Conclusion

The winter diversity of the cetacean community in the Western Approaches of the English Channel, with a total of 7 different species seen during both surveys, highlights that the area is an important winter cetacean habitat. The dual platform data suggest that estimates for the winter population of the short-beaked common dolphins in the survey area from the same vessel may have been positively biased by at least a factor of 1.5 as a result of responsive movement. Uncertainties in the level of bias due to responsive movement are a problem for all current estimates of common dolphin abundance. Nevertheless, the observed relative index for abundance is among the highest recorded for common dolphins in the NE Atlantic indicating the importance of the western Channel as a winter habitat for this species.

A bycatch level for small cetaceans of more than 1.7% of the best available estimate of abundance has been deemed in the relevant international forum to be unacceptable (1). Based on our corrected estimate for Stratum E (the area overlapping with the current main fishing grounds) this would equal some 52 (24-111) animals. During the 2003/2004 fishing season, a bycatch of 169 common dolphins was recorded in the area in the UK bass fishery alone, producing an extrapolated total estimated mortality for the UK fishery of 439 animals (19).

Little is known about the overall winter distribution of common dolphins in the NE Atlantic or their seasonal movements. The dolphin abundance estimate for the relatively small survey area in this study is small compared to overall abundance estimates for the NE Atlantic (10). Nevertheless, the high levels of bycatch reported in the Channel area raise both conservation and animal welfare concerns. If this area is only used by a subset of the total Northeast Atlantic population of common dolphins, or if the Northeast Atlantic hosts several different common dolphin populations, there is a risk of depletion within the Channel area. If local depletion were to occur, it is not clear whether common dolphins from further away would then start to exploit and re-populate the Channel area. There is some evidence of population structure within the common dolphins of the NE Atlantic (11, 15).

A more comprehensive and wide-ranging assessment of bycatch, including statistically robust observer programs in both pelagic trawl and also gillnet fisheries is urgently needed. The data from this survey show that the winter population of common dolphins in the English Channel could well become depleted as a result of bycatch.

Acknowledgements

We are grateful to all contributors and advisers. Analytical advice was kindly provided by Cara Miller. The survey was funded by GET and WDCS. We would like to thank everyone – including volunteers, WDCS staff, Captain and crew – who helped to make this survey possible. Our thanks also to Sarah Duthie for her support. Analysis by Russell Leaper was funded by the International Fund for Animal Welfare.

References

1. ASCOBANS. *Resolution on incidental take of small cetaceans*. Annex 9c of Proceedings of the Third Meeting of the Parties to ASCOBANS. Bristol, UK: 2000, p. 93-96.
2. Buckland ST, Turnock BJ. A robust line transect method. *Biometrics* 48:901-909. 1992.
3. Buckland ST, Anderson DR, Burnham KP, Laake JL, Borchers DL, Thomas L. *Introduction to Distance sampling: estimating abundance of biological populations*. New York: Oxford University Press Inc, 2001.
4. Cañadas A, Desportes G, Borchers D. 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. *Journal of Cetacean Research and Management* 6:191-198. 2004.
5. De Boer MN, Simmonds MP. *Small cetaceans along the coasts of Wales and Southwest England*. Chippenham, UK: WDCS, 2003, p. 32-33.
6. DEFRA. *UK Small cetacean bycatch response strategy*. London, UK: DEFRA, 2003, p. 13-14.
7. Goujon M, Antoine L, Collet A, Fifas S. *Approche de l'impact écologique de la pêcherie thonière au filet maillant dérivant en Atlantique nord-est*. Plouzané, France: Department of Living Resources, IFREMER-RI.DRV-93.034. 1993, 47pp.
8. Hammond P, Berggren P, Benke H, Borchers DL, Collet A, Heide-Joergensen MP, Heimlich S, Hiby AR, Leopold MF, Øien N. Abundance of harbour porpoise (*Phocoena phocoena*) and other cetaceans in the North Sea and adjacent waters. *Journal of Applied Ecology* 39:361-376. 2002.
9. Hammond P, Benke H, Berggren P, Borchers DL, Buckland ST, Collet A, Heide-Joergensen MP, Heimlich-Boran S, Hiby AR, Leopold MF, Øien N. *Distribution and Abundance of the harbour porpoise (Phocoena phocoena) and other small cetaceans in the North Sea and Adjacent Waters*. Final report to the European Commission under contract LIFE 92-2/UK/027. St Andrews UK: SMRU, 1995, p. 118-139.
10. ICES. Report of the Working Group on Marine Mammal Ecology (WGMME), ICES Advisory Committee on Ecosystems, 2006, p. 5.
11. Lahaye V, Bustamante P, Spitz J, Dabin W, Das K, Pierce GJ, Caurant F. Long-term dietary segregation of common dolphins *(Delphinus delphis)* in the Bay of Biscay, determined using cadmium as an ecological tracer. *Marine Ecology Progress Series* 305:275-285. 2005.
12. Leaper R, Gordon J. Application of photogrammetric methods for locating and tracking cetacean movements at sea. *Journal of Cetacean Research and Management* 3(2):131-141. 2001.
13. Macleod K, Walker D. *Highlighting potential common dolphin (Delphinus delphis)-fisheries interactions through seasonal relative abundance data in the western Channel and Bay of Biscay*. Abstract submitted to the European Cetacean Society, 18th Annual Conference, Sweden. 2004.
14. Morizur Y, Berrow SD, Tregenza NJC, Couperus AS, Pouvreau S. Incidental catches of marine-mammals in pelagic trawl fisheries of the northeast Atlantic. *Fishery Research* 41:297-307. 1999.
15. Murphy S, Herman JS, Pierce GJ, Rogan E, Kitchener AC. Taxonomic status and geographical cranial variation of common dolphins (*Delphinus*) in the eastern North Atlantic. *Marine Mammal Science* 22(3): 573-599. 2006.
16. Palka DL, Hammond PS. Accounting for responsive movement in line transect estimates of abundance. *Canadian Journal of Fisheries and Aquatic Sciences* 58:777-787. 2001.
17. Ross A, Isaac S. *The Net Effect?* A review of cetacean bycatch in pelagic trawls and other fisheries in the north-east Atlantic. Chippenham, UK: WDCS, 2004, p. 13-17.
18. Sabin RP, Jepson PD, Reid RJ, Chimonides PDJ, Deaville R, Patterson IAP, Spurrier CJ. *Trends in cetacean strandings around the UK coastline and marine mammal post-mortem investigations for the year 2002*. London: Natural History Museum, 2003, p. 26.
19. SMRU. *Dolphin bycatch mitigation work in the bass pair trawl fishery*. St Andrews, UK: SMRU, 2004, p. 16.
20. Tregenza NJC, Collet A. Common dolphin, *Delphinus delphis*, bycatch in pelagic trawl and other fisheries in the Northeast Atlantic. *Report of the International Whaling Commission* 48:453-459. 1998.
21. Turnock BJ, Buckland ST, Boucher GC. Population abundance of Dall's porpoise (*Phocoenoides dalli*) in the western north Pacific Ocean. *Report of the International Whaling Commission (Special issue)* 16:381-387. 1995.