Preliminary report on a survey to estimate abundance and distribution of blue whales in Chiloense Ecoregion, southern Chile in 2009

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INTRODUCTION

At its annual meeting in Santiago in 2008, the IWC SC recommended that the authors of SH/60/SH46 present a full report of their boat-based data at this year's meeting (IWC 2009, p. 35). In February and March 2009, a team led by researchers from Universidad Austral de Chile and Centro Ballena Azul conducted a systematic sightings survey for blue whales in the Chiloense Ecoregion, and a report of that survey is presented here.

METHODS

The Chiloense ecoregion, located in northern Patagonia, Chile, receives direct influence from the Pacific Ocean and the Cape Horn Current from the West and is characterised by a complex system of inner seas, archipelagos, channels and fjords. The survey was designed following the principles laid out in a paper by Thomas *et al*. (2007) for surveying in complex regions. The original intent was to survey: as far as the 200m depth contour; including approximately 1000nm (1852km) of trackline; and offering approximately 20 replicate transects. A single-stratum survey was planned. The automated survey design engine in Distance 6.0 (Beta 5, Thomas *et al*. 2006) was used to evaluate the performance of parallel line and equal-spaced zigzag samplers. The equal-spaced zigzag design was chosen, because it offered good coverage probability during 100 simulations while retaining high efficiency. The design axis was set to run in a roughly north-east to south-west direction, so that transect lines ran roughly perpendicular to the coast. This resulted in several short lines, while sampling across the presumed gradient in blue whale density (thereby minimising between-transect variability in animal density).

Field protocols followed standard line-transect survey methods (Buckland 2001) with some modifications specific to small-boat surveys (Dawson *et al*. 2008; Williams and Thomas 2007, 2009). Only one observer platform could be used, so all analyses assumed certain detection on the trackline. Three people served on the primary observer team: a port and starboard observer and a data recorder. In addition to observers, one person sat in the wheelhouse to operate the computer. The primary observer team searched ahead of the ship, that is, a sector from the trackline to 90° abeam the ship, while concentrating primarily on the trackline. Observers searched a sector spanning from 10° on one side of the trackline to 90° on the other. The data recorder recorded when a sighting was made, and assisted the observer with species identification or group size estimation. A GPS was connected to a computer running *Logger 2000* software (Logger 2000, International Fund for Animal Welfare). This collected positional information every 10s, which was used for calculating length of trackline covered, as well as ship's course and speed. The computer operator entered information on sighting conditions every 15min, or as conditions changed, and noted the position of each team member at the beginning of every hour. Observer rotation occurred every half-hour. Information collected on factors that could affect sighting conditions included sea-state, cloud cover and precipitation and a subjective sightability code.

Whenever a sighting was made of a marine mammal, it was assigned a sighting number and reported to the computer operator via two-way radio. An angle board mounted on the deck was used to measure radial angle to the school, and a visual estimate was made of the range to the first sighting. A graduated perpendicular sighting gauge was available, but only used for a few sightings. In those cases when a visual estimate had to be made, radial distance estimates were corrected subsequently using observer-specific distance estimation experiments (Williams *et al*. 2007). Distance estimation experiments were conducted for each observer using rangefinders and radar to measure distance to objects within a range of 50m to 3nm. Linear regression models were fitted to the distance estimation experimental data with standard error proportional to true distance. Bias in visual estimates was addressed by dividing estimated distances by the slope of the regression through the origin.

RESULTS

Realised survey effort

The western boundary of the planned design proved to be impractical when faced with poor weather conditions. As a result, a decision was made in the field to relocate the western survey boundary to a line 12nm offshore, which would complement the region surveyed during the 1997/98 SOWER blue whale cruise (Findlay *et al*. 1998). The realised survey effort is shown in Figure 1. Realised trackline effort totalled 755.50 nm, 20 transects, and 33 on-effort sightings of blue whale schools were recorded with a total of 47 individuals. Off-effort blue whale sightings during transit and poor weather conditions totalled 16 schools and 35 individuals. The latter sightings were not included in this preliminary, conventional distance sampling analysis.

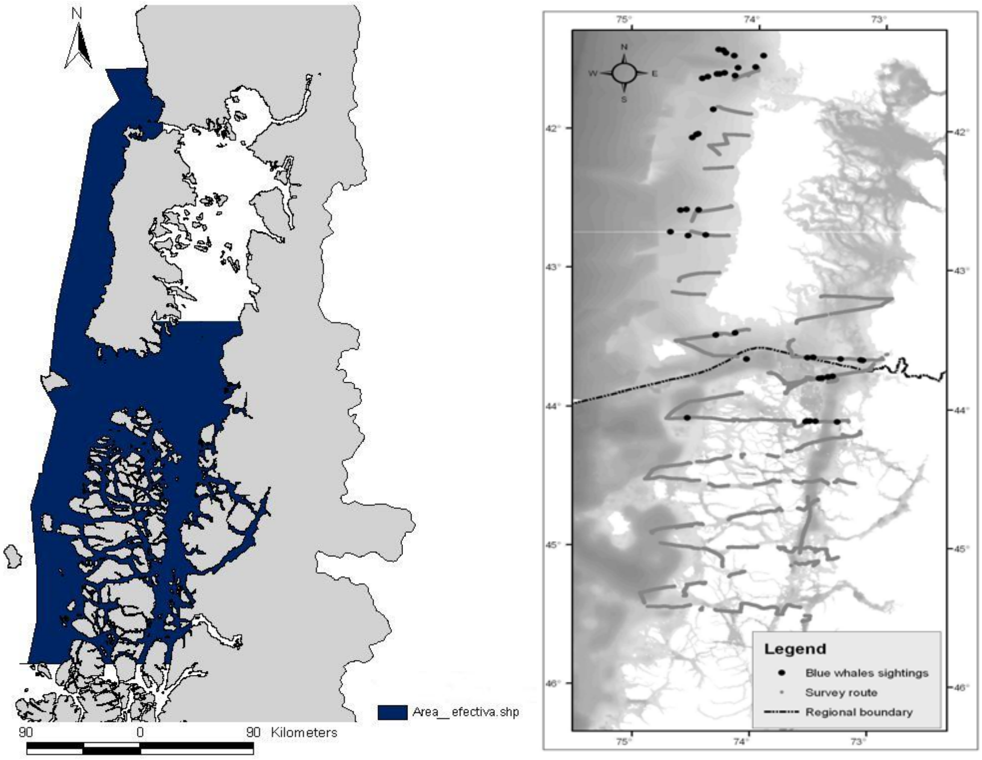

Figure 1. The planned survey region (left), and a rough illustration of realised effort (right). Each sighting of a blue whale or school is shown as a single black dot (right). Note that the sightings are all on-effort sightings, *i.e.*, associated with a trackline, but the GPS/Logger system failed frequently, especially in the northwest.

Transect	**Planned**	**Modified**	**Realised**	**N. Sightings**	**N. Individuals**
1	23.28	15.47	7.16	5	7
2	57.84	19.35	10.36	8	12
3	45.54	15.84	12.95	0	0
4	49.57	15.30	14.97	3	3
5	42.14	13.60	10.21	0	0
6	33.61	15.67	15.67	0	0
7	38.54	16.67	13.99	3	4
8	86.95	70.38	15.05	0	0
9	83.1	68.40	37.49	0	0
10	120.34	95.62	59.24	0	0
11	120.19	86.83	69.57	5	8
12	114.5	94.65	61.5	5	8
13	107.48	88.62	64.8	4	5
14	97.21	77.57	62.48	0	0
15	99.68	82.25	69.18	0	0
16	95.2	77.91	46.04	0	0
17	82.05	63.64	44.35	0	0
18	78.76	63.10	42.07	0	0
19	66.35	47.50	33.04	0	0
20	5.27	5.27	3.06	0	0

Table 1. Effort and sightings summary. Trackline length is in nautical miles. ‘Planned’ length refers to the original survey design, out to the 200m depth contour; ‘Modified’ refers to new length based on the decision in the field to stop at 12nm offshore due to poor weather; and ‘Realised’ means the on-effort line length actually surveyed. The number of on-effort sightings of blue whale schools and individuals is also shown.

Analysis

Two detection function models (hazard rate, HR; half-normal, HN) were fitted to the corrected perpendicular sightings data. A truncation distance of 4000m was used. The HR model was preferred over the HN, despite marginally higher AIC, because it provided a better visual fit to the data and fit well with the biological expectation that the detection function should have a wide shoulder. However, sample size was small, so there was little power to discriminate quantitatively which detection function was actually better. Both estimates are presented for completeness, but HR is the more biologically plausible of the two. Future work could involve model averaging on the detection function (Williams and Thomas 2009), but we avoided doing so in this case because there were strong biological reasons to prefer the hazard rate over the half-normal model.

Model 1: Hazard Rate key, k(y) = 1 - Exp(-(y/A(1))**-A(2))

Parameter	Point Estimate	Standard Error	Percent Coef. of Variation	95 Percent Confidence Interval	
A(1)	2123.	441.1			
A(2)	4.171	2.349			
f(0)	0.40242E-03	0.57396E-04	14.26	0.30091E-03	0.53817E-03
p	0.62124	0.88605E-01	14.26	0.46453	0.83082
ESW	2485.0	354.42	14.26	1858.1	3323.3

Table 2. Summary statistics for the HR detection function.

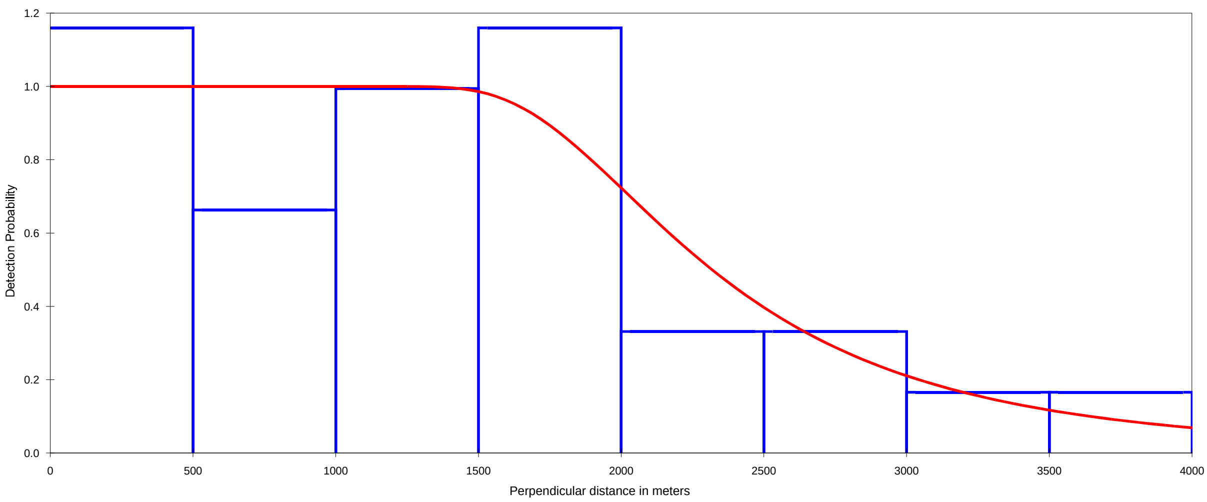

Figure 2. The selected detection function.

Model 2: Half-normal key, k(y) = Exp(-y**2/(2*A(1)**2))

		Estimate	%CV	df	95% Confidence Interval
Hazard/Cosine					
	DS	0.16199E-01	67.78	19.68	0.44861E-02, 0.58492E-01
	D	0.22760E-01	68.17	20.13	0.62770E-02, 0.82528E-01
	N	232.00	68.17	20.13	64, 840

Table 3. Overall density and abundance estimates from the HR model.

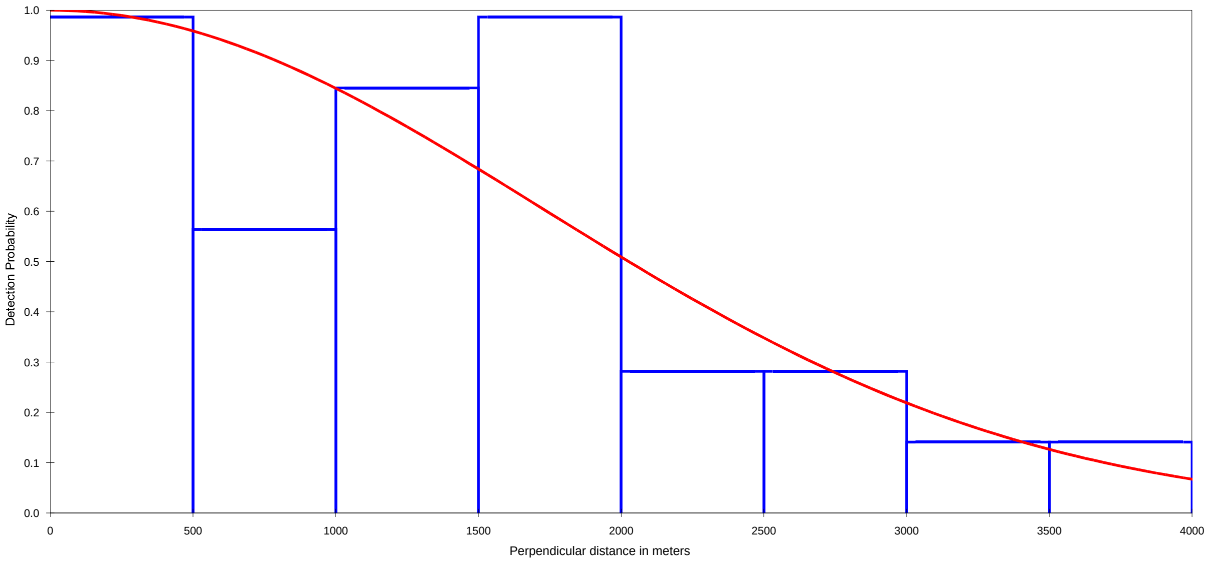

Figure 3. The half-normal detection function.

Model	Delta AIC	ESW	D	D CV	N	N CV
HN	0	2113.675	2.66E-02	0.69	270	0.69
HR	0.9642029	2484.969	2.28E-02	0.68	232	0.68

Table 4. Blue whale detection function analysis summary. (HN=half-normal; HR=hazard rate; ESW=effective strip half-width (m); D=density (individuals/nm^2); D CV=coefficient of variation on the density estimate; N=number of individuals in the study area; N CV= coefficient of variation on the abundance estimate).

DISCUSSION

These are obviously preliminary results, based on a small sample size, but they do represent useful new information from a systematic survey from an important region for Chilean blue whales. The survey also complements previous information on blue whale distribution in the ecoregion. Our abundance estimates will change in future, as our next steps will involve incorporating the off-transect blue whale sightings into fitting the detection function (but not in abundance estimation) as well as conducting density surface modelling.

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