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Estimates of target strength of southern blue whiting (*Micromesistius australis*) from the Campbell rise and Pukaki Rise, September 2000

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7. Executive Summary

Southern blue whiting target strength data collected from the Campbell Island Rise and the Pukaki Rise during the 2000 acoustic survey are analysed and presented in this report. Data were collected on 5 separate occasions from a mixture of adult and immature fish. Five new target strength estimates were obtained, 2 from immature fish (25–30 cm) and 3 from adults (~ 40 cm). The results suggest that the target strength for southern blue whiting is higher than that currently used in biomass estimation and also that the slope of the target strength–length relationship may be steeper.

New swimbladder modelling results, obtained using improved scanning technology and updated modelling software, were found to be more consistent with the *in situ* target strengths than previous swimbladder modelling work on southern blue whiting (McClatchie *et al.* 1998). Both the *in situ* and the recent modelling results indicate that the target strength-length relationship currently used in biomass estimation may need to be modified. It is therefore strongly recommended that further work be done to allow a new relationship to be determined.

8. Objectives

This report addresses objective 3 from Ministry of Fisheries project SBW1999/01: **"To refine estimates of acoustic target strength from *in situ* measurements"**.

9. Methods

9.1 Introduction

The data analysed in this report were collected from *Tangaroa* during an acoustic survey of southern blue whiting (SBW) on the Campbell Rise and Pukaki Rise in September 2000. The data consists of *in situ* target strength data collected on specific acoustic marks. Further information can be found in Hanchet (2000b).

Recent studies of SBW target strength (Hanchet 2000a; Hanchet & Grimes 2000) have shown some variability in the target strength values, and in addition a discrepancy between the *in situ* results and those obtained from swimbladder modelling (McClatchie *et al.* 1998). The swimbladders analysed by McClatchie *et al.* (1998) were obtained during an acoustic survey in 1997 (Hanchet 1997). During this project the opportunity arose to scan several of the swimbladders from this collection. This allowed new swimbladder modelling to be carried out using the improved scanning techniques and software described in Macaulay *et al.* (2001). The tilt angle distribution of McClatchie *et al* (1998) was used to allow comparison with previous work.

9.2 Acoustic equipment description

Acoustic target strength data were collected using a towed split-beam 38 kHz transducer. All data were processed and stored using the NIWA *CREST* data acquisition system (Coombs 1994). The particular *CREST* system configuration was a four channel towed system, with underwater electronics, connected to a Simrad type ES38DD split beam transducer. The equipment and operational parameters used for the target strength data collection are given in Table 1.

CREST is computer based, using the concept of a 'software echo sounder'. It supports multi-channels, each channel consisting of at least a receiver and usually also a transmitter. The receiver has a broadband wide dynamic range pre-amplifier and serial analog-to-digital converters (ADCs), which feed a digital signal processor (DSP56002). The ADCs have a conversion rate of 100 kHz and the data from these are complex (quadrature) demodulated, filtered and decimated. The filter was a 100-tap linear-phase finite impulse response digital filter. For target strength work the bandwidth was 4.86 kHz and the decimated frequency 10 kHz. Following decimation a 40 log R time-varied gain was applied. The results were shifted to give 16-bit resolution in both the real and imaginary terms and the complex data were stored for later processing.

The transmitter is a switching type with a nominal power output of 2 kW rms. It will operate over a wide range of frequencies (12-200 kHz). For target strength work the transmitted pulse length was 0.32 ms (12 cycles at 38 kHz). Time between transmits was 1.2 seconds. The receiver and transmitter were mounted in a flat-nosed, torpedo-shaped, 3 m long 'heavy weight' towed body.

The digital data from the receiver are sent to a control computer where they are combined with position and transect information and stored. The data are transmitted via the tow cable to the control computer on the towing vessel. All four transducer quadrants (beams) are energised simultaneously from a single transmitter but on receive, the system operates as four semi-independent echosounders. Data are processed independently on the four channels but operation is tightly synchronised by the transmit key and by using a common clock for all the ADCs. For target strength recording, the beams are treated separately to reject multiple echoes and calculate the position of the echoes in the beam.

The acoustic systems were calibrated with the standard procedure using a 38.1 mm diameter tungsten carbide sphere as detailed in MacLennan and Simmonds (1992). The towed *CREST* system was calibrated at sea during a subsequent orange roughy acoustic survey. This yielded a calibration in agreement with previous at-sea calibrations carried out in 1998 and 1999.

9.3 Trawl data collection

Trawling was carried out using both bottom and mid-water trawls. Mid-water trawls used a new pelagic trawl (headline height ca. 40 m). Bottom trawls used the standard NIWA fine meshed orange roughy wing trawl (headline height ca. 45 m). All trawls were made with a 40mm mesh liner in the cod-end.

All catches were weighed; with more detailed biological information taken from SBW, ling, and miscellaneous other species using *Tangaroa's* computerised wet-lab system.

9.4 *In situ* target strength data collection and processing

To collect *in situ* data, marks that were expected to be southern SBW were located and the towed transducer deployed 40–150 m above the marks. The marks were trawled, before and/or after the target strength work, to identify the species and to obtain an estimate of the size distribution.

The recorded acoustic data preserve both amplitude and phase information and allow both target position and amplitude to be calculated. To estimate target strength it is first necessary to filter out all echoes that do not originate from a single fish. To achieve this the following echo characteristics were checked:

- width of the combined beam
- relative width of the four beams
- phase stability of the combined beam
- similarity of amplitude between beams
- angle of arrival of the echo

These characteristics are based on those listed by Soule *et al.* (1995) and Soule *et al.* (1997) and from discussions with Soule. They were used to filter data to reject all echoes formed by more than one fish. The values of these characteristics that were considered indicative of echoes from single fish were set by conducting an experiment involving two spheres at constant angles in the acoustic beam, but at a range of different distances (after Soule *et al.*, 1997). Echoes were considered to be from a single fish if the following conditions were met:

- The width of the echo was between 63% and 157% of the transmit pulse width at half the maximum echo amplitude (the 6dB amplitude points).
- The standard deviation of the electrical echo phase between the 6dB amplitude points was less than 0.2 radians on the combined echoes.
- The width of the four individual echoes at the 6dB amplitude points varied by less than 33% of the transmit pulse width.
- The echo peak was more than 0.75 m in range from other echoes.
- The mean and standard deviation of the difference between the echo amplitude on beam 1 and the same echo on beams 2, 3 and 4 was less than 3.0 and 1.5 dB respectively for all three comparisons.
- The estimated angle of arrival of the echo was within 3.55 degrees of the normal to the transducer face.

After filtering, the positions of the echoes remaining in the beam were calculated (Ehrenberg 1979) and the amplitudes corrected accordingly. In addition, the maximum amplitude in each echo was estimated by fitting a quadratic to the three samples that made up the peak of the echo and taking the maximum of this quadratic as the target strength value for the subsequent data analysis.

In addition to the filters discussed above, target strength data were selected only from within visually identified SBW marks on the echograms (Dunford 2000).

9.5 Calculation of target strength estimates

Target strength estimates of SBW were obtained by comparing the modes in the filtered *in situ* target strength data with those in fish length data obtained from trawls.

9.6 Swimbladder collection and processing

Swimbladders for target strength modelling were collected during the 1997 survey of the Bounty Platform and Pukaki Rise (Hanchet 1997). Some bladders have previously been analysed by McClatchie *et al.* (1998), using different scanning techniques and software to those presented here. During the course of this project the opportunity arose to scan a small number of these bladders using a hand-held laser 3D scanner (Polhemus 2000). This replaced the sectioning and digitising used previously which was both time-consuming and error-prone. In addition, an updated version of the modelling software was used. Details of the procedure can be found in Macaulay *et al.* (2001). The tilt angle distribution was chosen to allow comparison with McClatchie *et al.* (1998) and had a mean of 0° and standard deviation of 15°.

A total of eight swimbladders were scanned with the 3D laser scanner. Application of the Kirchhoff modelling method (Macaulay *et al.* 2001) to the scanned bladders yielded 8 new target strength estimates.

10. Results and discussion

10.1 Trawl

Details of the trawls associated with target strength transects are given in Table 2, and include trawl time and location. A summary of the species composition of these trawls and the percentage catch of SBW is given in Table 3. The length frequency distributions of SBW from research and observer trawls are shown in Figure 1 and Figure 2 respectively. The mid-water trawl for set 2 (trawl 11) had a low catch of whiting and has not been incorporated into the mean length for this set.

10.2 *In situ* target strength

Five sets of target strength recordings with associated trawls were obtained and these are summarised in Table 4. Each set contained a number of transects in the area where the trawl was carried out. In the following analysis each group of transects is considered as a single data set.

A visual comparison of the hull and towbody echograms was made to identify marks that were SBW. Distributions of target strengths from regions assessed as being SBW are shown in Figure 3 for all sets.

Data from set 5 had 3 distinct modes at –32, –40 and –47 dB. To illustrate the inter-transect variability, the paths and target strengths for individual transects in set 5 are shown in Figure 4 and Figure 5 respectively. Transect 4, on a mid-water layer outside the main SBW mark, had a pronounced mode at –47 dB. Note that the set 5 dataset excludes transect 4. Although no trawling was carried out on this background layer, it is assumed that this mode corresponds to non-SBW targets such as silverside, rattails and javelin fish. Furthermore, this target strength value is well outside the range of likely values for gadoids (McClatchie pers. comm.). The peak at –40 dB in set 5 was assumed to be due to 25–30 cm SBW because this mode was also present in set 4, which comprised only 2-year-old SBW. The peak at –32 dB was assumed to be due to adult fish. In sets 2 and 3 the main mode at –30 dB was similarly assumed to be adult fish. Set 1 contained insufficient target strength data and is excluded from further analysis.

The linear means for both adult and 2 year old fish are given in Table 5 along with the mean length for each set. The ranges for these linear means were chosen to include the 'adult' and '2 year old' modes in each set.

There is reasonably good agreement between the target strengths for 2 year old SBW and the deconvolution results of McClatchie *et al.* (1998) with the current results being about 1 dB higher than the deconvolution work (Figure 6). The adult whiting target strength estimates are 3–5 dB higher than previous modelling (McClatchie *et al.* 1998) and *in-situ* results (Macaulay 1999). However, they are comparable to those from the 1999 survey (Dunford 2000), which found target strengths of –32 dB to –30 dB for fish with lengths of about 37cm.

Before discussing possible reasons for the higher target strengths it is prudent to consider both the upper bound and variability of the target strength values, particularly in view of the relatively small number of points. Target strengths presented here are all within allowable limits, based on data for similar species

(McClatchie pers. comm.). Thus, all of the adult target strengths from the 2000 survey, and also those from the 1999 survey, are realistic in this sense.

It is possible that some of the values are artificially high due to the inclusion of multiple echoes, particularly those from sets 2 and 3, and also those from the 1999 survey. Preliminary investigations have been inconclusive and this problem should be looked at further. The use of a `drifting frame' echosounder rather than the conventional towed body may also be beneficial in this regard allowing closer and more undisturbed observation.

10.3 Swimbladder modelling

The results obtained from the swimbladder modelling are shown in Figure 6. Although somewhat provisional, being based on a relatively small number of bladder casts and also sensitive to the assumed tilt-angle distribution (McClatchie *et al.* 1996), these results are generally higher than those of McClatchie *et al.* (1998). This is most likely due to the improved scanning methods and software used. These new swimbladder estimates are also more consistent with both the *in situ* results and the relationship for northern blue whiting and suggest that further swimbladder modelling is highly desirable.

Although there are insufficient points to determine a relationship based solely on *in situ* data, the current data lend weight to the hypothesis that the target strength of SBW is higher than that currently used for biomass estimation. There is also evidence that the slope of the relationship may be different from that currently used. These conclusions are supported by the more recent modelling results. It is clear that there is still work to be done on both *in situ* target strength and swimbladder modelling of target strength.

11. Conclusions

Southern blue whiting target strength data collected from the Campbell Rise and the Pukaki Rise during September 2000 are analysed in this report. The results suggest that the target strength for SBW is higher than that currently used in biomass estimation and also that the slope of the relationship may be steeper.

Although the possibility that multiple echoes influenced some target strength estimates cannot be discounted, there is currently insufficient data to determine this conclusively. It is recommended that further *in situ* data be obtained to allow this to be investigated further and that the 'drifting frame' be used to allow both *in situ* system calibration and simultaneous video and acoustic observation of the fish.

Some preliminary swimbladder modelling was done using improved scanning techniques and software. These results were higher than the earlier modelling work of McClatchie *et al.* (1998) and are more consistent with the current *in situ* data and the Northern Hemisphere relationship (Figure 6), and also with the results from the 1999 survey. It is recommended that further swimbladder modelling be done to refine these initial estimates.

In summary, recent swimbladder modelling results are more consistent with the *in situ* target strength for southern blue whiting than earlier work. Both methods indicate that the target strength-length relationship currently used in biomass estimation may need to be modified. It is therefore highly advisable that further work be done in both areas to allow a new relationship to be obtained.

12. Publications

None

13. Data storage

Data collected from trawling is stored in the Ministry of Fisheries Trawl survey database. Acoustic data is stored in the Ministry of Fisheries Acoustics Database.

14. References

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Table 1. Configuration of the echosounder used to collect target strength data

System number	2
Transducer model	Simrad ES38DD
Transducer serial no.	28327
Nominal 3 dB beamwidth(°)	7.0
Effective beam angle (sr)	0.0079
Operating frequency (kHz)	38.156
Transmit interval (s)	1.2
Nominal pulse length (ms)	0.32
Filter bandwidth (kHz)	4.86
Initial sample rate (kHz)	100.0
Decimated sample rate (kHz)	10.0
TVG	$40 \log R + 2\alpha R$
Nominal absorption (dB/km)	8.0
SL+SRT (dB re 1V at 1m)	62.5
Calibration valid at (m)	250
$20\log_{10}G$	49.5

Table 2. Trawl station data for trawls associated with target strength recordings

Trawl	Start date	Start time (NZST)	Start latitude	Start longitude	Length (nmi)	Trawl Type
3	07 Sep 2000	12:21	49.441 S	172.191 E	1.7	BT
5	07 Sep 2000	21:34	49.444 S	172.178 E	3.3	MW
10	12 Sep 2000	17:59	53.202 S	170.817 E	1.7	BT
11	12 Sep 2000	22:40	53.217 S	170.837 E	3.2	MW
16	19 Sep 2000	16:25	52.984 S	170.392 E	1.5	BT
17	21 Sep 2000	15:28	52.244 S	170.369 E	1.7	BT
27	27 Sep 2000	17:07	49.471 S	172.109 E	3.1	BT

Table 3. Catch (in kg) from trawls with associated target strength recordings. The bottom row indicates the percentage of southern blue whiting in the trawl, by weight

							Trawl
	3	5	10	11	16	17	27
Species							
ANT			0.4			1.3	
API			0.1		0.5		
CAR	0.3						0.3
CAS	5.6	0.2	6.3		46.0	12.0	1.8
CFA			0.1		0.1		
DCO		0.1	0.1		0.2		
DSP					0.3		0.3
GSP			2.0				2.5
HAK		2.1					11.0
HCO			0.2				
HOK			2.5				
JAV			2.9		15.0		0.2
LAN				0.1			
LDO					0.3		
LIN		17.0	6.3		0.9		66.0
MAN			2.9				
MIQ					2.2		
ONG			2.0				
OPA					0.1		
OPI						4.4	
POS				65.0			
RCO	2.3						
SBW	230.0	22.0	260.0	12.0	180.0	430.0	460.0
SCD						3.8	1.7
SPD	4.8	2.8	3.2		1.1		14.0
SQU			1.2		1.0		
SSI	2.0	3.9	6.1		3.1	2.1	1.6
SSK			2.1				
TOP			3.5		1.0	1.6	
WWA						1.2	2.4
SBW %	94	45	86	16	72	94	82

Table 4. Summary of acoustic target strength data and associated trawls

Set	Date	Start Time (NZST)	Number of transects	Hours of data	Mean towbody depth (m)	Area	Associated Trawl
1	07 Sep 2000	18:04	3	2.4	260	Pukaki	3 & 5
2	12 Sep 2000	20:12	4	3.5	230	Campbell	10 & 11
3	19 Sep 2000	18:27	6	1.8	280	Campbell	16
4	21 Sep 2000	16:38	6	2.6	260	Campbell	17
5	27 Sep 2000	18:57	10	4.5	230	Pukaki	27

Table 5. Mean fork length and linear mean target strength. The ranges for both fork length and target strength means have been chosen to include the adult and 2 year old modes in the respective data sets. Adult mean lengths are the average of data from both research and observer trawls.

Set	2 year olds		Adults	
	Length (cm)	Target Strength (dB)	Length (cm)	Target strength (dB)
	$24 \leq \ell \leq 31$ cm	$-42 \leq \ell \leq -38$ dB	$32 \leq \ell$ cm	$-36 \leq \ell \leq -26$ dB
2			38.8	–29.9
3			39.4	–29.7
4	27.4	–39.9		
5	28.5	–39.9	41.4	–31.9

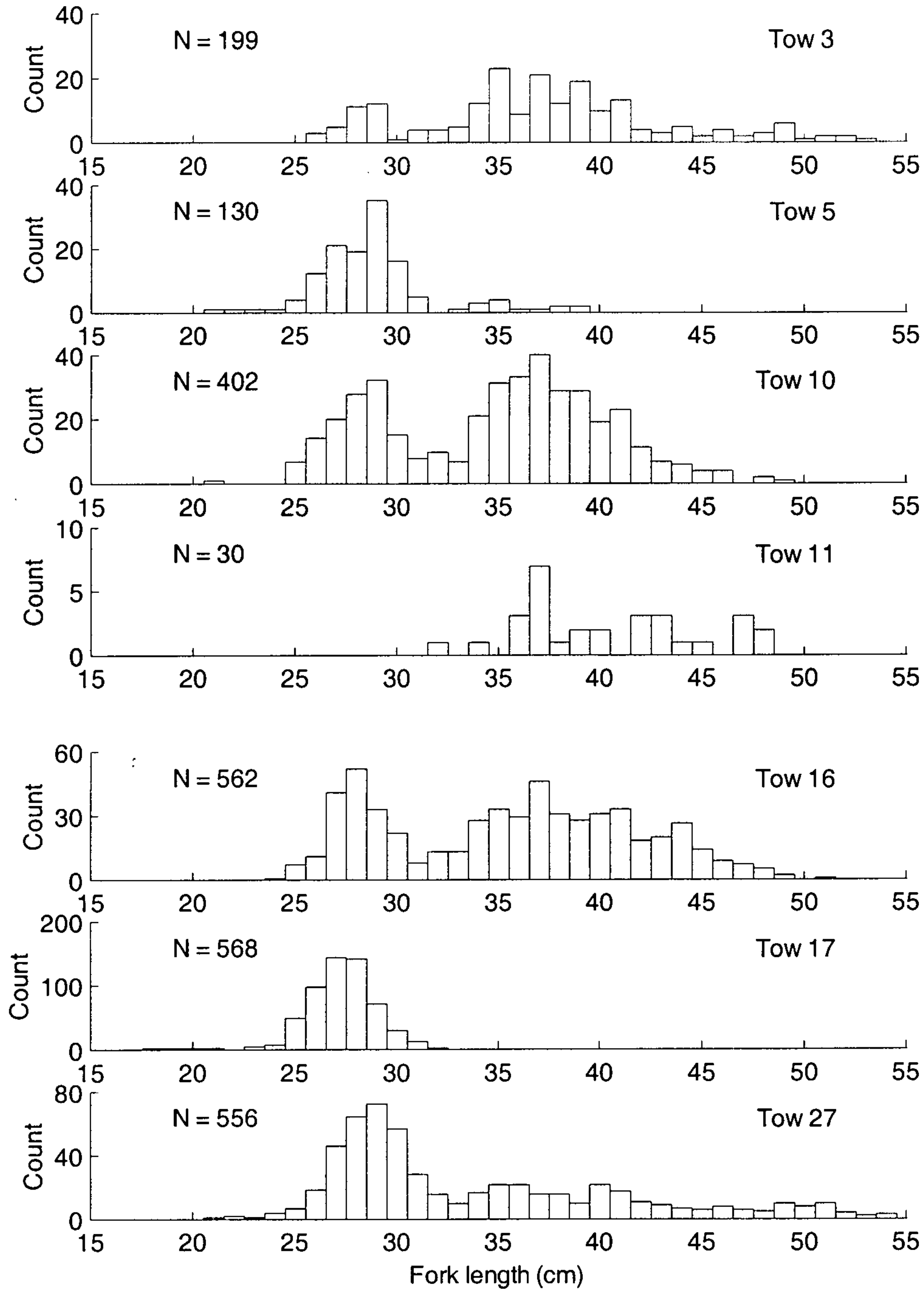

Figure 1. Southern blue whiting length distribution from all tows.

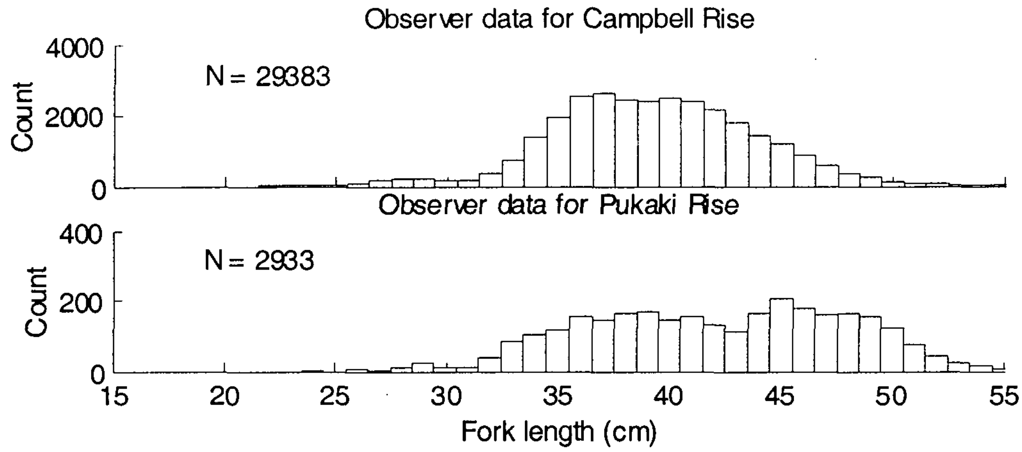

Figure 2. Observer length-frequency data for the Campbell Rise and the Pukaki Rise.

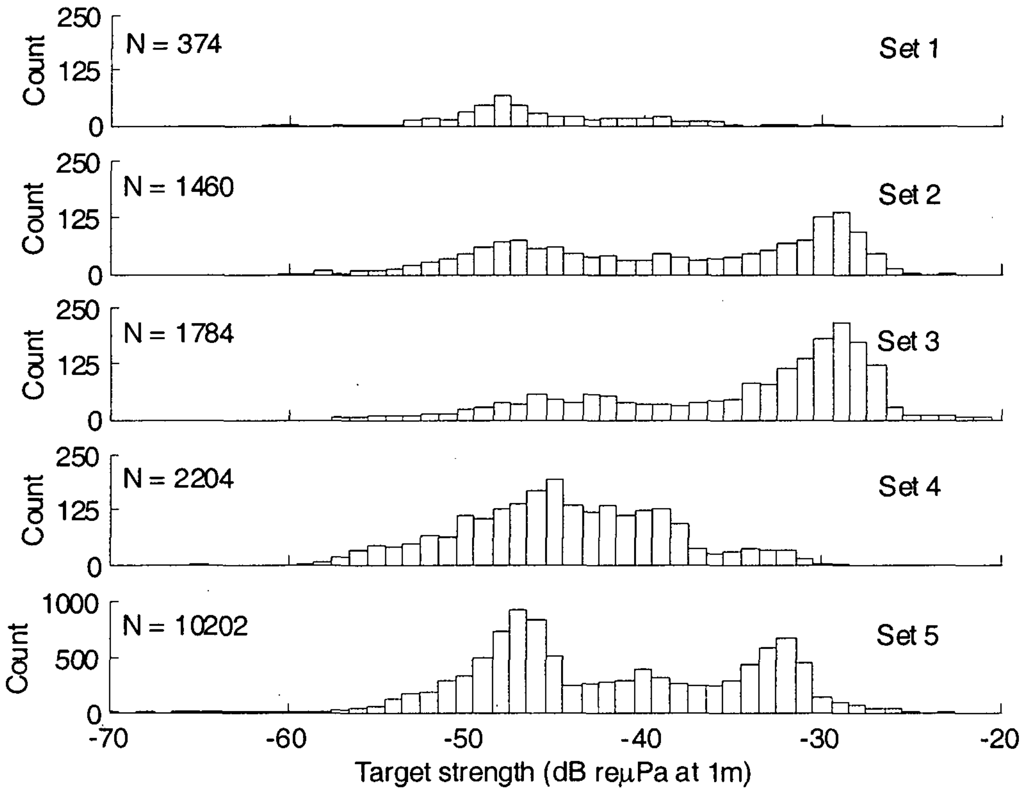

Figure 3. Target strengths for the five sets corresponding to tows shown in Figure 1.

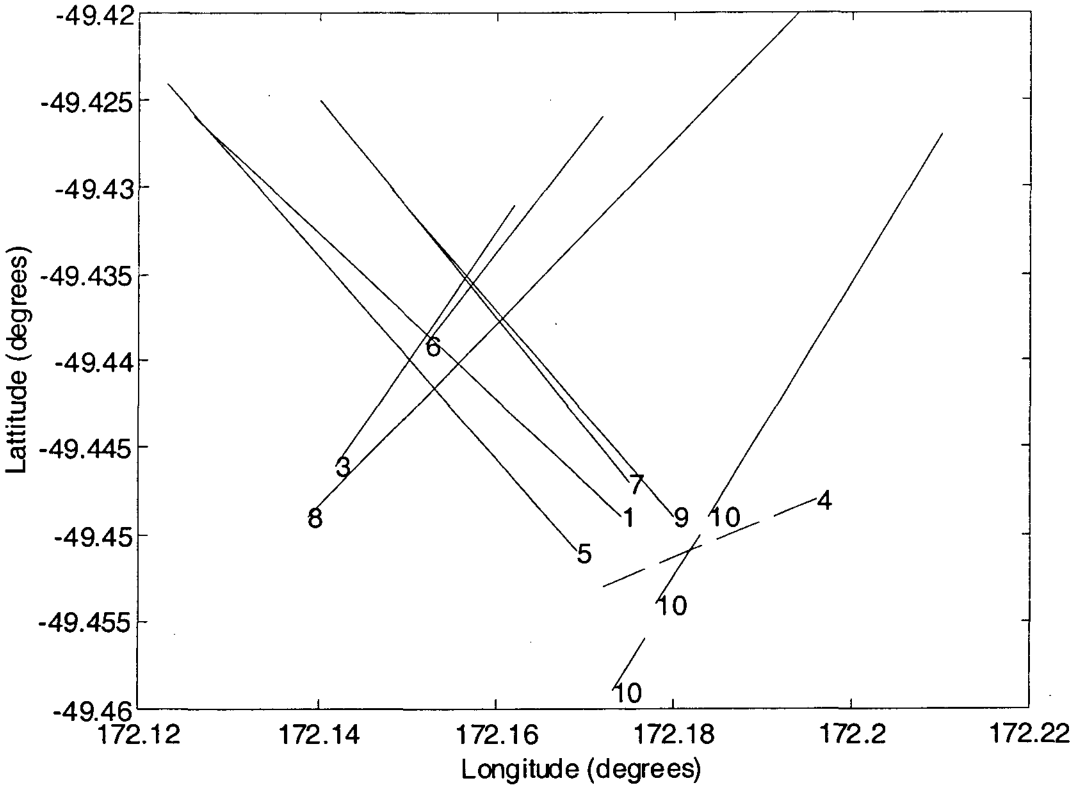

Figure 4. Paths for transects in set 5. Transect 4 (dashed) was in mid-water and has not been included in the target strength analysis.

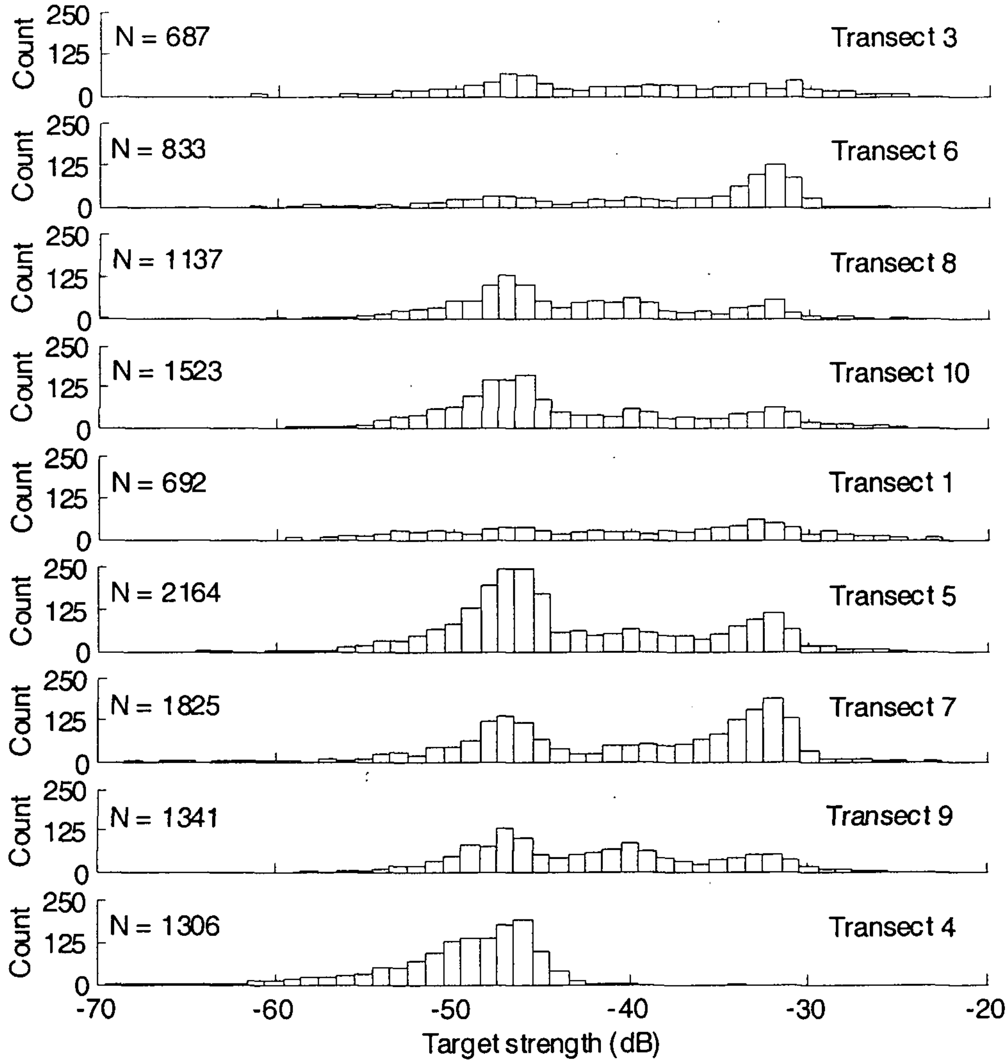

Figure 5. Target strength distributions for individual transects in set 5. Transect paths are shown in Figure 4. Transects 3, 6, 8 and 10 were along depth contours while transects 1, 5, 7 and 9 were across the depth contours. Transect 4 sampled a mid-water 'background' layer.

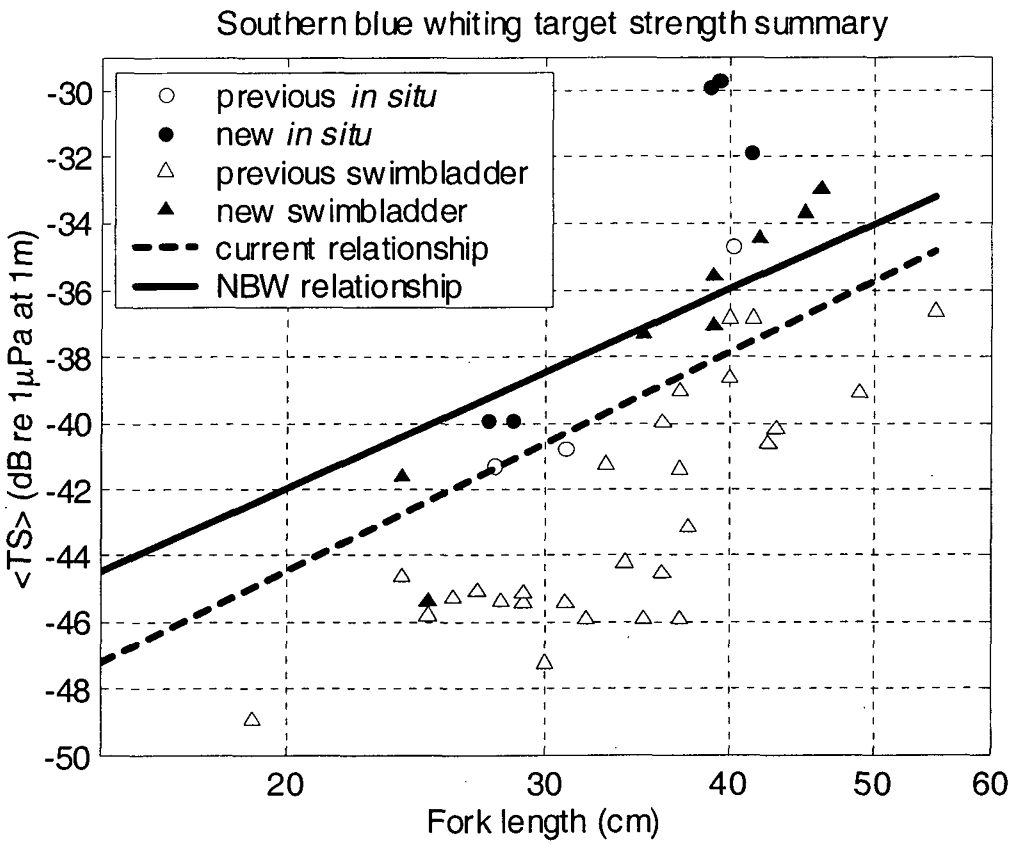

Figure 6. Target strength data from Table 5 and historical data (Macaulay 1999; McClatchie *et al.* 1998). Also shown are modelling results from 8 recently scanned bladder casts, using the tilt-angle distribution of McClatchie *et al.* (1998).