NIWA
Taihoro Nukurangi

Estimates of target strength of southern blue whiting from the Campbell Rise, August – September 2004

Adam Dunford

**Final Research Report for
Ministry of Fisheries Research Project SBW2003-02
Objective 2**

National Institute of Water and Atmospheric Research

July 2006

Final Research Report

Report Title:	Estimates of target strength of southern blue whiting from the Campbell Island Rise, August – September 2004
Authors:	Adam Dunford
1. Date:	20 July 2006
2. Contractor:	National Institute of Water and Atmospheric Research Limited
3. Project Title:	Biomass estimation of southern blue whiting using acoustic surveys
4. Project Code:	SBW2003-02
5. Project Leader:	Richard O'Driscoll

6. Duration of Project:

Start date:	13 February 2004
Completion date:	30 September 2005

7. Executive Summary:

In situ data from the 2004 southern blue whiting (SBW) survey were analysed to investigate the possibility that echoes from multiple targets were being incorrectly assumed to originate from a single fish. Inclusion of multiple echoes can upwardly bias *in situ* target strength (TS) which has implications for the TS-length relationship derived from those results. Analysis of the 2004 data suggests that multiple echoes could be influencing adult SBW *in situ* TS. Should future research confirm that this is the case it is nevertheless unlikely that the TS-length relationship currently used for stock assessment will be upheld as the most appropriate relationship for SBW.

8. Objectives: 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 Island Rise in August – September 2004. The data consist of *in situ* target strength (TS) data collected on specific acoustic marks. Further information can be found in O'Driscoll et. al. (2005). Recent studies of SBW TS (Hanchet 2000, Hanchet & Grimes 2000) have shown some variability in the TS values, and in addition a discrepancy between the *in situ* results and those obtained from swimbladder modelling (McClatchie et al. 1998). In particular, the measured *in situ* TS of adult SBW is significantly higher than the swimbladder modelling results for similar-sized fish (Dunford 2003).

One possible reason for this discrepancy is the inclusion of multiple echoes in the *in situ* data (MacLennan & Simmonds 1992). Although the TS analysis uses sophisticated filtering of the acoustic signal to reject echoes which come from multiple targets it is nevertheless worth investigating whether multiple echoes could be affecting the *in situ* results. The primary methods for this are filtering on density of targets (Gauthier & Rose 2001, Sawada et al. 1993) and selection of targets from clearly defined 'fish tracks' (Furusawa & Miyanohana 1988, McQuinn & Winger 2002). Both of these filtering techniques are applied to the 2004 SBW TS data to investigate the likelihood of the adult TS being contaminated by the inclusion of multiple echoes.

9.2 Acoustic equipment description

Acoustic TS data were collected using a towed split-beam 38 kHz transducer and NIWA's Computerised Research Echo Sounder Technology (CREST) (Coombs et al. 2003) system. CREST is computer based, using the concept of a 'software echo sounder'. It supports multi-channels, each channel consisting of a receiver and, in some systems, 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 acoustic system was calibrated during the survey in Perseverance Harbour at Campbell Island on 10 September. A deep calibration of Towbody 2 was also carried out prior to this survey in July 2004. Details of the acoustic system and its calibration are provided in Table 1.

One towed CREST system was used on all TS transects in this survey. This system consisted of a split-beam 38 kHz CREST echosounder connected to a towed Simrad split-beam transducer via ~2000 m of Rochester type 301301 tow cable. The towed body was a 3 m long flat-nosed, torpedo-shaped, 'heavy weight' design. Digital data from the receiver were sent to a control computer where they were combined with position and transect information and stored.

9.3 Trawl data collection

Trawling was carried out using both bottom and mid-water trawls. Mid-water trawls used the NIWA 119 hoki midwater trawl (headline height, 40 m; codend mesh, 40 mm). Bottom trawls used the orange roughy wing trawl (also called the 'ratcatcher';

headline height, 3.5 m; codend mesh, 32 mm). For each trawl the catch was sorted into species and weighed on motion-compensating scales accurate to about 0.3 kg. A random sample of up to 500 SBW and 50–200 of other important species from every tow was measured. In most trawls the gonad stage and sex of all SBW in the length sample were also recorded.

Trawling was only carried out between 12:00 and 24:00 NZST for operational reasons. Acoustic recordings were made of all trawls using the 12 kHz and 38 kHz hull-mounted *CREST* acoustic system.

9.3 *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 the data was first filtered to remove all echoes that did 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). 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 187% of the transmit pulse width at half the maximum echo amplitude (the 6dB amplitude points).
- The width of the four individual echoes at the 6dB amplitude points varied by less than 32% of the transmit pulse width.
- The standard deviation of the electrical echo phase between the 6dB amplitude points was less than 0.1 radians on the combined echoes.
- The standard deviation of the angle of arrival phase difference was less than 1 degree.
- The echo peak was more than 0.6 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 subsequent data analysis. Echoes from below the detected bottom were excluded.

Two additional filtering methods were used to exclude multiple echoes; the first entailed taking 'single target' echoes only from regions of low density and the second used 'fish tracking' of the echoes detected above to isolate single targets. The density filtering method (Gauthier & Rose 2001, Sawada et al. 1993) uses echo-integration of the TS data and an assumed TS to calculate the number of fish per sample volume. Prior to integration the TVG of each data file was changed from 40 Log R to 20 Log R and the calibration value adjusted appropriately. The echograms were integrated in cells of 50 pings × 5 m using a TS of –38.7 dB. The TS for converting volume backscatter to number of fish per sample volume was determined from the mean fish length from the trawls associated with the TS experiments and the TS to fish-length relationship of (Dunford & Macaulay 2006). If the number of fish per sample volume for the integration cell was less than some threshold, single target echoes from within that region are accepted.

The second method of selecting single targets groups echoes from successive pings into 'tracks' which are then taken to be replicate echoes from a single fish. Fish tracking can also give information of tilt or swimming angles (Furusawa & Miyanohana 1988, Macaulay 2004, McQuinn & Winger 2002). Echoes were considered to be part of a 'track' if echoes from adjacent pings were no more than 5 acoustic samples apart vertically and if the track was at least 10 pings long. The TS data used for tracking was processed in the usual way except that only two filters were used. Echoes were selected if they were between 63% and 156% of the transmit pulse width and if the estimated angle of arrival of the echo was within 3.55 degrees of the normal to the transducer face. The TS for each fish was then found by taking the linear mean of all the individual values along the track.

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 these trawls are shown in Figure 1. The mean fork length from all trawls was 36.1 cm.

10.2 *In situ* target strength

The combined TS distribution from all transects (Figure 2) has a well-defined mode at around –33 dB; the linear mean of all TS values > -40 dB is –30.6 dB. This is in line with other adult SBW TS reported by Dunford (2003). To investigate whether these values could be influenced by inclusion of multiple echoes, two techniques were used to restrict targets to those from single fish.

The first method selected targets from regions where the density of fish, as determined by echo-integration, was lower than 0.1 fish per acoustic sample volume. Figure 3 shows the TS distribution from all echoes which were selected from these low density regions. Although there are fewer targets than in Figure 2 it can be seen that the TS results are generally lower. The linear mean TS for all values > -40 dB is –34.3 dB. The second method used tracking to identify tracks from individual fish. The TS for each fish is taken to be the mean of all the TS values along the track. Figure 4 shows the histogram of the TS for each fish; the linear mean TS for all values > -40 dB is –33.1 dB.

Both methods give substantially fewer values than Figure 2 and lower mean TS than that obtained using filtering based only on the properties of the echo (Figure 5). Although not conclusive, this suggests that some of the values in Figure 2 may be multiple echoes. SBW forms dense monospecific schools and while this makes it an ideal candidate for echo-integration surveys it also presents challenges for measuring *in situ* TS.

If future research provides more evidence that multiple echoes are an issue for SBW then the implications for previously collected data will need to be considered. Although the density filtering method could be applied to existing data – the tracking method requires a drifting platform and so could not be used – the appropriate density thresholds to use for filtering would need to be investigated prior to any reanalysis. This is important as selection on target density has a circular aspect, in that TS is required to convert integrated backscatter to fish density. However if the 'true' TS is unknown, as here, then assuming a TS for echo-integration effectively means that the density threshold becomes a relative threshold.

Gauthier & Rose (2001) present a novel method for selecting a density threshold based on comparing the number of targets estimated by standard TS methods and the number obtained from echo-integration on the same region. The basis of the method is that these will be equal until multiple targets begin to be included in the TS results and the point at which they are no longer equal becomes the density threshold to use. Application of this method to the 2004 data unfortunately gave inconclusive results.

Future target strength experiments should aim to use a towbody which is stationary or slowly drifting above the fish to maximise the likelihood of obtaining multiple pings off the same fish. Poor weather during the 2004 survey meant that drifting was not possible and this made it difficult to obtain large numbers of tracks from individual fish. The acquisition of further fish tracking data would continue to improve the quality of the results from this technique.

This analysis of the likelihood of multiple echoes does not contradict the conclusion of Dunford (2003) that the TS-length relationship currently used for stock assessment is not appropriate for SBW. The values from all single-target filtering methods used here are higher than predicted by the current relationship (Figure 5). Should future work conclude that SBW adult *in situ* TS is biased by multiple echoes, it is unlikely that reanalysis of existing *in situ* data will give results which support the current relationship. In addition, swimbladder modelling results for SBW, which are independent of any *in situ* data, also suggest higher adult TS and do not support the current relationship (Dunford & Macaulay 2006).

11. Conclusions:

Analysis of the 2004 results suggest that multiple echoes could be influencing the *in situ* TS of adult SBW. Multiple echoes have the potential to upwardly bias *in situ* TS results and this has implications for previously collected data. Should future research confirm that this is the case it is nevertheless unlikely that the TS-length relationship currently used for stock assessment will be upheld as the most appropriate relationship for SBW.

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:

Coombs, R.F.; Macaulay, G.J.; Knol, W.; Porritt, G. (2003). Configurations and calibrations of 38 kHz fishery acoustic survey, 1994-2000. Fisheries Assessment Report. *No. 2003/49*. 24 p.

Dunford, A.J. (2003). Review and revision of southern blue whiting (*Micromesistius australis*) target strength, 1994-2002. Unpublished Final Research Report held by the New Zealand Ministry of Fisheries. 16 p.

Dunford, A.J.; Macaulay, G.J. (2006). Progress in southern blue whiting (*Micromesistius australis*) target strength: Swimbladder modelling results. *ICES Journal of Marine Science 6(5)*: 952-955.

Ehrenberg, J.E. (1979). A comparative analysis of *in situ* methods for directly measuring the acoustic target strength of individual fish. *IEEE Journal of Oceanic Engineering OE–4(4)*: 141-152.

Furusawa, M.; Miyanohana, Y. (1988). Application of echo–trace analysis to estimation of behaviour and target strength of fish. *Journal of the Acoustical Society of Japan 9(4)*: 169-180.

Gauthier, S.; Rose, G.A. (2001). Diagnostic tools for unbiased in situ target strength estimation. *Canadian Journal of Fisheries and Aquatic Sciences 58*: 2149-2155.

Hanchet, S.M. (2000). Southern blue whiting (*Micromesistius australis*) stock assesment for the Campbell Island Rise for 1999 and 2000. Fisheries Assessment Report. *No. 2000/15*. 36 p.

Hanchet, S.M.; Grimes, P.J. (2000). Acoustic biomass estimates of southern blue whiting (*Micromesistius australis*) from the Bounty Platform, August 1999. Fisheries Assessment Report. *No. 2000/30*. 25 p.

Macaulay, G.J. (2004). "Target strength estimates of hoki." Final Research Report to the Ministry of Fisheries

MacLennan, D.N.; Simmonds, E.J. (1992). Fisheries acoustics. Chapman and Hall, London. 325 p.

McClatchie, S.; Macaulay, G.J.; Hanchet, S.M.; Coombs, R.F. (1998). Target strength of southern blue whiting (*Micromesistius australis*) using swimbladder modelling, split beam and deconvolution. *ICES Journal of Marine Science 55*: 482–493.

McQuinn, I.H.; Winger, P.D. (2002). "Tilt angle and TS: target tracking of Atlantic Cod." Presented at Acoustics in fisheries and aquatic ecology, Montpellier, France, June 2002.

O'Driscoll, R.L.; Grimes, P.J.; Hanchet, S.M.; Dunford, A.J. (2005). Acoustic estimates of southern blue whiting from the Campbell Island Rise, August-September 2004. Fisheries Assessment Report. *No. 2005/41*. 35 p.

Sawada, K.; Furusawa, M.; Williamson, N.J. (1993). Conditions for the precise measurement of fish target strength *in situ*. *Journal of the Marine Acoustics Society of Japan 20*: 15-21.

Soule, M.; Barange, M.; Hampton, I. (1995). Evidence of bias in estimates of target strength obtained with a split–beam echosounder. *ICES Journal of Marine Science 52*: 139–144.

Soule, M.; Barange, M.; Solli, H.; Hampton, I. (1997). Performance of a new phase algorithm for discriminating single and overlapping echoes in a split–beam echosounder. *ICES Journal of Marine Science 54*: 934–938.

Table 1. Echosounder configuration settings and calibration values for the 38 kHz CREST system used to collect target strength data during the 2004 SBW survey. V_T is the in-circuit voltage at the transducer terminals for a target of unit backscattering cross-section at unit range. G is the voltage gain of the receiver at a range of 1 m.

NIWA system number	2
Transducer model	Simrad ES38DD
Transducer serial no.	28327
Nominal 3 dB beamwidth(°)	7.0
Effective beam angle (sr)	0.0083
Operating frequency (kHz)	38.156
Transmit interval (s)	1.2
Nominal pulse length (ms)	0.32
Filter bandwidth (kHz)	4.53
Initial sample rate (kHz)	60.0
Decimated sample rate (kHz)	10.0
TVG	$40 \log R + 2\alpha R$
Nominal absorption (dB/km)	8.0
V_T (V)	1365.7
G	164.85

Table 2: Trawl station details. Gear type codes: BT = bottom; MW = mid-water.

Tow	Gear type	Date	Start Time	Start position latitude E	longitude S	Max tow depth (m)	Tow length (n. mile)
9	BT	6-Sep-04	18:19	53 19.74	170 19.59	559	1.67
10	MW	6-Sep-04	20:47	53 17.42	170 27.76	520	0.88
11	MW	6-Sep-04	22:38	53 17.74	170 29.87	519	1.26
12	MW	7-Sep-04	13:28	53 22.06	170 17.22	588	0.79
13	MW	8-Sep-04	12:42	53 21.99	170 14.22	584	0.16

Table 3: Catch of the main species by trawl. Species codes: SBW = southern blue whiting; LIN = ling; SSI = silverside; HAK = hake. The last column gives the percentage of SBW in the trawl, by weight.

Tow	Catch (kg)							% SBW
	SBW	LIN	SSI	HAK	Rattails	Sharks	Total	
9	344.0	18.4	10.5	-	54.7	2.3	454.9	75.6
10	21.9	-	-	-	-	-	22.1	99.1
11*	4 656.9	4.5	-	24.7	-	-	4 686.1	99.4
12	959.3	-	-	-	-	-	963.5	99.6
13	773.1	-	-	5.3	0.6	50.0	829.1	99.2

* Net window burst.

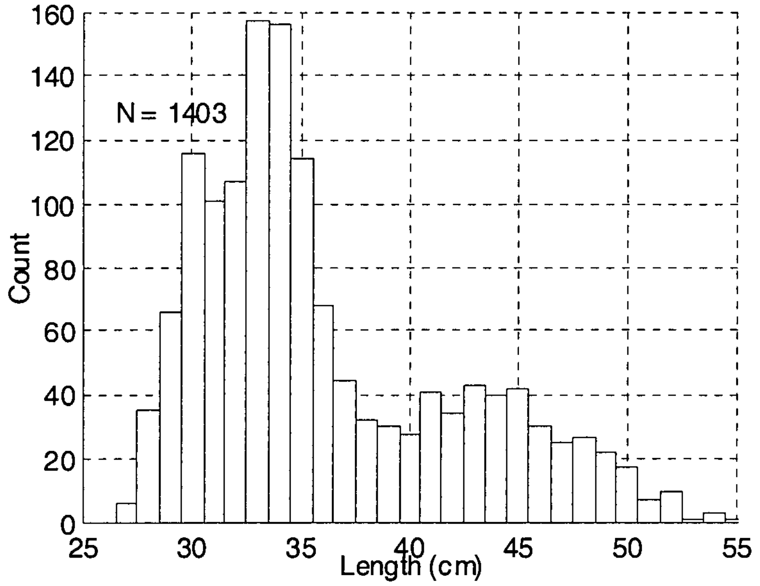

Figure 1. SBW fork length from all trawls associated with TS measurements.

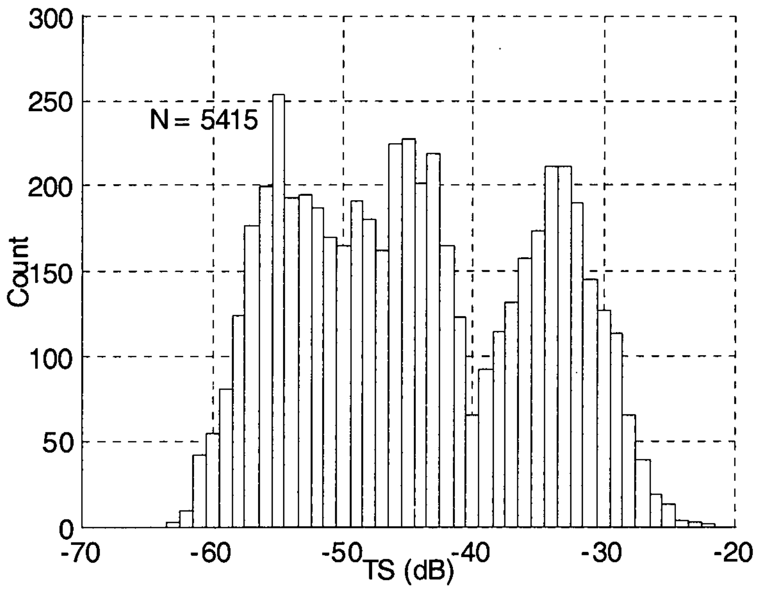

Figure 2. Combined TS distribution from all transects.

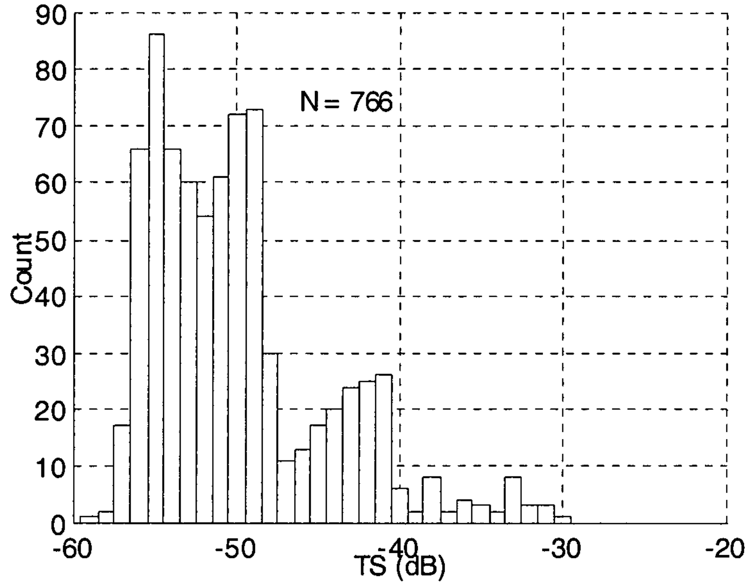

Figure 3. Combined TS distribution using standard single target filtering in conjunction with filtering based on target density, as determined by echo-integration. See text for details.

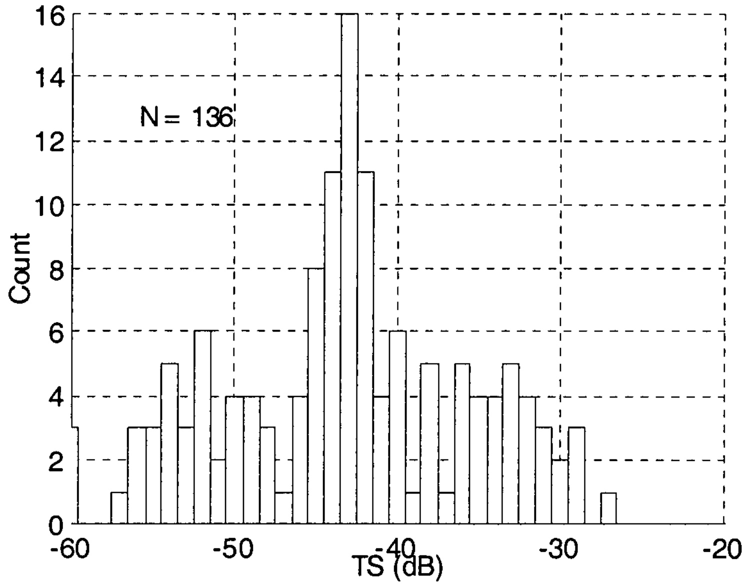

Figure 4. Combined TS distribution using only echo-width and angle of arrival single target filtering in conjunction with filtering based on fish tracking. See text for details.

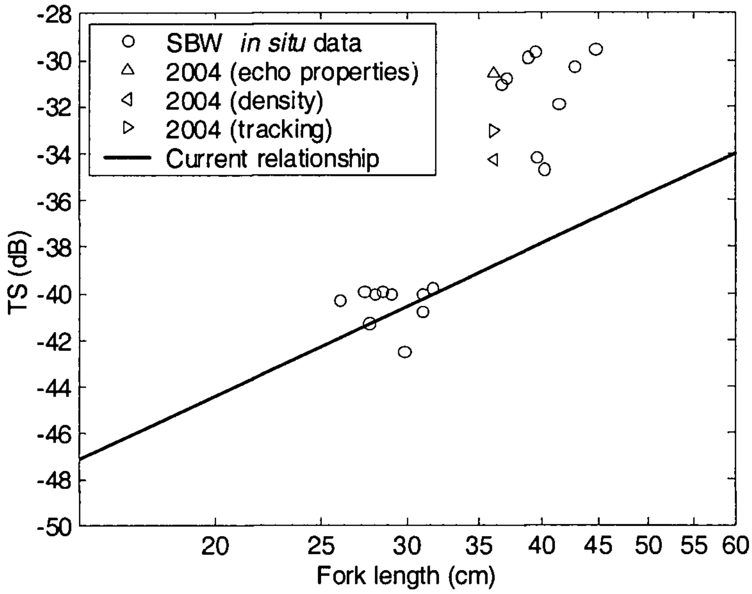

Figure 5. Existing SBW *in situ* data compared with 2004 *in situ* data. The various filtering methods used to determine whether an individual echo originates from a single fish are detailed in the text. The TS-length relationship currently used for SBW stock assessment is shown for comparison.