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Estimates of the target strength of hoki

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7. Executive Summary

Acoustic target strength data were collected during hoki surveys from the west coast of the South Island in July/August 2000, the Chatham Rise in January 1999, and Cook Strait in July/August 1999. A revised target strength to length relationship for hoki has been derived from the *in situ* data collected during these voyages. The relationship is:

$$TS = 18 \log_{10} FL - 74,$$

where TS has units of dB re 1 μPa at 1 m, and FL is the fish length in cm. This relationship gives broadly similar target strengths when compared with previous relationships for adult fish. However, for smaller fish the relationships fall into two groups, and highlights the current uncertainty in target strength of small hoki. Research currently underway in MFish project HOK2000/03 is seeking to address this uncertainty.

8. Objective

To refine estimates of target strength of hoki

9. Methods

9.1. Introduction

The data analysed in this report were collected from *Tangaroa* during a voyage off the west coast of the South Island in July/August 2000 (voyage TAN0007). Data collected in 1999 from voyages in January on the Chatham Rise (TAN9901) and July/August in Cook Strait (KAH9911), and originally reported upon in Cordue et al. (2000) are re-analysed and the results also presented. The data consist of acoustic *in situ* target strength recordings and trawls made on specific fish marks.

9.2. Acoustic equipment description

Acoustic target strength data were collected using a towed split-beam 38 kHz transducer. All of the data was 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.

The acoustic systems were calibrated using the standard procedure (MacLennan & Simmonds 1992) with a 38.1 mm diameter tungsten carbide sphere. For voyage TAN0007 the towed *CREST* systems were calibrated at sea during July 2000 (at depths ranging from 50 to over 800 m). The systems were also calibrated before (during June 2000) and after the voyage (during October and November 2000) in the deep tank at the NIWA Greta Point laboratories. For the 1999 voyages the *CREST* systems were calibrated in the deep tank in December 1998, June 1999, and September 1999. They were also calibrated at sea during October 1998, June 1999 and September 1999. All calibrations yielded consistent results. The data from the deep calibrations were modelled with polynomials (coefficients given in Table 1) and used to correct the calibration for the depth of the transducer on a ping-by-ping basis.

9.3. Trawl data collection

Trawling was carried out using bottom and midwater trawls. During TAN0007, the standard NIWA 8 seam hoki bottom trawl with a 60 m groundrope, 45 m headrope and a cod-end mesh size of 60 mm was used (net plans contained in Hurst et al., 1994). Rigging included 100 m long sweeps, 50 m bridles and 12 m backstrops. Midwater trawling was carried out using the NIWA 119 midwater trawl with 150 m bridles and a 60 mm cod-end. Both gear types used 6.1 m^2 Super V trawl doors. Details of the trawl gear used during TAN9901 and KAH9911 are given in Cordue et al. (2000).

All trawls were targeted on specific marks (or lack of marks) and were nominally 3 n. miles in length. All catches were weighed, and fish length measured using NIWA'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 hoki were located and the towed transducer deployed 30–70 m above the marks, for several hours. The marks were then trawled on to identify the species and to estimate the size composition.
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 examined:

- width of the combined beam
- relative width of the four beams
- proximity of other echoes
- 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 188% 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 62% of the transmit pulse width.
- The echo peak was more than 1.2 m in range from other echo peaks.
- 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 1.5 and 3.0 dB respectively for all three comparisons.
- The estimated angle of arrival of the echo was within 5.0 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.

Not all of the echoes that pass the above filters are from hoki; hence it is necessary to further filter the echoes to leave just those from hoki. The technique used in this report is a relatively recent development and uses the change in phase through each echo and the target strength of the echo to group them into those considered to be from hoki and those not from hoki. This technique is discussed in more detail in Barr (2000) and Barr (2001).

Different scatterers tend to form distinct groups on a plot of phase slope and target strength. For example, non-swimbladdered fish, such as orange roughy tend to form broad marks that cover a wide phase slope range, but within a small target strength range. Our observations to date suggest that fish such as hoki form tight clumps, and only cover a small phase slope range.

Each target strength experiment consisted of at least one trawl on a mark and one or more acoustic transects over the same mark. All experiments where the combined catch of hoki from all relevant trawls was less than 50% by weight were discarded. For the remaining experiments, a plot of phase slope versus target strength was produced from the acoustic data collected during that experiment. Groups of points on these phase plots that were considered likely to be from hoki were selected and the mean target strength (in the linear domain) of the echoes in these groups was calculated. Likewise, for all of the trawls in each experiment, the mean hoki length was calculated. This gave a number of target strength/fish length pairs, which were used to calculate a target strength to fish length relationship.

The trawls and acoustic files that constitute each experiment are given in Table 2.

10. Results

10.1. Trawl results

Details on the catch of hoki, proportion of total catch, and the length frequency sample size for each trawl are given in Table 3. Only trawls that were more than about half hoki by weight were used in the subsequent analysis, and are the only ones given in the table. Two trawls contained 49% hoki by weight, and were included. Also included was trawl 119 from TAN9901, where the percentage of hoki was 32%, but when combined with the other trawls in set 1 of TAN9901, gave a proportion over 50%.

10.2. *In situ* target strength results and discussion

The target strength/fish length pairs for data collected on all three voyages are given in Table 2. Examples of the phase slope/target strength plots are given in Figure 1, where the closed regions indicate the points considered to be from hoki. The broad band of echoes centred at approximately –50 dB are likely to be from small mesopelagic fish. The origin of the echoes that form the sloping group below –60 dB is unknown. The echoes with target strengths greater than approximately –35 dB are likely to be from large fish such as hake or ling.

The target strength results are graphed in Figure 2. Also included in the figure are *in situ* data collected before 1999 (summarised in Bradford, 1999), and some recent swimbladder modelling results (Cordue et al. 2000). Not included are some earlier swimbladder modelling results that are now considered to be suspect (Coombs & Cordue 1995, Do & Surti 1990, Grimes et al. 1997).

There is considerable variability in the target strength points, with a spread of target strength values of over 10 dB for similar fish lengths. However, this wide variability is due mainly to data from Bradford (1999), which is consistently lower than all of the other data. It is stated in Bradford (1999) that many of the points presented are considered to be dubious, and for this reason, these points have not been used when calculating the new target strength to fish length regression presented in this report.

A linear regression has been fitted to all of the data presented in Figure 2, except for those from Bradford (1999), and is $TS = 18\log_{10} FL - 74$, where TS has units of dB re 1 μPa at 1 m, and FL is the fish length in cm.

The modal analysis technique of Cordue et al. (2001) was also applied to the data from the three voyages. However, it gave inconsistent results, particularly between the 2000 and 1999 data. The main problem was the absence of clear hoki modes in the 2000 *in situ* data, and subsequent mis-matching of length modes to target strength modes. Further work on improving the mode-matching technique is planned as part of MFish project HOK2000/03. The phase slope technique gave better results mainly due to the clear separation of hoki echoes from other fish on the phase slope plots, and was used to re-analyse the 1999 data to give a larger set of data analysed using a consistent technique.

To place the latest target strength relationship into context, all earlier hoki target strength to length relationships are presented in Figure 3. These include the initial swimbladder modelling results from Coombs & Cordue (1995), the re-analysis of this data (Grimes et al. 1997), early *in situ* results (Bradford 1999), recent swimbladder modelling results (Cordue et al. 2000), and the modal fitting technique applied to *in situ* data collected in 1999 (Cordue et al. 2000). The relationship derived in this report is also included.

Within the typical length range of adult hoki (60–100 cm), all six relationships give broadly similar results. However, for smaller lengths, the relationships separate into two groups, one with low target strength, and one with higher target strengths. This highlights the on-going uncertainty in the target strength of small hoki. This is due to a number of factors and includes the difficulty in collecting *in situ* data from such fish, the variability in the size of swimbladder casts, the uncertainty over swimbladder inflation levels, and the small number of data points. Further work is required in this area. A large number of hoki swimbladders have been collected as part of MFish project HOK2000/03 and will be used to improve our knowledge of the target strength of small hoki (among other things). This work is due to be reported upon in May 2002.

11. Conclusions

Ten new *in situ* target strength points have been calculated, covering a hoki length range from 68 to 83 cm. Data from 1999 have been re-analysed to give a total of 17 new *in situ* points covering 42 to 83 cm. In combination with 10 existing swimbladder modelling estimates, a revised target strength to fish length regression has been estimated as:

$$TS = 18\log_{10} FL - 74,$$

where TS has units of dB re 1 μPa at 1 m, and FL is the fish length in cm.

Comparison with previous relationships indicates that the main area of uncertainty in hoki target strength is now with small hoki. Work is currently in progress in MFish project HOK2000/03 to resolve this uncertainty.

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 echosounders used to collect target strength data.

System number	1	1C	1Calt	1D	2	2A
Voyage	TAN9901	TAN0007	TAN0007	TAN0007	KAH9911	TAN0007
Transducer model	Simrad ES38DD	Simrad ES38DD	Simrad ES38DD	Simrad ES38DD	Simrad ES38DD	Simrad ES38DD
Transducer serial no.	28326	28326	28326	28326	28327	28327
Nominal 3dB beamwidth (°)	6.9	6.9	6.9	6.9	7.0	7.0
Effective beam angle (sr)	.0079	.0079	.0079	.0079	.0079	.0079
Operating frequency (kHz)	38.156	38.156	38.156	38.156	38.156	38.156
Transmit interval (s)	4.0	1.4	1.2	1.2	1.4	1.4
Nominal pulse length (ms)	0.32	0.32	0.32	0.32	0.32	0.32
Filter bandwidth (kHz)	4.86	4.86	4.86	4.86	4.86	4.86
Effective initial sample rate (kHz)	100.0	125.0	125.0	100.0	100.0	100.0
Decimated sample rate (kHz)	10.0	12.5	12.5	10.0	10.0	10.0
TVG	$40 \log R + 2\alpha R$	$40 \log R + 2\alpha R$	$40 \log R + 2\alpha R$	$40 \log R + 2\alpha R$	$40 \log R + 2\alpha R$	$40 \log R + 2\alpha R$
Absorption (dB/km)	8.0	8.0	8.0	8.0	8.0	8.0
SL+SRT (dB re 1 V at 1 m)	61.2	60.8	60.8	61.4	61.8	62.5
Depth at which calibration is valid at (m)	500	500	500	500	500	500
$20\log_{10}G$	49.7	55.9	49.9	49.5	49.5	49.5
SL+SRT correction (re. 500 m) c_0 coefficient (*)	-0.63325	0.3625	0.3625	-0.63325	0.9525	0.9525
c_1 coefficient (*)	$1.7 \cdot 10^{-3}$	$-7.25 \cdot 10^{-4}$	$-7.25 \cdot 10^{-4}$	$1.7 \cdot 10^{-3}$	$-2.485 \cdot 10^{-3}$	$-2.485 \cdot 10^{-3}$
c_2 coefficient (*)	$-8.67 \cdot 10^{-7}$	0	0	$-8.67 \cdot 10^{-7}$	$1.16 \cdot 10^{-6}$	$1.16 \cdot 10^{-6}$

* The correction to SL+SRT, in dB, for depth R (in metres from the surface), is given by $c_0 + c_1 R + c_2 R^2$.

Table 2: Target strength/fish length pairs, associated trawls, acoustic files and towbody used. Target strength has units of dB re 1 μPa at 1 m, and length is the fish length in cm.

Voyage	Set	Trawl(s)	Acoustic file(s)	Towbody	TS	Length
TAN0007	1	24	9–11	1D	−38.7	72
	2	25	12–14	1D	−39.6	68
	3	123	113–117	1C	−36.9	69
	4	124	119	1C	−40.6	69
	5	145	163–166	1C	−42.8	77
	6	147	167–172,174,175	2A	−41.7	78
	7	148	176–180	2A	−32.7	83
	8	150	196,197,199,200	2A	−41.8	75
	9	168	222,223	1C	−41.6	79
	10	171	228–231	1Calt	−41.0	80
TAN9901	1	117–119	11,13	1	−42.4	45
	2	120–122	17,22	1	−41.3	42
	3	130	26	1	−39.3	67
	4	141,142	38	1	−38.5	65
KAH9911	1	7,8	70–77	2	−42.0	62
	2	9–11	79–91	2	−40.8	57
	3	12,13	93–106	2	−42.8	65

Table 3: Details of hoki caught for each trawl used in the target strength analysis.

Voyage	Trawl	Hoki catch (kg)	Hoki catch/ total catch (%)	No. of hoki measured
TAN0007	24	200	54	146
	25	900	67	823
	123	300	53	267
	124	150	49	126
	145	1700	90	1131
	147	2200	100	1521
	148	1400	99	734
	150	460	81	344
	168	1500	85	900
	171	800	49	474
TAN9901	117	2378	80	617
	118	1321	78	612
	119	39	32	91
	120	4152	91	679
	121	2294	76	626
	122	426	82	516
	130	1157	70	629
	141	234	49	254
	142	375	64	372
KAH9911	7	1067	79	608
	8	283	80	160
	9	404	99	257
	10	539	99	393
	11	366	97	260
	12	519	85	666
	13	439	85	586

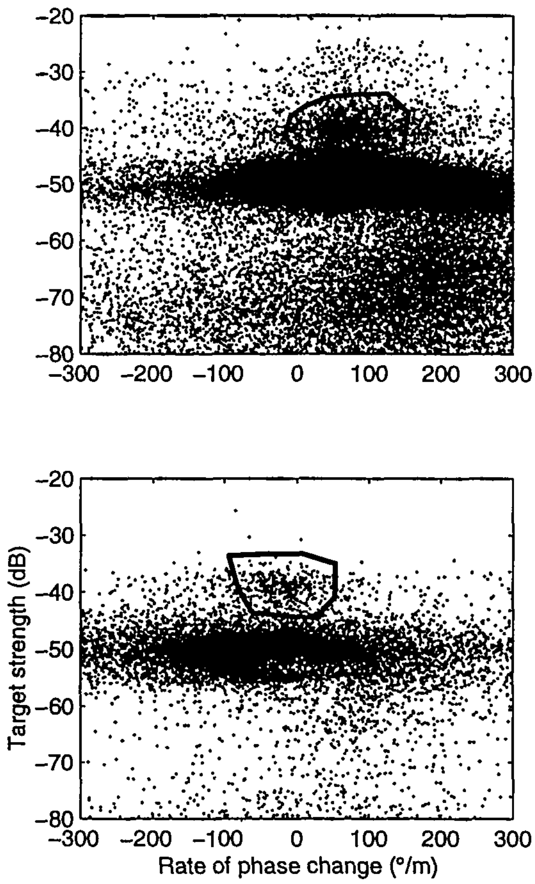

Figure 1: Example of typical phase slope/target strength plots. The closed regions indicate the points considered to be from hoki.

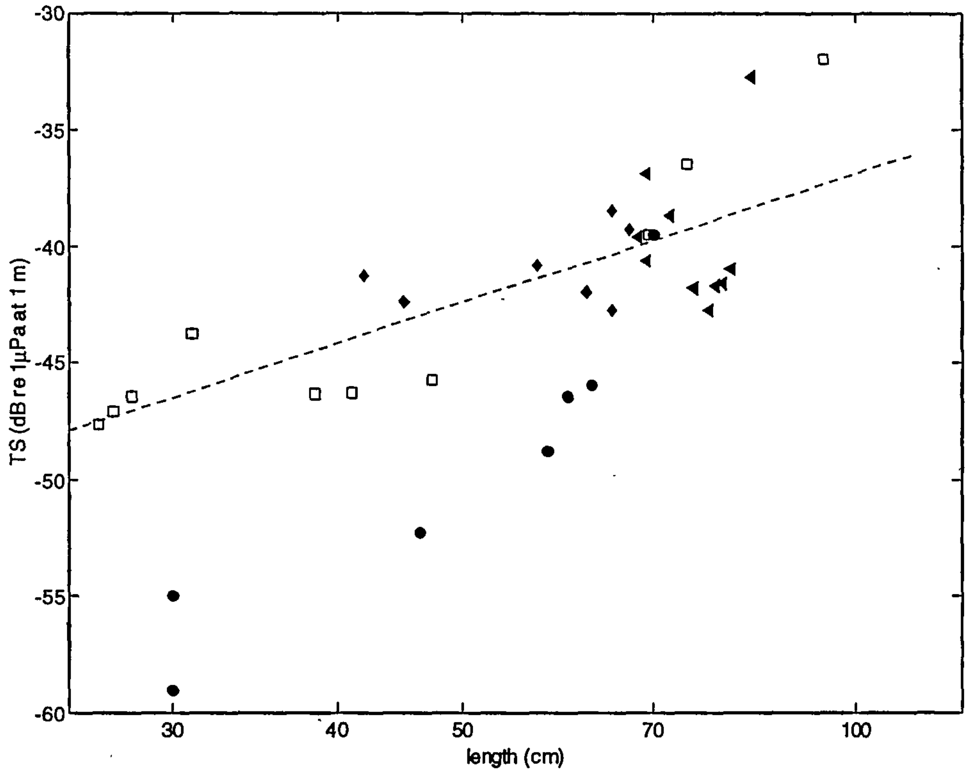

Figure 2: All available hoki target strength estimates. Filled symbols are from *in situ* data and hollow symbols from swimbladder modelling. The circles are from Bradford (1999), diamonds from the reanalysis of the 1999 *in situ* data, triangles from the 2000 *in situ* data and the squares from Cordue et al. (2000). The dotted line is a linear regression to all of the data points except for the solid circles.

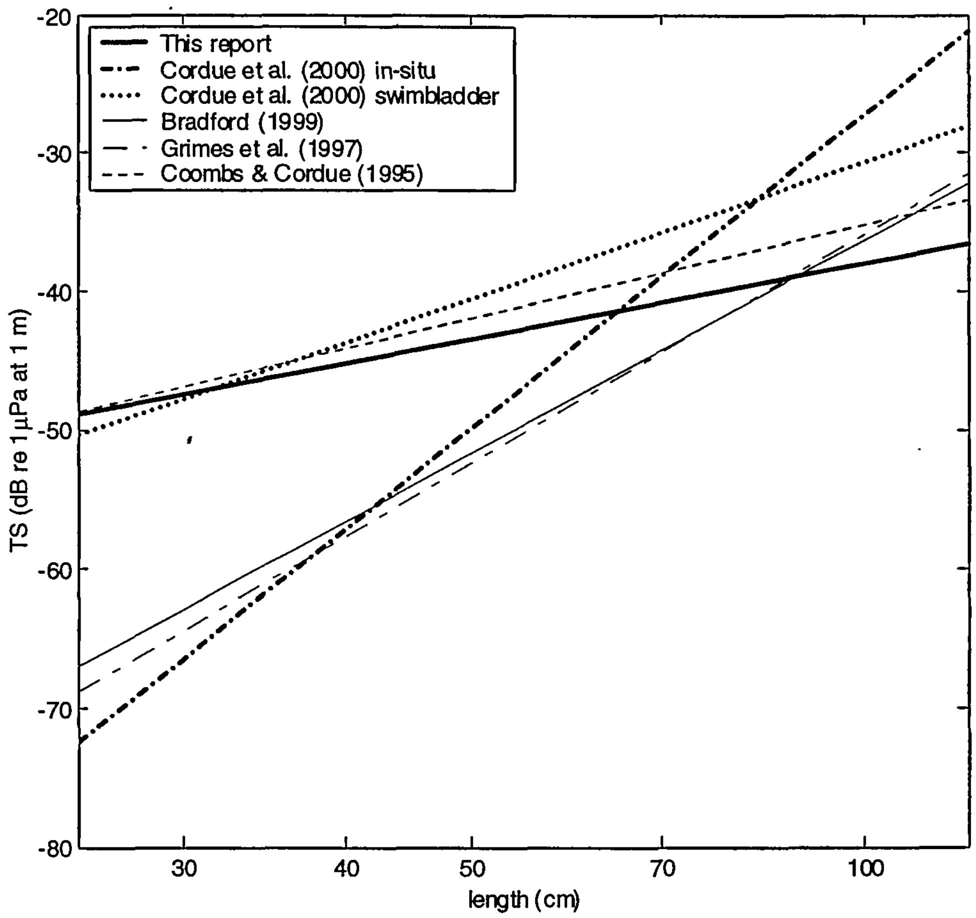

Figure 3: Comparison of existing hoki target strength to length relationships. The key indicates the report in which each regression was derived.