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In situ target strength measurements of orange roughy (*Hoplostethus atlanticus*)

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7. Executive summary

New *in situ* acoustic target strength data on orange roughy were collected during an acoustic survey on the Chatham Rise in July 1999. Appropriately filtered echoes were analysed to produce distributions of target strength for fish in the vicinity of plumes of spawning orange roughy. Distributions of the *in situ* target strengths were compared to the predicted distribution of target strength. Predictions were made from a published target strength - length regression (McClatchie *et al.* 1999) corrected for pressure and temperature at depth (McClatchie & Ye 2000) and the length frequencies for orange roughy trawled near where target strength measurements were made. Predicted and measured distributions overlapped, but the modes of the measured target strengths were lower than the predicted modal target strength by ~1.5 – 2.5 dB. Further work on *in situ* target strength is necessary before a definitive target strength – length regression can be estimated.

8. Objectives

To estimate the *in situ* target strength of orange roughy.

9. Methods

Introduction

New *in situ* target strength data were collected from *Tangaroa* during an acoustic survey of the northwest hill complex on the Chatham Rise in 1999. Target strength data were collected whenever suitable weather conditions and appropriate fish marks occurred together. These data were analysed using a set of single echo detection filters to produce distributions of *in situ* target strength. The data consist of 9 target strength transects and 12 associated trawls.

The spatial distribution of single echo targets in the range –53 to –47 dB was plotted for each transect in relation to the sea bed and the track of the towbody. When these patterns are compared to towbody echograms the location of single echoes of appropriate magnitude for orange roughy can be seen in relation to the location of the orange roughy plumes.

Species composition and size distributions of orange roughy were described from the trawl catches. The size distributions of the orange roughy were combined with a target strength-length regression for orange roughy (corrected for pressure and temperature at depth) to generate a predicted target strength distribution. The measured target strength distributions were compared to the predicted target strength distribution.

Acoustic equipment

Acoustic target strength data were collected using a towed split-beam 38 kHz transducer. All of the 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 $\log_{10}$ 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).

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 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 (MacLennan & Simmonds 1992) using a 38.1 mm ± 2.5 µm diameter tungsten carbide sphere with a nominal target strength of –42.4 dB. System 2 was used during TAN9908 on the Chatham Rise and was calibrated in the deep tank at the NIWA Greta Point laboratories in December 1998, June 1999 and September 1999. It was also calibrated at sea (at depths ranging from 50 to 800 m) during October 1998, June 1999 and September 1999. All calibrations gave consistent results. The resulting data from the various deep calibrations was fitted with two linear regressions:

$S_L = 0.0015588\ d_L + 61.1801,$
$S_H = 0.0004841\ d_H + 61.8107,$

where S_L and S_H is the combined source level and transducer receiving response ($SL+SRT$) in dB re 1 V, d_L and d_H are the transducer depth in metres, $0 \leq d_L \leq 600$ and $d_H > 600$.

Trawl data collection

Eight trawls from the Graveyard and four trawls from Scroll or isolated marks on the flat were used for target identification. Trawl gear used by *Tangaroa* on the hills was the 6-panel rough bottom orange roughy trawl with cut away lower wings and 100 mm mesh in the cod end (net plans described in McMillan (1996). Catches were processed using the computerised fish laboratory facility on *Tangaroa*. For smaller catches, all species in the catch were measured (to the nearest mm), counted, and weighed. For larger catches, 1000 individuals per species were measured, but all individuals were still counted. The proportion of species in each trawl was estimated by number, rather than by weight, to facilitate target identification, because the relevant comparison for target identification is between numbers of individual fish by species in the catch and numbers of single echoes in the target strength transect. Species composition data were extracted for all tows.

Sample volume analysis

A preliminary analysis was carried out to determine whether there were any regions near orange roughy plumes that were likely to have appropriate densities for target strength measurements (i.e. much less than one fish per sample volume). Volume backscattering was estimated from the hull 20 $\log_{10}$R TVG data corresponding to three target strength transects (d50, d51 and d55). Fish density was estimated by dividing the volume backscatter (Burczynski 1979) by the acoustic cross section estimated from a 35 cm orange roughy, and correcting for the towed transducer sampling volume (MacLennan & Simmonds 1992). Acoustic cross section was obtained from the <TS> - length regression from live fish experiments (McClatchie *et al.* 1999), corrected for pressure and temperature effects using the model of roughy target strength (McClatchie & Ye 2000). The relation is:

$$\langle TS \rangle \text{ (dB)} = (16.374 \log_{10} SL \text{ (cm)} - 71.621) - 2 \qquad \text{(McClatchie } et\ al. \text{ 1999)}$$

The towbody depth during the 40 $\log_{10}R$ TVG target strength transects was used to determine the minimum and maximum transducer depth during the transects. The number of fish in the towbody sampling volume was calculated by estimating the number of fish per m^3 from the hull data and then estimating the number of fish per m^3 of the towbody sampling volume at ranges greater than the minimum depth of the towbody. Plots were generated showing the density of fish per sampling volume, assuming that fish distribution in the beam was actually random.

In situ target strength data collection and processing

Marks that were expected to be orange roughy were located and the towed transducer deployed 50–100 m above the marks, for 1 to 2 hours. The marks were then trawled to identify the species and to obtain an estimate of the size composition. Three target strength transects were recorded from Zombie, four from the Graveyard and two from Scroll.

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
- phase stability of the individual 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 58% and 135% of the transmit pulse width at half the maximum echo amplitude (the 6 dB amplitude points).
- The standard deviation of the electrical echo phase between the 6 dB amplitude points was less than 0.2 radians on both the combined and individual echoes.
- The width of the four individual echoes at the 6 dB amplitude points varied by less than 31% 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 1.5 and 3.0 dB respectively for all three comparisons.

- The estimated angle of arrival of the echo was within 3.55° 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.

The depth distribution of single targets was compensated for changes in the depth of the towbody and plotted to highlight the locations of single echoes with target strengths in the range –53 to –47 dB (i.e. around the magnitude expected to be orange roughy).

10. Results

Trawl results

Data analysed from trawl catches from the Graveyard and Scroll hills and isolated marks away from the hills are summarised in Tables 2, 3 & 4 . The locations of trawls are shown in Figure 1. These locations are the positions of the vessel at the start and end of the tow. The actual trawl track is on the order of ~500–1000m behind the vessel (and is not known accurately).

Species composition is presented based on fish counts and the numbers of fish counted is shown to document catch sizes (Tables 2 & 3). The percentage composition of catches, by numbers of individuals, was dominated by orange roughy. In 8 trawls on the Graveyard hill, 75% to 100% of the fish were orange roughy, and in 4 of these 8 trawls, more than 94% of the fish caught were orange roughy. In 4 trawls on the Scroll hill or isolated marks, orange roughy were 74 to 94% of the catch, and in 2 of these 4 trawls, more than 97% of all fish caught were roughy. Unfortunately, net selectivity has to be considered and we cannot make any quantitative estimate of the proportions of small mid-water fishes (including myctophiids) that were present because these species are caught inefficiently by the bottom trawl.
Length frequencies for orange roughy determined from the 8 Graveyard trawl catches are shown in Figure 2. The modal size is slightly smaller than 35 cm. Sizes ranged between 27 and 41 cm standard length.

Sampling volume results

In water adjacent to the plumes we estimated fish densities of ~1–2 fish m^{-3} at ~600 m range (assuming the fish were orange roughy) which corresponds to a fish spacing of about 3 body lengths. This preliminary analysis suggested that that there were few regions with densities of much less than 1 fish per sampling volume required to yield useful target strength results.

In situ target strength results

The location of target strength transects is shown in Figure 1. These locations are the positions of the vessel at the start and end of the transect. The actual towbody track is on the order of ~500–1000m behind the vessel.

An example of the location of single echoes with target strengths near the expected magnitude for orange roughy (–53 to –47 dB) and the associated 40 $\log_{10}R$ echogram is shown in Figures 3 & 4. When single echoes were mapped onto the corresponding echogram for each target strength transect by matching transmit numbers and depth (or range), three general patterns became apparent. For most of the transects (d46, d47, d48, d52, d53 and d55) single echoes were detected only on the sides of the hill because there was a plume of roughy over the crest of the hill and fish were too dense in the plume to permit resolution of single echoes. In two transects (d50 and d49), the plume extended horizontally away from the crest of the hill and single echoes were detected beneath the horizontal part of the plume. In one transect (d51) there were no fish on the crest of the hill and single echoes were only detected away from the hill. These echoes are unlikely to be orange roughy, but unfortunately the mode of the target strength distribution corresponds with what would be expected for orange roughy.

Modal (subjectively estimated by eye), linear mean and median target strengths for the distributions in Figure 5 are presented in Table 5. Five of the 9 modal values are –50 dB, and two modes are –51 dB. Mean values depend upon the range of the data and are also influenced by extreme values. The overall mean for the range –60 to –46 dB, as used by Kloser *et al.* (2000), was –51 dB, which compares well with the Kloser *et al.* (2000) value of –51.5 dB. However, if the mean is taken over a wider range (–65 to –35 dB) the mean target strength increases to –47 dB, which is probably too high, judging by our previous published estimate of –48 dB from experiments and modelling (McClatchie and Ye, 2000).

When the distributions of *in situ* target strengths were compared to the predicted distribution of target strength, the predicted and measured distributions overlapped, but the modes of the measured target strengths were lower than the predicted modal target strength by ~1.5 – 2.5 dB (Figure 5).

11. Conclusions

New *in situ* target strength estimates for orange roughy have been obtained but the precise magnitude of the target strength for 35 cm (~modal size) orange roughy is still uncertain. The data collected are the first useful *in situ* target strength data for orange roughy collected to date by NIWA. They represent the third approach in an ongoing investigation of orange roughy target strength using experimental, modelling and *in situ* methods.

12. Publications

None.

13. Data storage

Data collected from trawling are stored in the New Zealand Ministry of Fisheries Trawl survey database. Acoustic data are 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.	28 327
Nominal 3 dB beamwidth(°)	7.0
Effective beam angle (sr)	0.0079
Operating frequency (kHz)	38.156
Transmit interval (s)	1.4
Nominal pulse length (ms)	0.32
Filter bandwidth (kHz)	4.86
Initial sample rate (kHz)	100.0
Decimated sample rate (kHz)	10.0
TVG	$40 \log_{10}R + 2\alpha R$
Nominal absorption (dB/km)	8.0
SL+SRT (dB re 1V at 1m)	62.2
Calibration valid at (m)	800
$20 \log_{10}G$	49.5

Table 2: **Species composition of trawl catches over the Graveyard hill that can be related to target strength measurements (see Figure 1 for tow locations). % = percentage of total catch estimated from fish numbers. Fish = number of fish caught. St = trawl station. Species codes in Table 4**

Species	St 1 Fish	St 1 %	St 7 Fish	St 7 %	St 8 Fish	St 8 %	St 12 Fish	St 12 %	St 20 Fish	St 20 %	St 21 Fish	St 21 %	St 30 Fish	St 30 %	St 36 Fish	St 36 %
BOE	1	0.51	–	–	–	–	–	–	–	–	4	0.32	–	–	–	–
ETB	21	10.66	–	–	–	–	23	3.37	–	–	83	6.74	16	1.85	34	2.83
ORH	**172**	**87.31**	**3**	**75.00**	**28**	**84.85**	**637**	**93.27**	**165**	**100**	**1011**	**82.06**	**829**	**95.95**	**1161**	**96.59**
SSO	3	1.52	–	–	–	–	23	3.37	–	–	109	8.85	16	1.85	4	0.33
CYP	–	–	1	25.00	–	–	–	–	–	–	3	0.24	–	–	2	0.17
CUB	–	–	–	–	5	15.15	–	–	–	–	–	–	–	–	–	–
CHG	–	–	–	–	–	–	–	–	–	–	1	0.08	–	–	–	–
CHP	–	–	–	–	–	–	–	–	–	–	2	0.16	–	–	–	–
CSE	–	–	–	–	–	–	–	–	–	–	1	0.08	–	–	–	–
CSU	–	–	–	–	–	–	–	–	–	–	5	0.41	–	–	–	–
PLS	–	–	–	–	–	–	–	–	–	–	12	0.97	2	0.23		
SMC	–	–	–	–	–	–	–	–	–	–	1	0.08	–	–	–	–
HOK	–	–	–	–	–	–	–	–	–	–	–	–	1	0.12	–	–
BSH	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	0.08

Table 3: **Species composition of trawl catches over the Scroll hill and isolated marks away from the hills that can be related to target strength measurements (see Figure 1 for tow locations). % = percentage of total catch estimated from fish numbers. Fish = number of fish caught. St = trawl station. Species codes in Table 4**

Species	St 9 Fish	St 9 %	St 22 Fish	St 22 %	St 34 Fish	St 34 %	St 39 Fish	St 39 %
BOE	–	–	–	–	17	2.30	–	–
ETB	–	–	3	0.29	–	–	2	0.74
ORH	**293**	**73.80**	**1009**	**98.82**	**596**	**80.76**	**264**	**97.78**
SSO	104	26.20	4	0.39	117	15.85	–	–
CYP	–	–			1	0.14	1	0.37
CUB	–	–	–	–			–	–
CHG	–	–	–	–	–	–	–	–
CHP	–	–	–	–	–	–	–	–
CSE	–	–	–	–	–	–	1	0.37
CSU	–	–	3	0.29	–	–	–	–
PLS	–	–	–	–	–	–	–	–
SMC	–	–	–	–	–	–	–	–
HOK	–	–	–	–	–	–	–	–
BSH	–	–	–	–	–	–	–	–
APR	–	–	1	0.10	–	–	1	0.37
BEE	–	–	1	0.10	1	0.14	–	–
CMA	–	–	–	–	1	0.14	–	–
CSQ	–	–	–	–	1	0.14	1	0.37
EPR	–	–	–	–	2	0.27	–	–
EPT	–	–	–	–	2	0.27	–	–

Table 4: **Species codes**

BOE black oreo, *Allocyttus niger*

ETB Baxter's lantern dogfish, *Etmopterus baxteri*

ORH orange roughy *Hoplostethus atlanticus*

SSO smooth oreo, *Pseudocyttus maculatus*

CYP long–nosed velvet dogfish, *Centroscymnus crepidater*

CUB cubehead, *Cubiceps spp.*

CHG giant chimaera, *Chimaera hantasma*

CHP brown chimaera, *Chimaera* sp

CSU four–rayed rattail, *Coryphaenoides subserrulatus*

PLS plunkets shark, *Centroscymnus plunketi*

SMC small–headed cod, *Lepidion microcephalus*

HOK hoki *Macruronus novaezelandiae*

BSH seal shark , *Dalatias licha*

CSE serrulate rattail, *Coryphaenoides serrulatus*

APR catshark, *Apristurus* spp

BEE basketwork eel, *Diastobranchus capensis*

CMA Mahia rattail, *Caelorinchus matamua*

CSQ *Centrophorus squamosus*

EPR *Epigonus robustus*

EPT deepsea cardinalfish, *Epigonus telescopus*

Table 5: **Mean and median target strengths (calculated in linear space) for the target strength distributions in Figure 5 for both the full data range in Figure 5 (–65 to –35 dB) and for the limited range used by Kloser *et al.* (2000) (–60 to –46 dB). Transects d46, d49 and d52 are from Zombie. Transects d47, d50, d53 and d55 are from the Graveyard. Transects d48 and d51 are from Scroll**

Transect	Mean <TS> –60 to –46 dB	median <TS> –60 to –46 dB	mean <TS> –65 to –35 dB	median <TS> –65 to –35 dB	mode <TS> dB
D46	–51.08	–52.64	–46.10	–51.28	–51
D47	–50.37	–50.80	–47.04	–50.08	–50
D48	–51.87	–54.05	–45.47	–52.56	not clearly defined
D49	–51.90	–53.25	–46.96	–52.72	–52
D50	–50.59	–51.63	–46.00	–51.10	–51
D51	–50.55	–51.23	–47.39	–50.96	–50
D52	–50.82	–51.83	–47.81	–51.47	–50
D53	–51.21	–52.32	–47.31	–51.80	–50
D55	–50.68	–51.27	–47.36	–50.61	–50

Overall mean (–60 to –46 dB) = –50.98 dB, and for (–65 to –35 dB) = –46.76 dB.

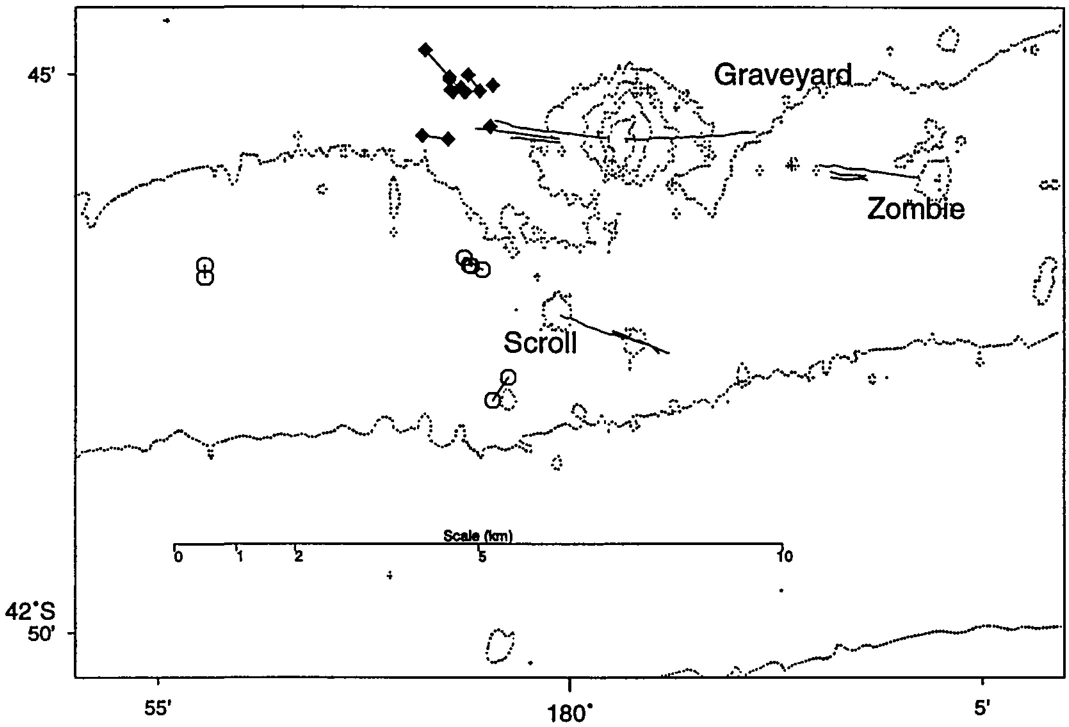

Figure 1: **Location of target strength transects (solid lines) and trawls (see Tables 3 & 4) used for ground truth on the northwest hill complex. Start and end–points of Graveyard trawls marked with diamonds. Start and end–points of Scroll trawls and isolated marks are delimited with open circles. Contours are 100 m depth intervals. Long contour lines are 900, 1000 and 1100 m from bottom–right to top–left of figure.**

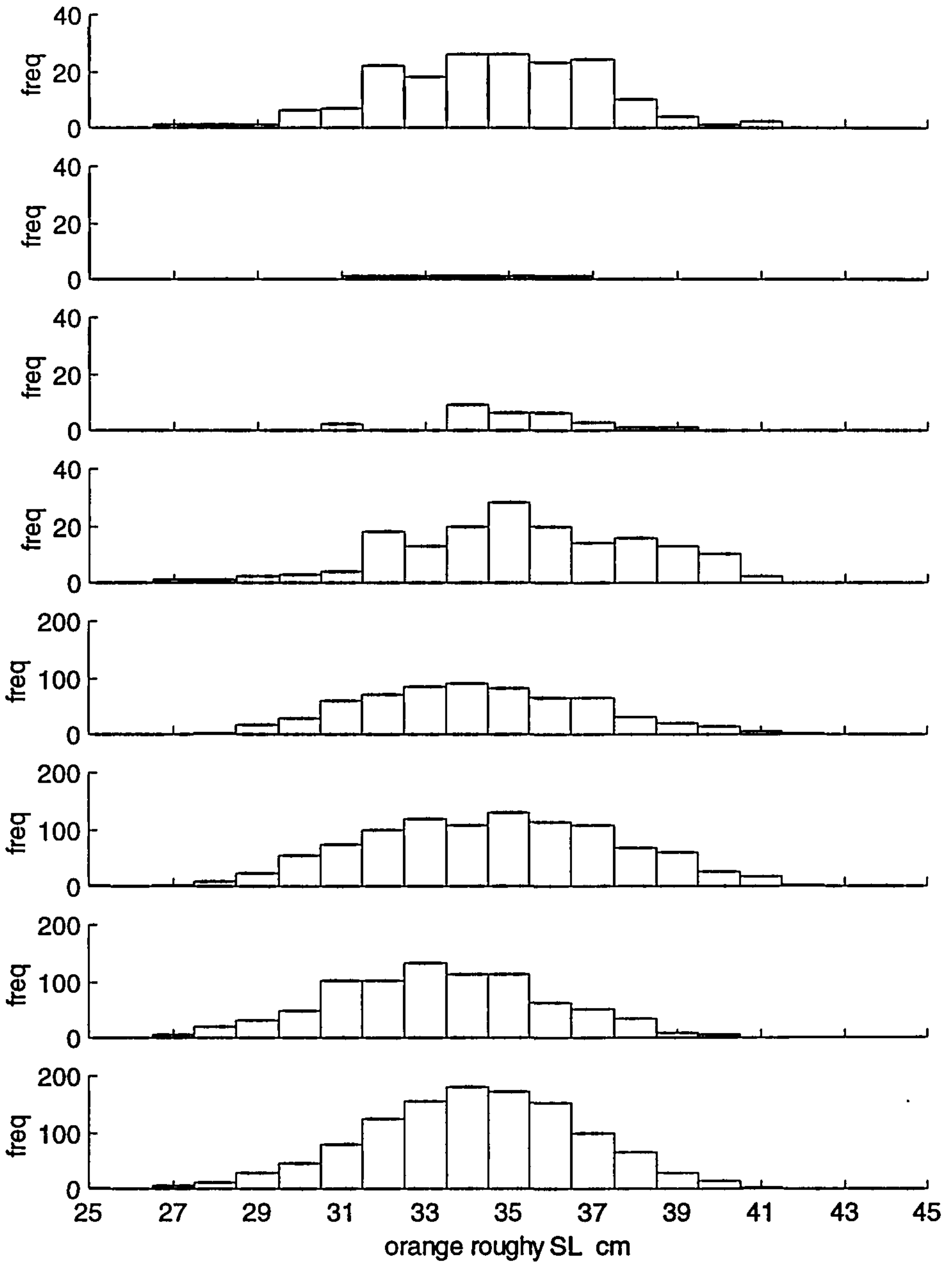

Figure 2: **Frequency distributions (number of fish caught) of orange roughy standard lengths (SL) from trawls on the Graveyard hill. Panels from top to bottom are trawl stations 1, 7, 8, 20, 12, 21, 30 and 36.**

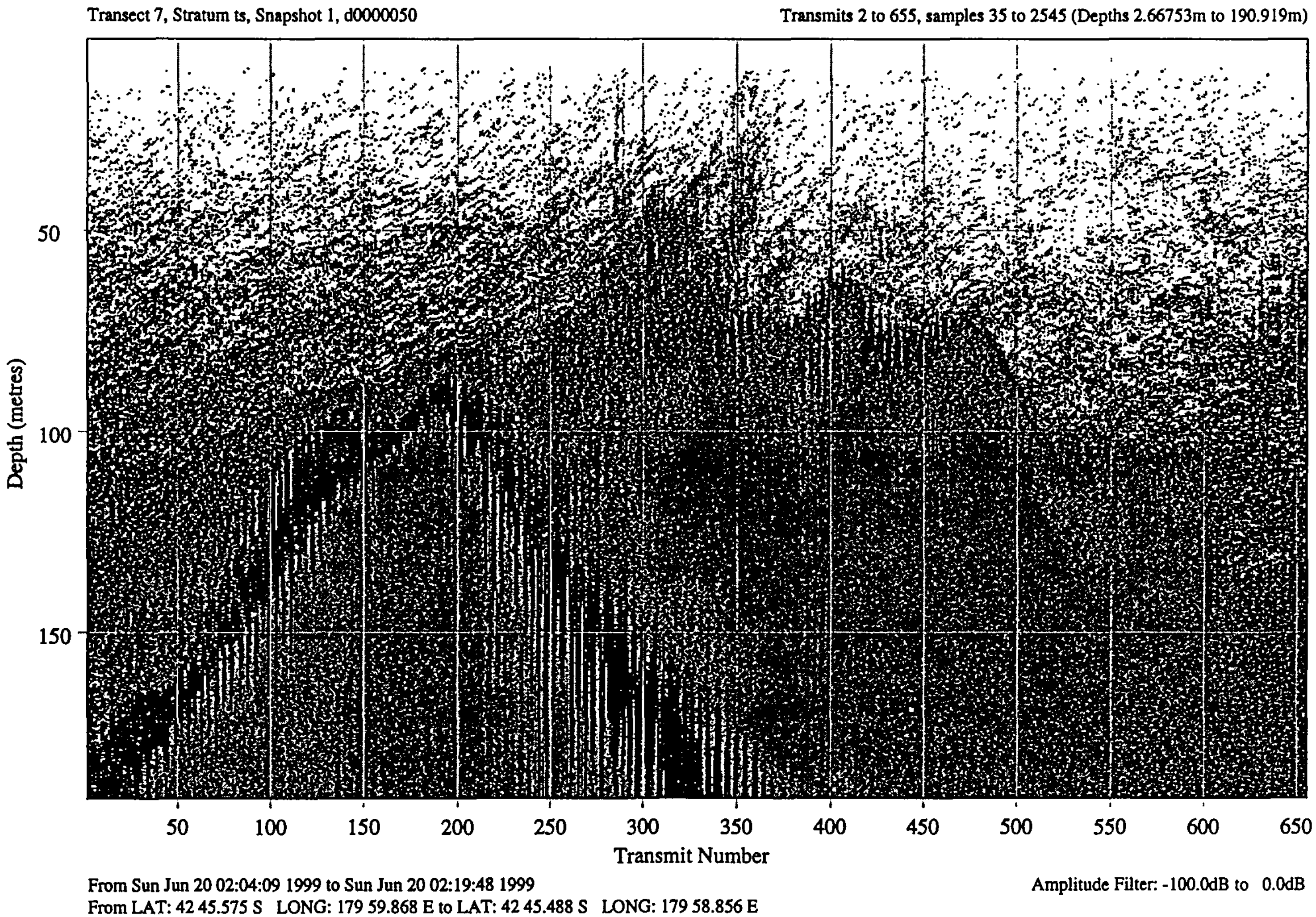

Figure 3: **40 $\log_{10}$R echogram for transect d50 on the Graveyard.**

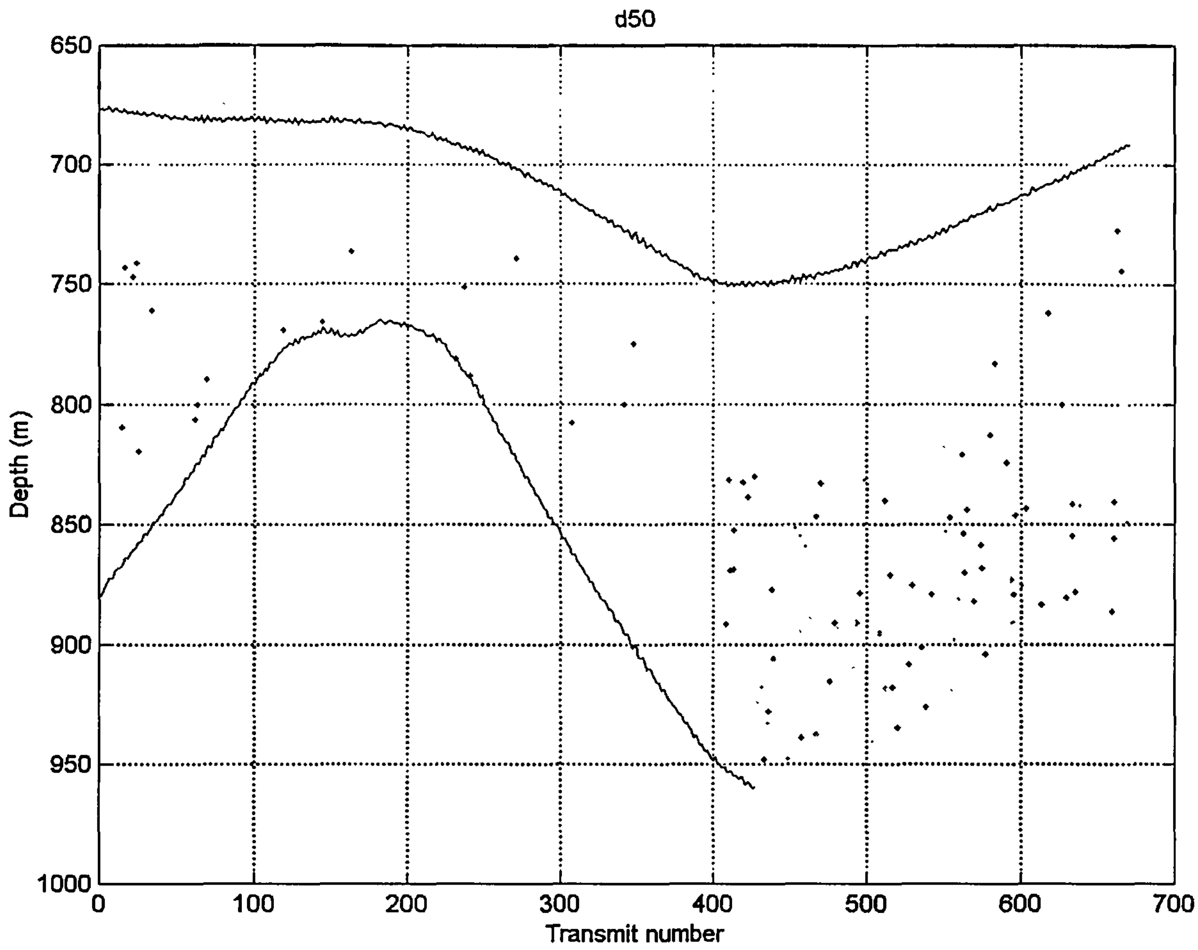

***Figure 4*: Location of single echoes with target strength in the range –53 to –47 dB for transect d50 on the Graveyard (see target strength frequency histogram in Figure 5 and echogram in Figure 3). Light grey points are single echoes outside the range –53 to –47 dB. Upper line is the towbody track, lower line is the bottom.**

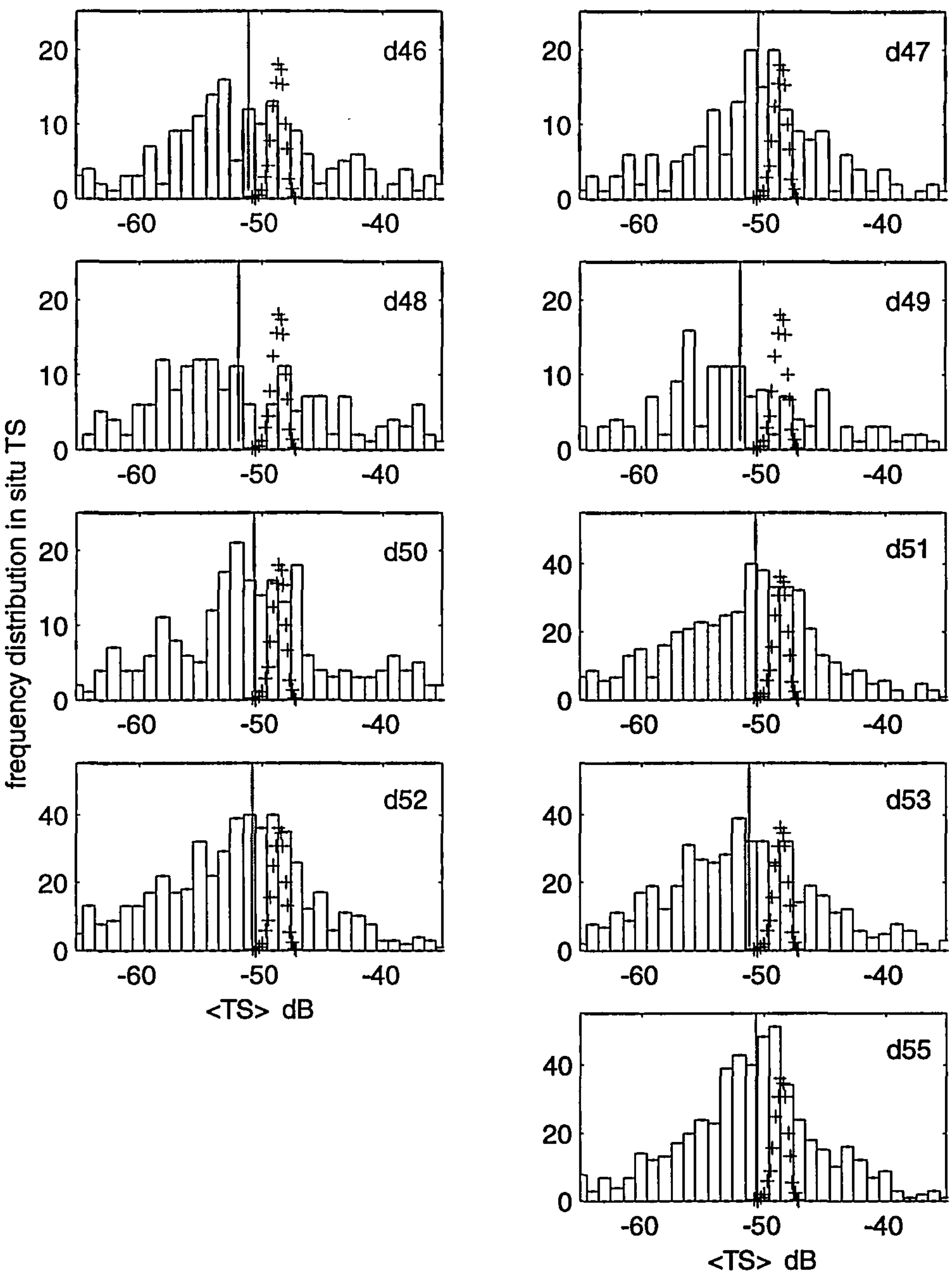

***Figure 5*: *In situ* target strength frequency distributions for 9 transects. Linear mean and linear median values for each transect are shown in Table 5. Vertical lines on the target strength distributions represent the linear means in the range –60 to –46 dB for comparison with Kloser *et al.* (2000). Pluses are the predicted <TS> from experimental and modelling data. Transects d46, d49 and d52 are from Zombie. Transects d47, d50, d53 and d55 are from the Graveyard. Transects d48 and d 51 are from Scroll.**