ICES Journal of Marine Science, 53: 273–279. 1996

Target-strength measurements of Pacific hake (*Merluccius productus*) in Canadian waters using quasi-ideal and conventional beam transducers

Akira Hamano, Toyoki Sasakura, Robert Kieser, Ken Cooke, Katsuhiko Kubota, and Allen Clay

Hamano, A., Sasakura, T., Kieser, R., Cooke, K., Kubota, K., and Clay, A. 1996. Target-strength measurements of Pacific hake (*Merluccius productus*) in Canadian waters using quasi-ideal and conventional beam transducers. – ICES Journal of Marine Science, 53: 273–279.

A joint Japanese/Canadian research cruise was carried out during May and June 1994 off the west coast of Canada to obtain two independent estimates of the *in situ* target strength (TS) of Pacific hake (*Merluccius productus*). Two vessels with independent quantitative echosounder systems were used. One was equipped with 120 and 50 kHz transducers, while the other used 38 kHz. The 120 kHz transducer featured a quasi-ideal beam pattern with a relatively flat response near the beam axis and low side lobes. Different single-beam TS estimation procedures were used to estimate TS from either system. Fish targets were identified by midwater trawling on the same or the next day. On one occasion both vessels were used to fish and measure TS simultaneously. The observed mean night-time TS for adult hake ranged from -36.4 to -30.4 dB kg^{-1}.

Key words: *in situ* target strength, Pacific hake, quasi-ideal beam, target tracking.

A. Hamano and K. Kubota: National Fisheries University, 2-7-1, Nagatahonmachi, Shimonoseki, 759-65, Japan. T. Sasakura: Furuno Electric Co., Ltd, 9-52, Ashihara-cho, Nishinomiya, Japan. R. Kieser and K. Cooke: Department of Fisheries and Oceans, Pacific Biological Station, Hammond Bay Road, Nanaimo, British Columbia, Canada V9R 5K6. A. Clay: Femto Electronics Ltd, PO Box 690, Lr. Sackville, Nova Scotia, Canada B4C 3J1.

Introduction

Pacific hake (*Merluccius productus*) is the most abundant species in Canadian waters, supporting the largest west coast groundfish fishery with an average annual catch of 91 000 t (1988–1992) (Saunders and McFarlane, 1992). The stock assessment of this important species has mainly been done hydro-acoustically (Cooke *et al.*, 1992; Saunders *et al.*, 1992). It is therefore important to estimate the *in situ* target strength (TS) of Pacific hake in their natural habitat.

Originally a TS of -32.0 dB kg^{-1} was used for hake and herring by Canadian researchers (Taylor and Kieser, 1982; Kieser, 1992). However, Dark *et al.* (1980) employed -35.0 dB kg^{-1} to analyze similar US survey data. To facilitate the comparison of the estimated biomass, both Canada and the US now use a TS of -35.0 dB kg^{-1} for Pacific hake, but additional measurements are needed to validate this choice.

The work described here has three aims: (1) to report the process of TS measurements of Pacific hake using quasi-ideal beam and conventional beam transducers, (2) to provide information on TS of Pacific hake and to obtain more reliable estimates of biomass, and (3) to find the variability between day-time and night-time TS values.

Methods

A Japan/Canada Joint Research Cruise was conducted in early summer of 1994 off the Pacific coast of Canada. Two stern trawler research vessels, the ‘‘Tenyo-Maru’’ (57.1 m, 877 t) of Japan and the ‘‘W. E. Ricker’’ (58.0 m, 1105 t) of Canada were employed. Independently developed and calibrated acoustic systems were used to collect *in situ* Pacific hake TS measurements off southern Vancouver Island, Canada (Fig. 1). Midwater trawl catches were made to provide biological information and assist in the interpretation of echograms.

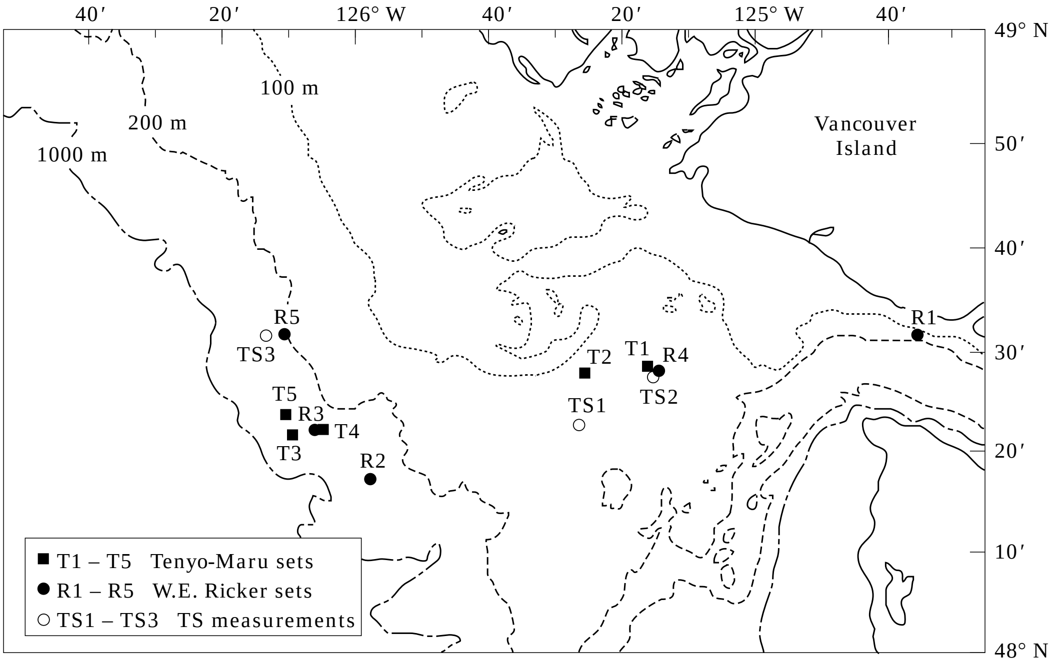

Figure 1. Set and TS measurement location. RV ''Tenyo-Maru'' made day- and night-time TS measurements at TS1/2 and TS3, respectively. Night-time measurements from RV ''W. E. Ricker'' were from TS3. The shelf edge coincides with the 200 m contour.

Table 1. Specification of the sounder during the present survey.

Specifications	Tenyo-Maru		W. E. Ricker
Frequency (kHz)	120	50	38
Source level (dB μ Pa)	223.9	228.8	221.2
Receiving sensitivity (dB V·μ Pa^{-1})	− 190.0	− 180.0	− 133.47
Pulse duration (ms)	0.6	0.6	0.6
Equivalent beam width (dB)	− 16.8	− 18.8	− 17.55
Absorption loss coefficient (dB km^{-1})	38.1	15.1	9.9
Sound velocity (m s^{-1})	1500	1500	1490
TVG function (log R)	40	40	20

Acoustic system

A dual frequency Furuno FQ-74 scientific echo-sounder and data-processing system was used on the ''Tenyo-Maru''. It included a 120 kHz quasi-ideal beam (Sasakura and Endo, 1987) and a 50 kHz conventional transducer. The quasi-ideal beam has a relatively uniform sensitivity across the main lobe of the beam and very low side lobes (Fig. 2). Both transducers were mounted in a towfish. A SONY PC208A eight-track DAT recorder was used to store the analog output from the echo-sounder.

A BioSonics 101 echo-sounder, 111 chart recorder, and 121 integrator were installed on the ''W. E. Ricker''. Its conventional 38 kHz transducer was mounted in a towfish. The analog output was recorded on a PCM/VCR tape-recording system (Cooke *et al.*, 1992). Both vessels used a Femto HDPS 9001 digital echo processor and editing system to record and visualize the echo data (Clay, 1994). Key specifications for the acoustic systems are given in Table 1.

Standard target calibrations (Foote *et al.*, 1987) were carried out in salt water at 38, 50, and 120 kHz, with a 38.1 mm diameter tungsten carbide calibration sphere. This type of target is commonly used at 38 kHz. Calculations (MacLennan, 1981) were carried out to explore its suitability at 50 and 120 kHz. A smooth response was found near both frequencies, except for a resonance at 115 kHz. Calculated sphere TS for a long and a 0.6 msec pulse (5 kHz receiver band width) show only 0.08 and 0.3 dB difference at 50 and 120 kHz, respectively. This indicates that the sphere can be used for all three frequencies.

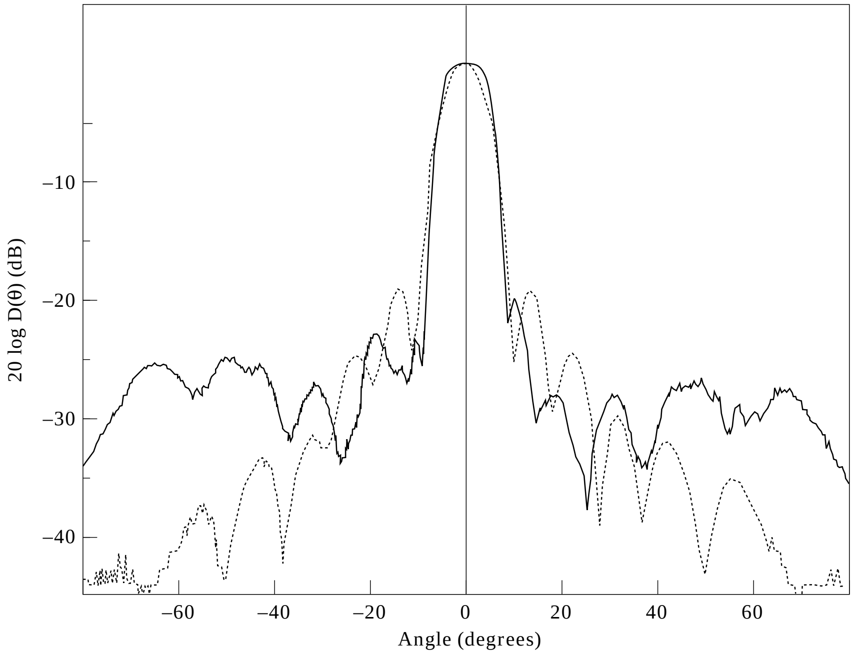

Figure 2. Beam pattern for the FQ-74, 120 kHz quasi-ideal (——) and 50 kHz conventional beam (- - -) transducer. Units for the vertical axis are in relative one-way power.

Single fish echo selection and echo tracing

The FQ-74 uses a 40 log R TVG and echoes were digitized at 7.5 kHz. A − 45 dB threshold was used to eliminate noise. This level was obtained by reducing an assumed initial TS of − 35 dB by 10 dB. A peak width criterion was employed to select single fish echoes. Consecutive single fish echoes from essentially the same depths were then identified as fish traces. A fish trace corresponds to an inverted V on the echogram (Fig. 3).

TS estimation

The FQ-74 used a new TS estimation procedure that relies on single-fish trace detection and the relatively flat response of the quasi-ideal beam transducer. A 10 m by 20 sec depth-distance bin was defined. The largest echo peak voltage from each trace was used to calculate a trace TS (TS_{tra}). TS_{max} and TS_{ave} were then defined as the maximum and average of all TS_{tra} in a given bin. A TS estimate is obtained when TS_{max} equals TS_{ave}. This condition must hold for both frequencies before the TS estimates are accepted. An example of the FQ-74 printed out is shown in Figure 4. Only the three circled 120/50 kHz records satisfied the TS selection criteria.

The BioSonics echosounder on the ‘‘W. E. Ricker’’ used a 20 log R TVG. The HDPS provided conversion to 40 log R. Single-peak echo detection but no echo tracing was employed. An empirical procedure was used to estimate TS from the single fish echoes (Clay and Castonguay, 1996).

Target identification

The identification of the echo sign was carried out by both vessels using a midwater trawl. The ‘‘Tenyo-Maru’’ used a standard Japanese midwater net (Hamano *et al.*, 1992) with a vertical opening of 5 to 10 m and a 13 mm mesh cod end liner. A Kaijo wireless net sounder was used to guide trawling and to monitor net depth and mouth opening.

The ‘‘W. E. Ricker’’ used a Canadian Diamond-7 midwater trawl with a 13.5 m vertical opening and 38 mm codend mesh, a pair of 5 m Suberkrub midwater trawl doors, 80 m sweep wires with 300 kg chain weights, and a SIMRAD FS3300 third wire headrope trawl sonar. Towing speed for both vessels was 3–4 knots. Nominal towing time was 30 min. Depending on anticipated catch, this time was adjusted to secure an appropriate sample for target identification. Echo-sounders and the real-time TS output on the FQ-74 were closely followed to guide the sampling process.

Results

TS measurements

The ‘‘Tenyo-Maru’’ collected day- and night-time TS measurements in areas with relatively pure Pacific hake

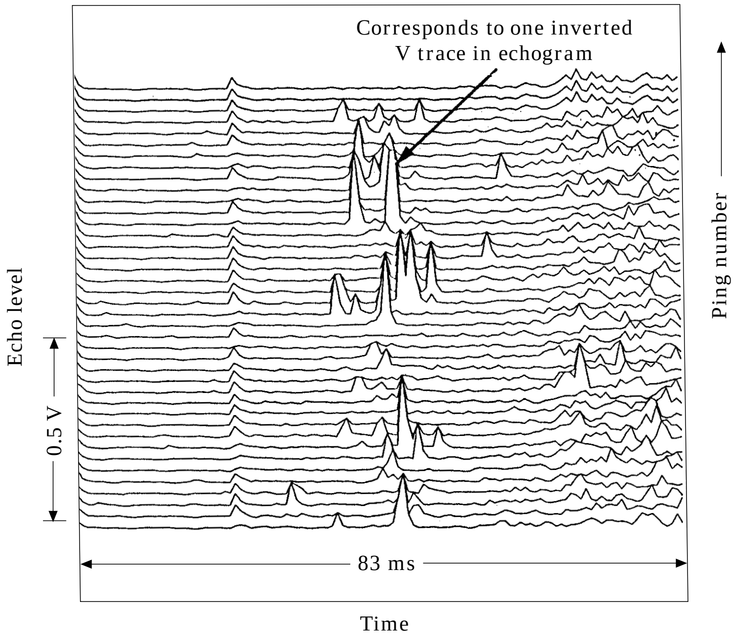

Figure 3. Echo voltages from successive pings, suggesting single-fish echoes and fish traces.

distributions. Day-time measurements were done while the ''Tenyo-Maru'' drifted in relatively shallow water (Fig. 1, locations TS1 and TS2). The towfish was suspended at 40 m depth to obtain better definition of single fish echoes. Night-time measurements were taken from several short transects near the shelf edge (Fig. 1, location TS3). Vessel speed was 3 knots. The towfish was deployed normally. The ''W. E. Ricker'' completed the same night-time TS transects with fewer repetitions.

Figure 5 shows day and night TS histograms. At 120 kHz, the average day and night TS were -36.9 and -38.2 dB fish^{-1}, respectively. The corresponding 50 kHz results were -37.5 and -35.5 dB fish^{-1}. The 38 kHz night average TS was -32.2 dB fish^{-1}. No day-time estimate was obtained at this frequency.

Target identification trawling

The ''Tenyo-Maru'' and the ''W. E. Ricker'' each completed five midwater tows, two being carried out on the continental shelf and three along or beyond the edge of the continental shelf (Fig. 1). Table 2 gives the catch records by vessel and location, with towing depths measured from the net sounder. All catches were dominated by Pacific hake, with the larger catches resulting from the shallower tows. The deep day-time sets (R2 and T5) yielded relatively small amounts of Pacific hake. Two species of micronekton (*Stenobrachius leucopsarus* and *Thysanoessa spinifera*) were taken with average body length of 53.7 and 24.2 mm, respectively. Catches were small as the nets and net liners would pass most of these small animals. The catch, however, indicates that micronekton, rather than Pacific hake, are likely to be the dominant scatterer at depths of about 350 m.

Species composition for the ''Tenyo-Maru's'' day-time TS sampling sites TS1 and TS2 was established from sets T1, T2, and R4. Hake represented 82–98.5% of the catch. Several days elapsed between sets T1/2 and measurements TS1/2. However, set R4 was concurrent with the TS1 and TS2 measurements. The ''Tenyo-Maru's'' night-time TS measurement at TS3 and the ''W. E. Ricker's'' set at R5 were made at the same time and nearly the same location. Pacific hake represented 99.3% of this catch. All sets indicated that Pacific hake was dominant and is by far the most likely target for our TS measurements.

The Pacific hake sampled from sets R4 and R5 were 474 ± 29 and 476 ± 32 mm in fork length, or 642 ± 121 and 676 ± 134 g, respectively, indicating that mean length and weight on the shelf and near the shelf edge were very similar.

Discussion

The measured day- and night-time average TS (dB fish^{-1}) for Pacific hake are summarized here in Table 3. The dB kg^{-1} values are based on a fish weight of 660 g.

Figure 6 compares our results with published *in situ* TS data. Most data points in this figure are from Foote

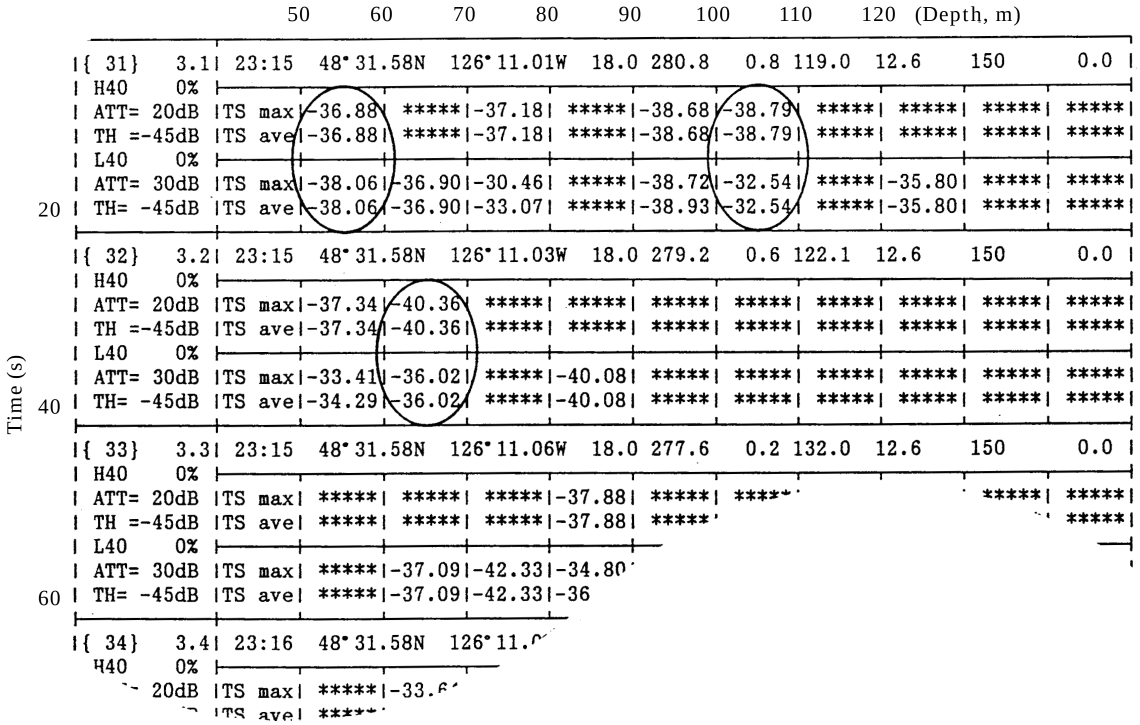

Figure 4. Selected FQ-74 output with 120 and 50 kHz depth distance bins. Each bin gives TS_{max} and TS_{ave}. Depth increases from left to right. Bins with accepted TS estimates are circled.

Table 2. Midwater trawl data.

Haul	Vessel	Date	Time	Position (N)	Position (W)	Headrope depth (m)	Catch: Pacific hake (kg)	Catch: Other species (kg)
1 R1	W. E. Ricker	30 May 1994	0800	48–31.6	124–36.1	72–75*	1940	31
2 T1	Tenyo-Maru		0815	48–28.2	125–15.9	87*	639	144
3 T2	Tenyo-Maru		1144	48–27.5	125–25.1	77–94*	2712	128
(4) T3	Tenyo-Maru	1 June 1994	0850	48–22.1	126–08.8	aborted	—	—
5 R2	W. E. Ricker		0927	48–17.4	125–57.0	300–280**	342	0
6 T4	Tenyo-Maru		1127	48–22.6	126–04.4	240**	231	0
7 T5	Tenyo-Maru		1418	48–23.9	126–10.1	383–340**	81	1.8 (micronekton)
8 R3	W. E. Ricker		1457	48–22.6	126–05.6	260–285**	200	0
9 R4	W. E. Ricker	2 June 1994	1331	48–27.8	125–13.8	72–79*	904	15
10 R5	W. E. Ricker	3 June 1994	2300	48–31.5	126–10.2	100–90**	282	2

*On the continental shelf.
**Beyond the edge of the continental shelf.
(4), Unable to adjust the working depth of net due to trouble in net-sounder.

Table 3. Average day- and night-time TS values.

Frequency (kHz)	Day (dB fish^{-1})	Day (dB kg^{-1})	Night (dB fish^{-1})	Night (dB kg^{-1})
120	− 36.9	− 35.1	− 38.2	− 36.4
50	− 37.5	− 35.7	− 35.5	− 33.7
38	—	—	− 32.2	− 30.4

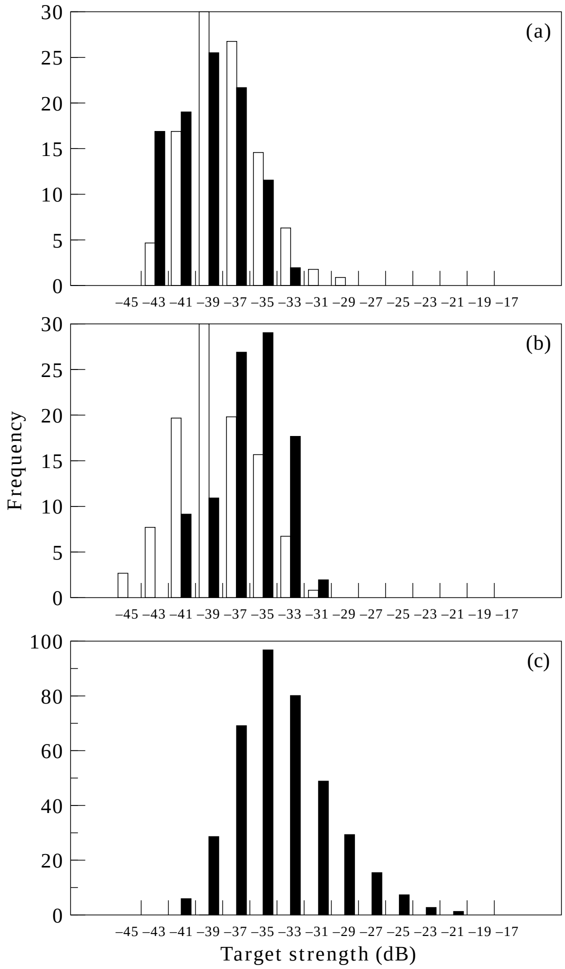

Figure 5. Histogram of (a) 120 kHz, (b) 50 kHz, and (c) 38 kHz TS measurements □ = Day, ■ = Night.

(1987) who reviewed published TS for physoclistous fish and concluded that they can be presented by a linear fit. The reviewed points have a standard deviation of 2.3 dB. Our TS are shown at 475 mm. Just to their right are three night-time TS measurements for slightly larger Pacific hake reported by Williamson and Traynor (1984). The agreement between our results among themselves and with those presented in Figure 6 is reasonable.

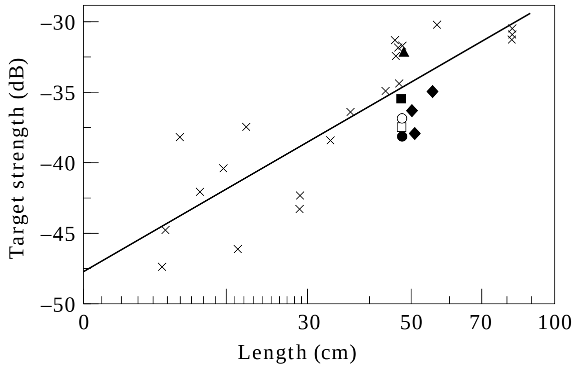

Figure 6. Comparison of the present results of *in situ* TS measurements with those already published. Present results: ○, ● = Pacific hake (day and night by 120 kHz), □, ■ = Pacific hake (day and night by 50 kHz), ▲ = Pacific hake (night by 38 kHz). Already published results: × = Physoclists (Foote, 1987), ◆ = Pacific whiting (Williamson and Traynor, 1984).

Our TS results were examined for the systematic day/night changes reported by Traynor and Williamson (1983) for walleye pollock (*Theragra chalcogramma*) in the eastern Bering Sea. Their measurements indicate that average day-time TS for walleye pollock are 3 dB higher than those found at night. Only our TS measurements at 120 kHz show a similar trend. A possible reason is that Pacific hake may show less consistent day/night TS differences.

One of the interesting aspects of this work is that the 120 kHz data were obtained with a quasi-ideal beam transducer and that echo tracking was used for the isolation of single-fish targets. However, subsequent TS analysis procedures are relatively simple and are likely to eliminate a large number of targets.

The empirical TS analysis procedure that was used for the 38 kHz data has been compared with concurrent split measurement (Clay and Castonguay, 1996). Work is in progress to substantiate its validity under a wider range of conditions.

Regarding the search for a better TS for the analysis of acoustic data from Pacific hake surveys, we note that the average of our night-time TS was between the − 32.0 and − 35.0 dB kg^{-1} values that have been used. However, the difficulty of finding suitable day and night-time hake concentrations at moderate depths and the variability in our published TS observations suggest that *in situ* TS measurements procedures need to be refined and that the long-term stability of Pacific hake TS must be established before a new value or range of values can be recommended.

In summary, we feel that our measurements are consistent with a wide range of published TS results. Additional measurements and analyses are planned to evaluate the stability of our results as a function of day/night, fish depth, and season. Cooperative work is planned to pursue refinements in our analysis.

Acknowledgements

The authors thank Emeritus Professor Dr H. Maeda of the National Fisheries University for his constructive advice. Stimulation discussions and the use of Dr C. Clay's deconvolution programs for exploratory data analysis are gratefully acknowledged. This work was supported in part by a Japan Science and Technology Grant from the Canadian Department of External Affairs.

References

Clay, A. 1994. HDPS Manual. Femto Electronics Ltd. 102 pp.

Clay, A. and Castonguay, M. (In press). *In situ* target strengths of Atlantic cod (*Gadus morhua*) and Atlantic mackerel (*Scomber scombrus*) in the northwest Atlantic. Canadian Journal of Fisheries and Aquatic Sciences.

Cooke, K., Kieser, R., Saunders, M. W., Andrews, W. T., and Smith, M. S. 1992. A hydroacoustic survey of Pacific hake on the continental shelf off British Columbia from the Canada/U.S. boundary to Queen Charlotte Sound: August 13 to 28, 1991. Canadian Manuscript Report of Fisheries and Aquatic Sciences, 2174. 40 pp.

Dark, T. A., Nelson, M. O., Traynor, J. J., and Nunnallee, E. P. 1980. The distribution, abundance, and biological characteristics of Pacific whiting (*Merluccius productus*) in the California–British Columbia region during July–September 1977. Marine Fisheries Research, 42: 17–33.

Foote, K. G. 1987. Fish target strength for use in echo integration surveys. Journal of the Acoustical Society of America, 82: 981–987.

Foote, K. G., Knudsen, H. P., Vestnes, G., MacLennan, D. N., and Simmonds, E. J. 1987. Calibration of acoustic instruments for fish density estimation: a practical guide. Cooperative Research Report, International Council for the Exploration of the Sea, 144. 69 pp.

Hamano, A., Uchida, K., and Takeda, Y. 1992. Sorting echoes of sternoptychid fish, *Maurolicus muelleri*, from quantitative sounder echograms with verification by midwater trawl. Bulletin of the Japanese Society of Fisheries Oceanography, 56: 295–308.

Kieser, R. 1992. Reassessment of target strength estimates for hake and herring implications for stock assessments. Appendix to PSARC working paper H93-3. 14 pp. Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, BC, Canada.

MacLennan, D. N. 1981. The theory of solid spheres as sonar calibration targets. Department of Fisheries for Scotland. Scottish Fisheries Research Report 22. 17 pp.

Sasakura, T., and Endo, Y. 1987. Quasi-ideal beam transducer. Japanese Journal of Applied Physics, 26: 94–96 (Suppl. 1).

Saunders, M. W., Kieser, R., Withler, P., and Andrews, W. T. 1992. A hydroacoustic survey of Pacific hake on the continental shelf off British Columbia from the Canada/U.S. Boundary to Queen Charlotte Sound: August 13 to 31, 1990. Canadian Manuscript Report of Fisheries and Aquatic Sciences, 2177. 47 pp.

Saunders, M. W. and McFarlane, G. A. 1992. Pacific hake. *In* Groundfish stock assessments for the west coast of Canada in 1991 and recommended yield options for 1992. Ed. by B. M. Leaman. Canadian Technical Report of Fisheries and Aquatic Sciences, 1866. 304 pp.

Taylor, F. H. C. and Kieser, R. 1982. Distribution and abundance of herring and other pelagic fish off the West Coast of Vancouver Island in September, November 1980, and March 1981, and in the Strait of Georgia in November 1980. Canadian Manuscript Report of Fisheries and Aquatic Sciences, 1682. 167 pp.

Traynor, J. J. and Williamson, N. J. 1983. Target strength measurements of walleye pollock (*Theragra chalcogramma*) and a simulation study of the dual beam method. FAO Fisheries Report, 300: 112–124.

Williamson, N. J. and Traynor, J. J. 1984. *In situ* target strength estimation of Pacific whiting (*Merluccius productus*) using a dual-beam transducer. Journal du Conseil International pour l'Exploration de la Mer, 41: 285–292.