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" Some observations on stability of hydroacoustic stock assessment system during long-term exploitation "

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ABSTRACT

One of the most important sources of errors in hydroacoustic stock assessment is related to the stability of the measuring system parameters during years of its exploitation. As an example, observations on hydroacoustic sensitivities of the echosounder and calibrating hydrophone of r.v. "Profesor Siedlecki" during 12 years of its exploitation are shown. On the basis of those data, regression lines of sensitivities reduction have been calculated and discussed. Conclussions on how to minimize the error related to stability of the system parameters are enclosed.

INTRODUCTION

The fisheries research vessel "Profesor Siedlecki" / 90m / was built in 1972 at Gdańsk Shipyard for the Sea Fisheries Institute /MIR/ in Gdynia. The vessel was equipped with SIMRAD scientific hydroacoustic system, with the main task to estimate fish resources. The system consisted of EK 38, EK 50, EK 120 sounders, SU-2, SK-120 sonars, QM MKII integrator and hydrophone monitor unit and calibration instrument set. In the most of cases EK 38 with narrow beam (5.5^ox 5^o) transducer was applied for stock assessment. As the standard for calibration purposes hydrophone LC 32, produced by Atlantic Research Corporation, was used till the present time. The intention of this paper is to determine possible errors of biomass assessment, estimated a posteriori, after a long period of exploitation. As the main subjects for discussion instrumental constant of EK 38 sounder and hydrophone sensitivity were observed. Conclusions should help in exploitation of hydroacoustic systems for evaluating the biomass of living resources of the sea.

MATERIALS AND DISCUSSION

Final result of calibrating procedure of hydroacoustic system is closely connected with accidental and systematic conditions during the measurements.

Accidental factors are caused by propagation situation, correct setting of hydrophone on acoustical axis, power supplying, regulation of measuring instruments and personal characteristics of responsible staff.

Systematic errors follow the instrument standards changes, especially transmitting and receiving response of the hydrophone. If the hydroacoustic system calibration procedure is realized by hydrophone, instrumental constant of the echosounder is expressed in the following way:

$$\begin{aligned} SR &= VR + SL = \\ &= \left[U - (M + d) + 20 \log r\right] + \left[U_{out} - S - U_{hydr} + 20 \log r\right] = \\ &= U - (M + S) + U_{out} - U_{hydr} + 40 \log r - d \qquad /1./ \end{aligned}$$

where:

SR	- system instrumental constant	[dB// V]
VR	- voltage response	[dB// V/μPa]
SL	- source level	[dB// μPa]
M	- hydrophone transmitting voltage response	[dB// μPa/V]
S	- hydrophone receiving voltage response	[dB// V/μPa]
U_{out}	- output voltage of sounder receiver	[dB//V]
U_{hydr}	- transmitting hydrophone voltage during SL measurement	[dB// V]
U	- receiving hydrophone voltage during VR measurement	[dB// V]
r	- distance transducer-hydrophone	[m]
d	- extension cable attenuation	[dB]

The factor (M + S) characterizes hydrophone calibrating properties, having a direct influence on calibration results and on biomass estimates finally.

Hydrophone LC 32, installed aboard r.v. "Profesor Siedlecki" was calibrated by SIMRAD at Horten in years 1971, 1972, 1978 and 1983.

In this paper parameters M + S, determined for 38 kHz, are taken under account.

Difference of M + S points / between initial and present values/ were approximated by regression line /Fig.1/ type $Y = ax^b$, and the curve equation was as follows /$r^2 = 1$/:

$$\Delta (S + M) = - (1.973 \times 10^{-4} \; t^{3.913}) \qquad / 2. /$$

t - number of years of exploitation

During 12 years of exploitation of the vessel, hydrophone summarized sensitivity (S + M) decreased by 3.3 dB. Reduction of sensitivity was very small /less than 0.1 dB per year/ during first 5 years of exploitation - and it has begun to increase rapidly afterwards, crossing 0.6 dB per year after 10 years. For the same period /Fig.2/ the relative error of biomass estimate, caused by hydrophone sensitivity losses / if it was not recalibrated in between/ was approximated from /2./. The bias over 5%, causing systematic error of biomass estimate, appears after 5 years since the moment of its installation. The error is increasing quickly and after 11 years is 10 times higher.

If we compare hydrophone constant at 120 kHz during the same period, reduction of sensitivity was much higher between 1972 and 1983 and it reached $\Delta (S + M) = -32.3$ dB.

It is supposed, that the hydrophone constant is mostly modulated by changes of properties of neoprene sheath, covering the piezoelectric ceramics. Strong decreasing of sensitivity after 5 years of exploitation eliminate the possibility of using the hydrophone as a standard for calibration.

Different problem is connected with echosounder constant, being the sum of its receiving and transmitting sensitivities. If the echosounder is calibrated during cruises, the instrumental constant change is measured and it has no direct influence on biomass estimation. But if the drift of echosounder parameters is high enough-calibration error should increase, and echosounder detection level is becoming not comparable with previous surveys, carried out during few consequent years. As an example of stability is shown the diagram of instrumental constant for EK 38 sounder /Fig.3/. The curve presented in the figure is calculated as the regression line, as it was done for hydrophone. The curve regression line equation /$r^2 = 0.96$ /was:

$$\Delta (SL + VR) = - (4.29 \times 10^{-3} \; t^{3.065}) \qquad / 3. /$$

Equation was based on calibration results, being averaged for every year, with time variation of hydrophone constant, taken under consideration a posteriori.

After a period of exploitation /1972-1983/ the transducer was rewound by SIMRAD and the instrumental constant has increased 3dB over the level from 1972. It means, that decreasing of instrumental constant of EK 38 could be associated with the changes of parameters of transducers mostly.
Reduction of instrumental constant for EK 38 was stronger than for hydrophone /Fig.4/ and total difference after the same period of exploitation was two times higher, over 7 dB. The transducer was installed inside the tank of stabilized platform and it seems to be profitable - because for other hull-mounted transducers observed sensitivity reduction was much higher /over 10 dB /.
Strong decrease of system sensitivity appears after 8 years of exploitation and since that moment the change is bigger than 1dB per year. It has a strong influence on biomass estimate error and in consequence on detection conditions / signal to noise ratio /.

CONCLUSIONS

Observations based on long period of exploitation of hydroacoustic stock assessment system and calibrating hydrophone parameters at 38 kHz can be finally summed up in following items:

1. Hydrophone sensitivities maintain good stability during first 5 years of exploitation / relative biomass estimation error was evaluated as smaller than 5% /.

2. Losses of hydrophone sensitivities in dB during next period of exploitation are increasing with the function $\sim t^4$ and the hydrophone can not be treated as any kind of standard for calibration.

3. It is recommended to install a new hydrophone every 4 years during vessel's class repair and to recalibrate it after 2 years of exploitation.

4. Losses in transducer sensitivities are stronger than for hydrophone, but they have no any direct influence on biomass estimate if the calibration of the system is carried out.

Change of transducers parameters has negative influence on echosounder detection level and it is suggested to replace transducers every 8 years of exploitation / every second 4 years class repair of the vessel/.

5. Figures of the time stability of hydroacoustic parameters can be used for estimation of system coefficients and evaluation of recalibration results.
It is important to pay attention on big changes of hydroacoustic sensitivity at higher frequencies and to take it under considaration when decision on choosing system frequency is discussed.

REFERENCES

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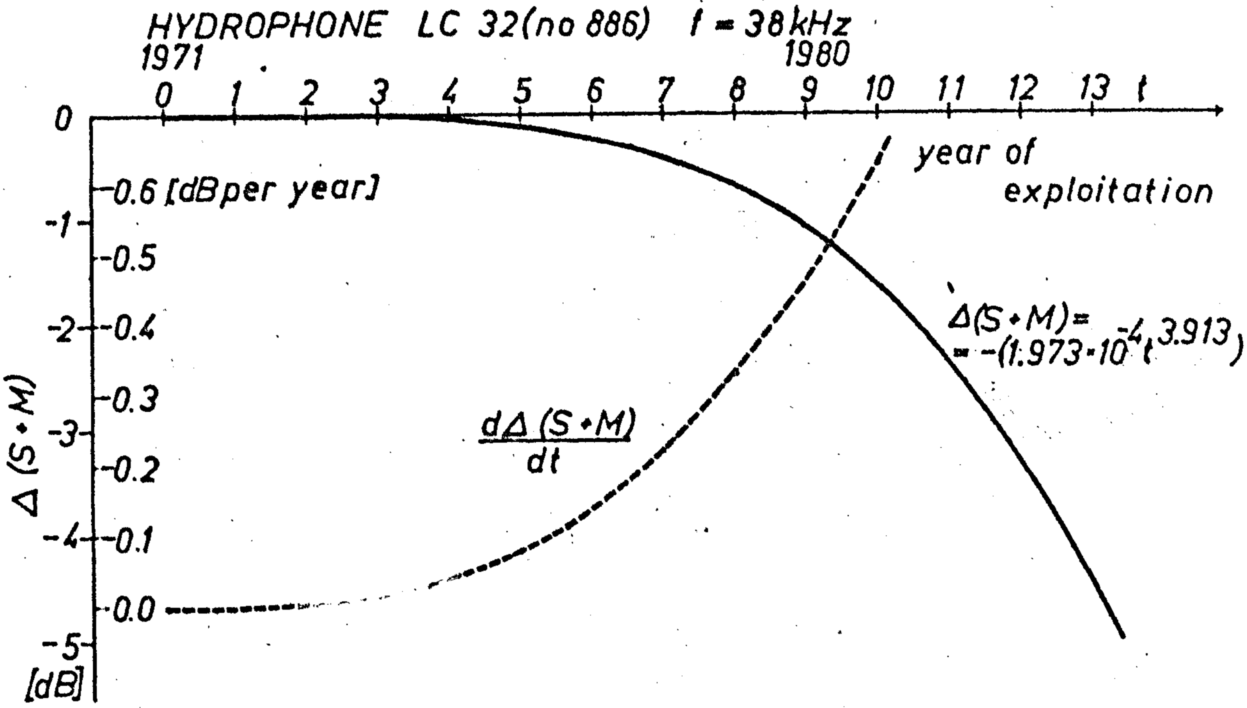

Fig.1. Regression lines presenting reduction of sensitivity of hydrophone LC 32 between years 1971-1983.

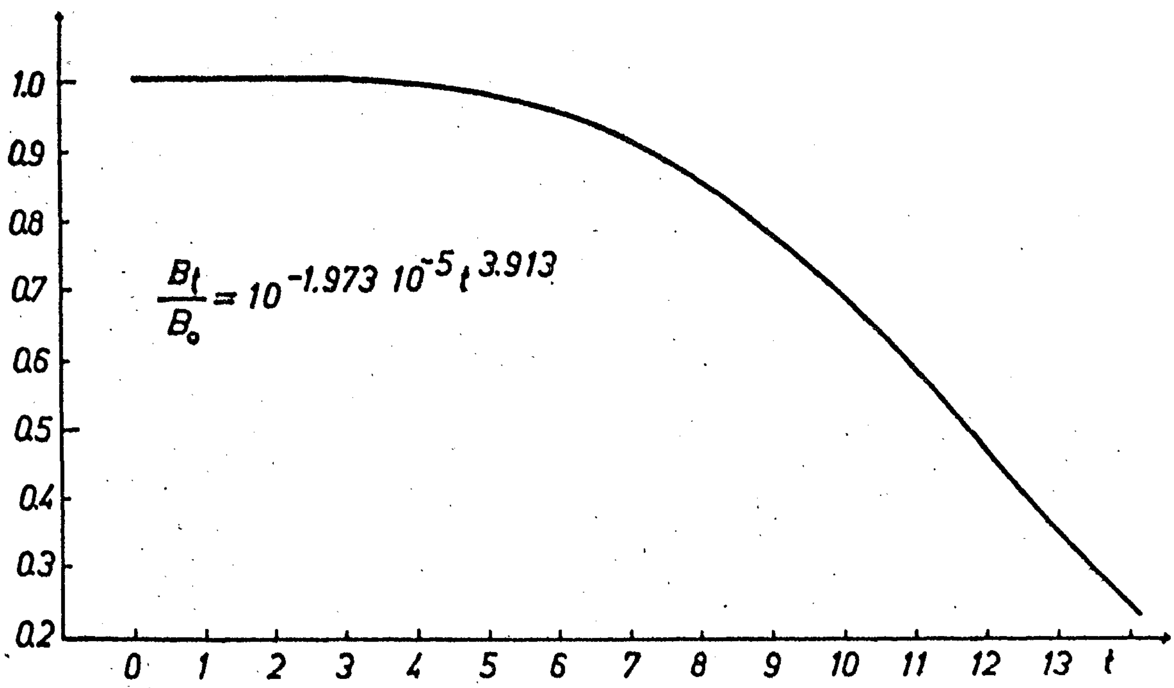

Fig.2. Relative biomass estimation bias related to calibrating hydrophone sensitivity reduction.

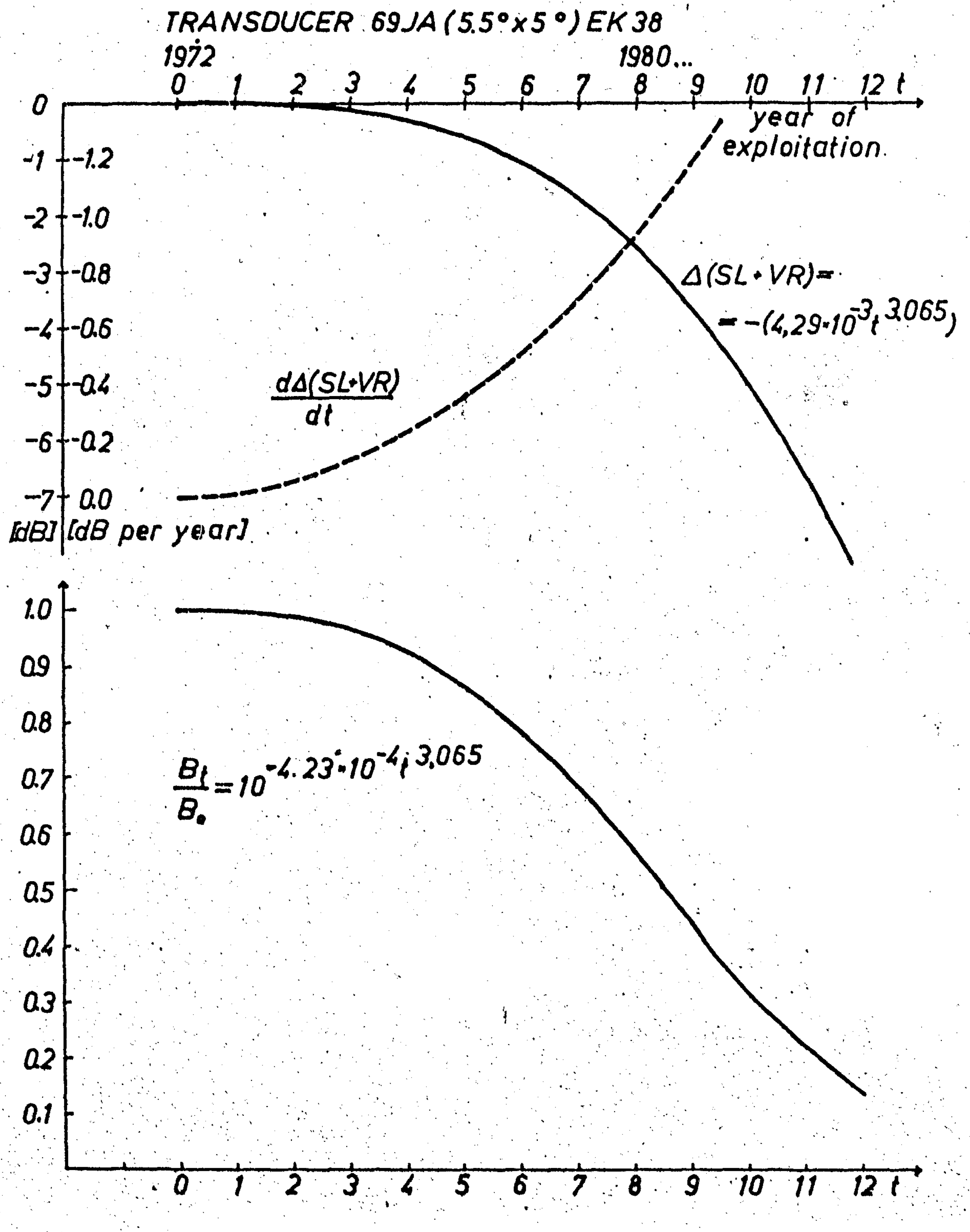

Fig.3. Regression lines presenting reduction of sensitivity of EK 38 echosounder between years 1972-1983. Relative biomass estimation bias related to reduction of the system sensitivity.

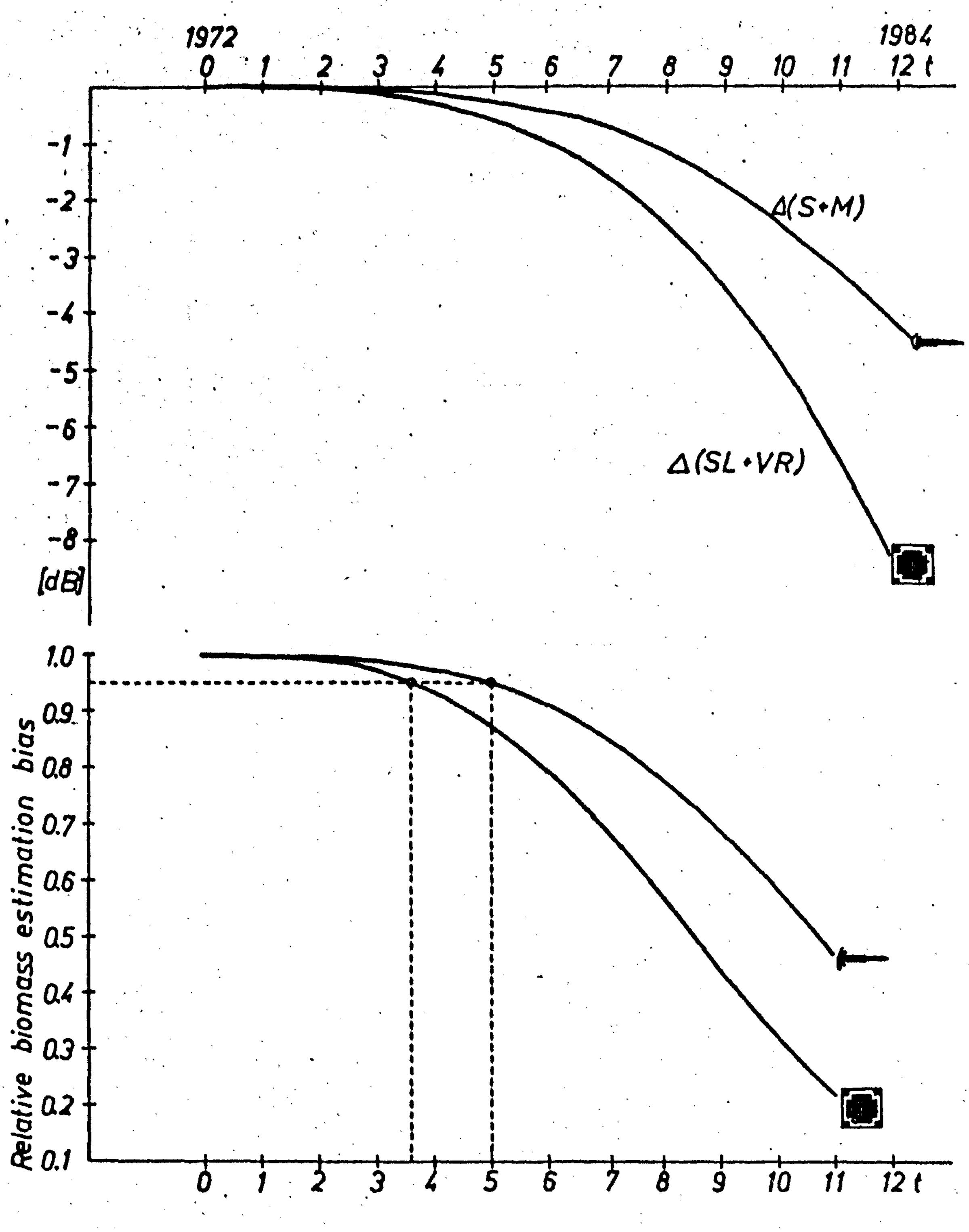

Fig.4. Comparison of acoustical stability during 12 years of exploitation of the echosounder and the hydrophone and the consequence of it on biomass estimation error.