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IN SITU TARGET STRENGTH MEASUREMENTS. PRELIMINARY DATA OF SARDINE (Sardina pilchardus W.) FROM THE MEDITERRANEAN SEA

by

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ABSTRACT

During the pelagic fishing stations of the acoustics surveys *Ecomed 91* and *Ecomed 92*, carried out in november 1991 and 92, series on sardine TS were collected using a SIMRAD EK-500 38 kHz split-beam echo sounder and echointegrator. Only data with similar features in bottom depth, trawling depth and % of capture were used. The Least-Mean-Square regression of mean TS on the logarithm of the mean fish length of the form *TS=mlog(l)+b* was finally applied to 11 data series giving m=29.73 and b=-74.08 with $r_{sq.}$=0.94 or, requiring that m=20, b=-63.34, which is higher than others to similars species but close to the Love's one. This could be explained for the trawling depth or for the short range of length analyzed.

INTRODUCTION

Since 1982 systematic acoustic surveys have been carried out in the Mediterranean Sea to estimate the sardine (Sardina pilchardus, W) and anchovy (Engraulis encrasicholus, L.) present in the continental shelf of the mediterranean spanish coast (Abad et al 1990, 1991).

Although sardine and anchovy are the most abundant pelagic species, there are also others important species like round sardinella (Sardinella aurita, Val.), horse mackerel (Trachurus trachurus, L.,T. mediterraneus, Std.and T. picturatus, Bowd.) and mackerel (Scomber scombrus, L., S. japonicus, Gm.). These species are mixed and the echograms and catches are normaly multispecific, being, sometimes, very difficult to allocate the echointegration.

For assessment purposes and in absence of an own TS, the sardine evaluation is done using the following TS equation of herring (Clupea harengus) (Degbonl et al, 1985) adopted for Iberian sardine (ICES, 1986):

$$TS = 20*Log(L) - 72.6 \quad (dB)$$

With the new Simrad EK-500 echosounder-echointegrator the *in situ* TS measurements are provinding and recorder on an echogram table splited by channel and in % by dB intervals (Bodholt, 1990).

The sardine *in situ* target strength measurements seems to be more suitable at sunset or night because sardine showed a typical behaviour characterized by different vertical distribution and school pattern during daytime and night. In the Mediterranean, during daytime sardine are concentrate in very dense and well separated close to the bottom schools; at night, lose this pattern, spreading for all the water column. The transition between these two kinds of behaviour occured during sunset and sunrise. When sardine are spread, the echoes can be resolved as single fish.

This paper describes the preliminary results on sardine *in situ* TS measurements collected during the fishing station of *Ecomed 91* and *Ecomed 92*, the two last acoustic surveys carried out in the continental shelf of the spanish mediterranean coast in november 1991 and 92.

MATERIAL AND METHODS

Preliminary material consist of acoustic and biological data collected during the fishing stations of *Ecomed 91* and *Ecomed 92* on R/V "Cornide de Saavedra", a 67 m long, 2,500 HP stern trawler, in the spanish Mediterranean Sea, between Point Europe and Cape Croisset.

1 Acoustic instrumentation

A Simrad EK-500 38 kHz split-beam echosounder-echointegrator was used for data collection. The integration layers were fixed at the next depth strata: 5-25, 25-50, 50-75, 75-100, 100-200, 200-300, 300-400, 400-500 and 500-1,000 m.

Two printers were connected with the echosounder, one of this recording 20 log r echograms (and the integrator table) and the other one recording 40 log r echograms and the TS-distribution by integration layer table at the end of each log interval (one nautical mile).

1.1 Calibration

Prior to each survey the echosounder system was calibrated using a 60 mm copper standard target sphere (Foote et al, 1987), which has a TS=-33.6 dB, and according with recommendations in the EK-500 manual. The calibration reports are shown in Table I.

2 Biological data

The biological data were collected using a pelagic trawl gear with a 20 mm codend and provided with a Simrad FR-500 netsonder. During *Ecomed 91* two differents gears were used; the first one with nets of 12 m vertical opening and was used in the firsts 20 fishing stations, and the second one with 22 m vertical opening for the others fishing stations. In *Ecomed 92* only a pelagic trawl with nets of 22 m vertical opening was used. The towed speed was 3.5-4.5 kn. In table II are summarized the characteristics of fishing station used in this work.

In each fishing station, catch was splited into species and weighted. Both biological and length samplings on each especie were made. For this analysis, only length composition and % in number on catch by especie were used. Table III shows the biological data used in this analysis.

4 TS data

In 40 log r echogram, TS table prints the TS distribution of individual echoes in % distributed into 24 groups each covering 1.5 dB. The lowest group covers TS values from -60 to -58.5 dB, and so on.

In each TS interval, the mean backscatering cross sections was calculated according to the equation (Foote et al., 1986):

$$\sigma = \frac{40\pi}{\ln 10} \frac{10^{TS2/10} - 10^{TS1/10}}{TS_2 - TS_1}$$

And the mean target strength,

$$TS = 10\log(\sigma/4\pi)$$

The number of echoes by TS interval in each fishing station was calculated as follow:

$$n_i = \frac{\Sigma p_{ij}}{\Sigma n_j} N$$

where,

- n_i is the number of echoes in the i-th TS interval
- Σp_{ij} is the summatory of the echoes proportion in the i-th TS interval and j-th mile of the fishing station
- Σn_j is the total number of nautical miles in the fishing station
- N is the total number of echoes in the fishing station

5. Data selection

In order to minimize the TS dependece from others variables than length composition, the following four criteria to select the data were used:

5.1 Trawling features

Data series were chosen according the following features:

- Bottom depth: Lower than 100 m
- Trawling depth: Trawl hauls made in the upper part of the water column (from 10-30 m).
- Time: from 19:30 to 22 GMT hour, when sardine was spread.

5.2 Catch composition

Only catches showing at least of 70% in number of sardine and less than 10% of anchovy and/or round sardinella were accepted.

5.3 Sardine length distribution

The length distribution had to be unimodal or with a clear mode and with short length range. Figure 2 shows the sardine length distributions used in this analysis.

5.4 TS distribution

Assuming a linearity between TS and length, similar length and TS distribution should be expected, that is, a normal distribution on TS is expected if the length distribution is close to the normality. Under this hypothesis only data series with a TS distribution close to the sardine length distribution were chosen. In cases, an amount of lower values in TS were observed in the TS distribution. Before to make the analysis, TS distribution were cleaned and the lower values removed. Table IV and figs. 3 and 4 show the TS distributions before and after removal the lower values.

RESULTS

After applying the selection criteria, 12 fishing station were used, 5 of 32 from *Ecomed 91* and 7 of 28 from *Ecomed 92*.

A Least-Mean-Square regression analysis of mean TS on the logarithm of mean fish length of the form *TS=mlog(l)+b* was applied and the result was:

Parameter	*Estimate*	*Std Error*	*T Value*	*Prob. Level*
Intercept	-74.5959	3.90662	-19.0947	.00000
Slope	30.0174	3.53583	8.4895	.00001

Correlation Coefficient: 0.937099 $R_{squared}$: 87.82 %
Std. Error of Estimation: 1.00139

Analizing the residuals it can be seen that the value corresponding to fishing station *P2191* is higher than others. In this fishing station, the % of anchovy is higher (10.9) and in the sardine length composition there is no a clear mode. A posterior ANOVA has shown that a significant portion of the variance of TS has not been explained by regression on logarithm of mean length.

For this reason the fishing station *P2191* was removed and the regresion analysis was recalculated giving:

Parameter	*Estimate*	*Std Error*	*T Value*	*Prob. Level*
Intercept	-74.0778	2.87373	-25.7776	.00000
Slope	29.7267	2.59825	11.4411	.00000

Correlation Coefficient: 0.967299 $R_{squared}$: 93.57 %
STD. Error of Estimation: 0.735374

With this regression, a large and significant portion of the vairance of TS is explained by regression on logarithm of the mean length.

The confidence limits for the slope are:

$$m = 29.73 \pm 5.88$$

which give a lower limit close to 23.85 with 95% confidence that does not reach to 20. In spite this, requiring that m=20 the TS function is:

$$TS = 20\log(l) - 63.34$$

DISCUSSION

The selection criteria applied to select the data series seem to be very restrictive, so the chosen data could be almost ideal for *in situ* target strength measurements of sardine. All fishing station are similars features and conditions and it should be expected that, in absence of other factors affecting the TS, only the differents length values might vary significantly the mean TS value from one fishing station to other. Statisticaly, the model fits well (R_{Sq} =93.57, 95% conf.), in spite of low number of data (11) and, the short range of length distribution (7.95 to 16.72 cm).

In any case, this TS value is very different than those assumed for sardine, but is similar to that calculated by Love (Love, 1971, 1977):

$$TS = 19.1 \log(l) - 0.9 \log(F) - 62.0$$

and for 38 kHz frequency give:

$$TS = 20 \log(l) - 64.32$$

For herring, which is a similar specie to sardine, the TS values for 38 kHz are:

Mean Length (cm)	b_{20}	*References*
21	-65.2	Nakken & Olsen, 1977
21	-72.6	Degnbol et al., 1985
28	-72.1	Foote et al., 1985,1986
14.6	-70.8	Lassen & Staehr, 1985
21	-71.9	Foote, 1987

TS are influenced by differents factors like the phisiology of fish or the fish behaviour. The differences between TS values might be caused for many factors as differences in salinity (Lassen, 1985), in length composition, depth, etc.

In this work, sardine has a low mean length (7.95 cm to 16.72) and it has been fished and studied close to the sea surface. With these conditions, and being sardine a physostome fish and in spite of low length, the swimbladder are more expanded and might give a high TS value .

On the other hand, the slope of the regression analysis is close to 30, and it suggests that TS is proportional to volume, l^3, and the echo strength could depend upon the volume of the fish, rather than the cross-section.

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Calibration report

Frequency: 38 kHz
Transducer: ES 38 B
2-Way Beam Angle (in Transceiver menu): -20.6 dB
Transducer Gain (in Tranducer menu): 26.5 dB
Target Strength of sphere: -33.6 dB

year	transmit power	ping interval	pulse length	band width	TS measur.	New tr. gain	S_A measur.	New 2-way beam ang.
1991	normal	1 sec	medium	wide	-33.6	25.9	5,741	-20.64
1992	normal	1 sec	medium	wide	-33.6	26.5	10,599	-20.80

Table I: Calibration report for both years 1991 and 92.

Fishing Station	Date	Time (GMT)	Lat(N)	Lon	Bottom Depth	Trawl. Depth	Vessel Speed	Gear Open.
P1191	30/10	19:20	38 07	00 26 W	55	25	4	12
P1391	31/10	19:20	38 35	00 03 E	51	25	4	12
P1491	31/10	21:50	38 43	00 16 E	58	25	4	12
P1791	01/11	21:55	39 17	00 10 E	38	20	4	12
P2191	03/11	20:00	40 06	00 36 E	70	25	4	22
P0292	28/10	21:30	41 19	02 13 E	69	15	4	22
P0992	02/11	20:15	40 39	01 10 E	95	15	4	22
P1092	03/11	20:45	40 06	00 27 E	57	15	4	22
P1592	06/11	21:00	43 09	04 24 E	76	15	4	22
P1892	11/11	19:45	39 36	00 04 W	58	15	4	22
P2192	14/11	19:45	38 35	00 11 E	55	15	4	22
P2392	15/11	20:30	38 02	00 31 W	57	15	4	22

Table II: Features of fishing stations.

Fishing Station	% Sardine	% Anchovy	% Rd.Sard	Mean Anchovy	Mean Rd.Sard	SARDINE Total	Sampling	Mean	S.D.	Range
P1191	93.46	-	5.34	-	13.70	4,029	266	13.34	1.04	11.5-17.5
P1391	87.65	6.88	4.95	7.90	15.38	11,218	138	11.13	0.89	8.5-13.0
P1491	89.49	0.52	9.00	-	18.25	3,252	107	11.64	0.91	9.5-14.0
P1791	92.12	0.78	6.31	-	16.83	1,470	178	10.60	0.64	8.5-12.5
P2191	84.99	10.90	0.81	12.69	-	11,827	152	12.36	0.96	9.5-14.0
P0292	81.92	2.79	0.35	8.23	-	5,760	128	7.95	1.64	5.5-12.0
P0992	89.57	6.71	-	12.24	-	6,956	162	14.81	1.02	12.0-20.0
P1092	71.08	0.04	0.04	-	-	1,722	274	13.49	0.67	11.5-16.0
P1592	89.35	7.52	2.97	10.78	18.04	4,926	340	15.18	0.96	13.0-19.0
P1892	84.95	-	3.56	-	20.25	858	250	14.03	0.96	12.5-18.5
P2192	74.06	-	0.16	-	-	10,497	330	13.02	1.12	10.0-16.0
P2392	69.97	4.30	0.07	10.82	14.25	2,066	341	16.72	0.98	13.0-19.0

Table III: Biological data of fishing stations.

Fishing Station	Before remove lower values			After remove lower values		
	Total Echoes	Mean (dB)	Std. Error	Total Echoes	Mean (dB)	Std. Error
P1191	6,594	-42.68	0.21	5,095	-41.62	0.13
P1391	20,835	-43.16	0.08	19,394	-42.87	0.06
P1491	5,426	-44.97	0.23	3,711	-43.52	0.14
P1791	11,420	-44.72	0.14	9,657	-44.03	0.09
P2191	5,888	-45.50	0.24	4,077	-43.99	0.16
P0292	3,298	-46.98	0.21	3,154	-46.81	0.19
P0992	1,353	-40.74	0.52	954	-39.29	0.30
P1092	1,190	-40.62	0.54	912	-39.51	0.30
P1592	1,768	-42.34	0.39	661	-39.31	0.36
P1892	1,005	-41.99	0.62	608	-40.00	0.33
P2192	4,585	-40.88	0.23	3,658	-39.97	0.14
P2392	1,731	-38.69	0.47	1,274	-37.34	0.27

Table IV: Acoustic data of fishing stations.

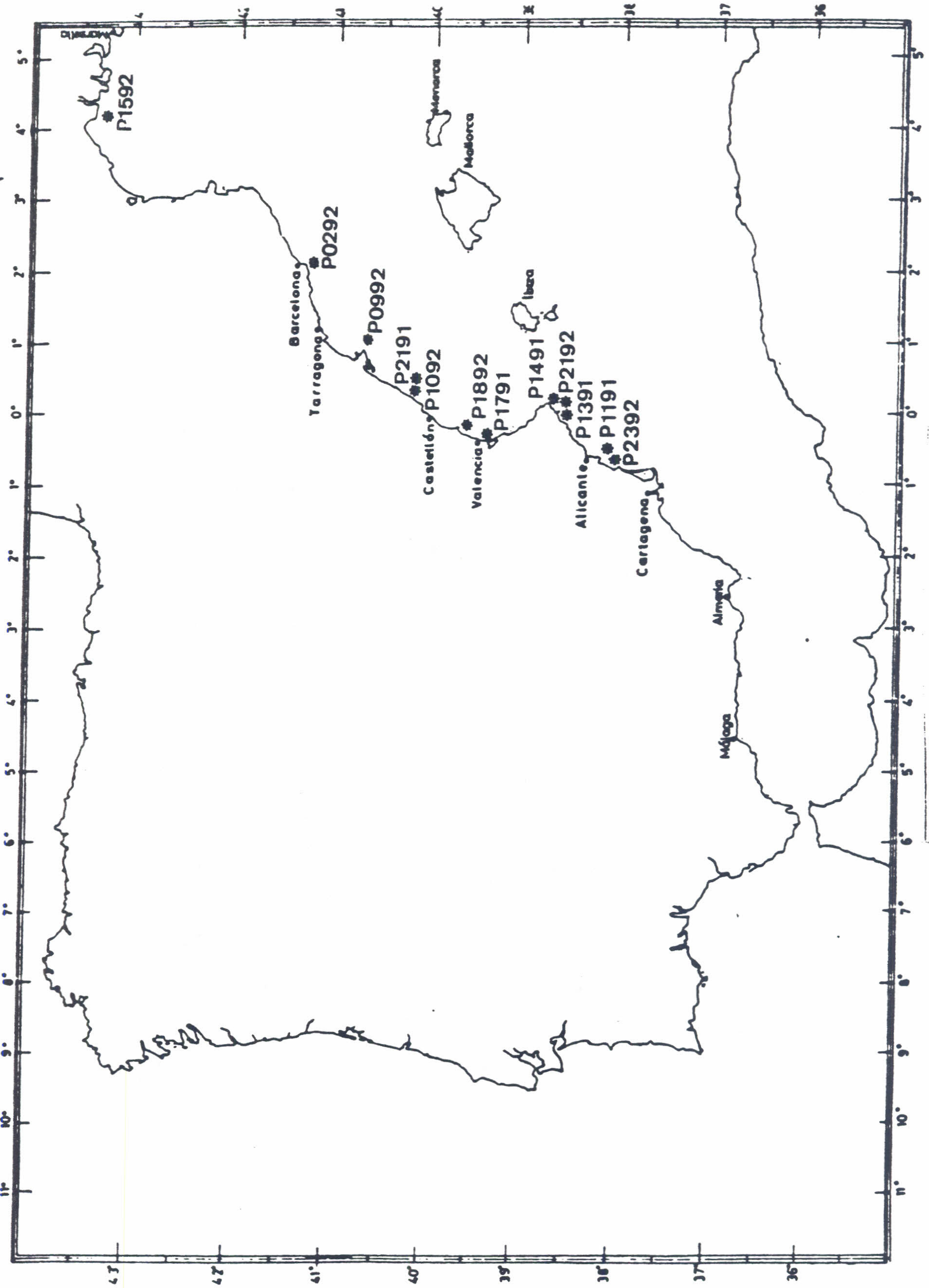


Figure 1: Pelagic trawl stations situation.

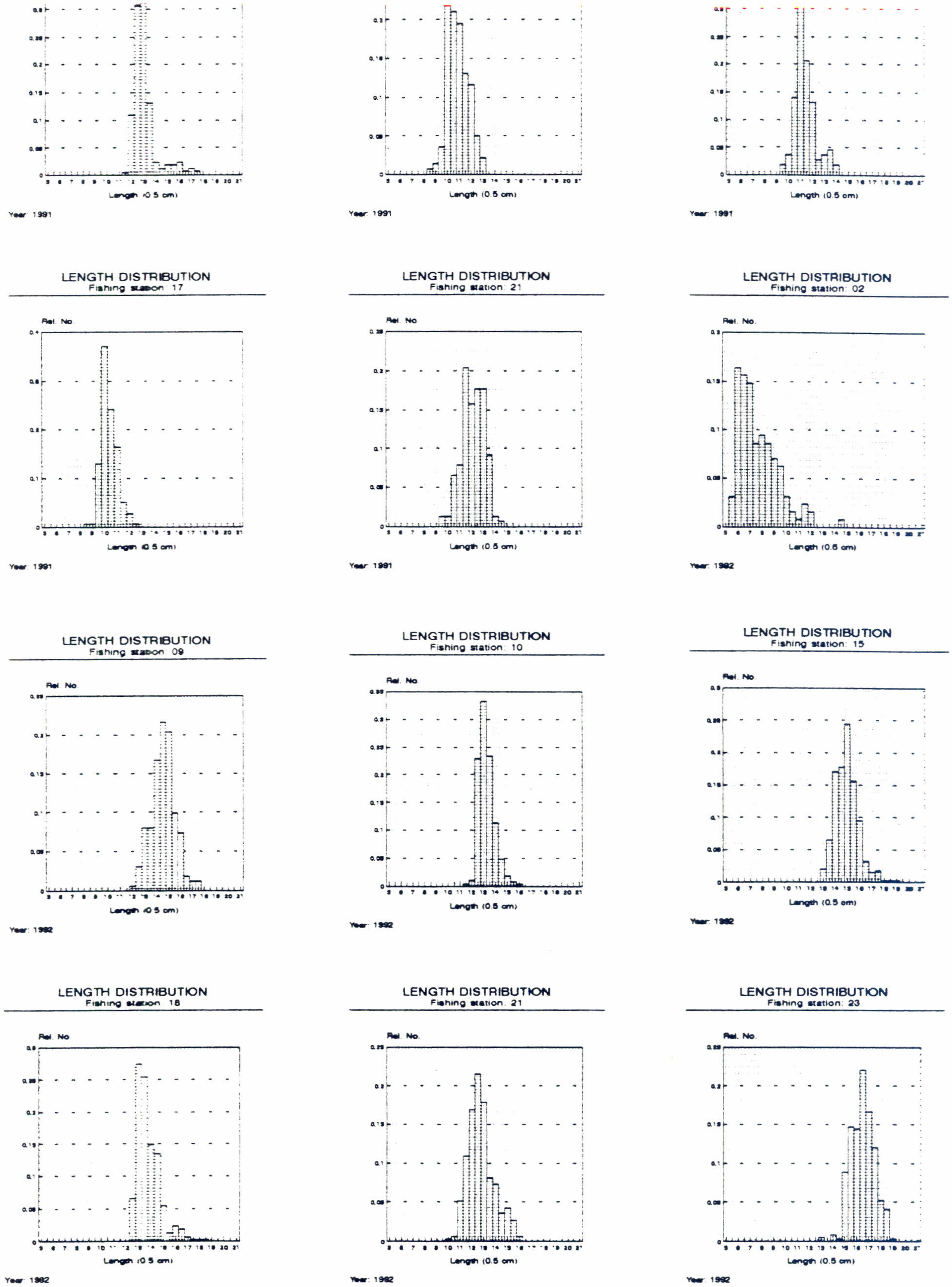


Figure 2: Length distributions.

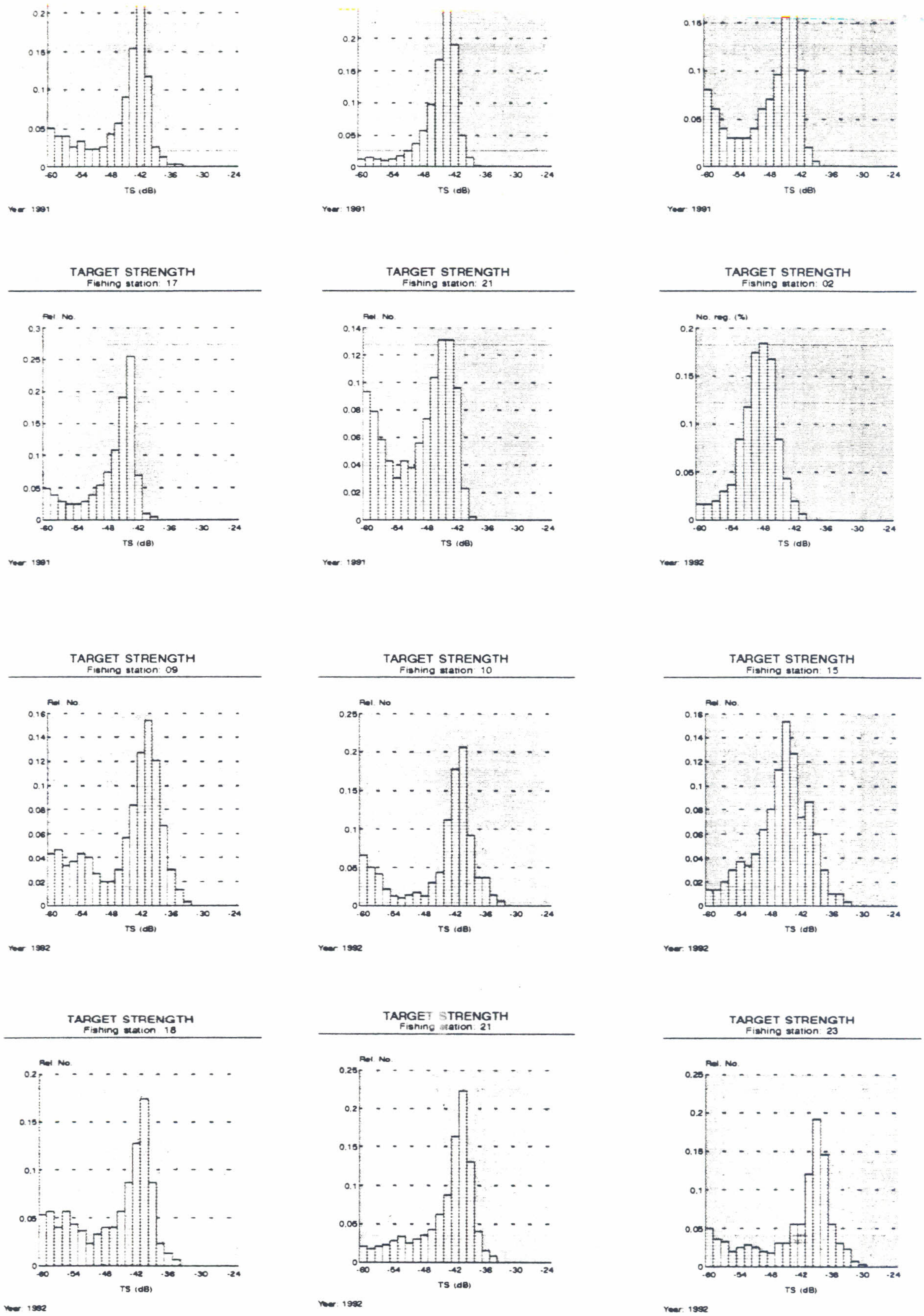
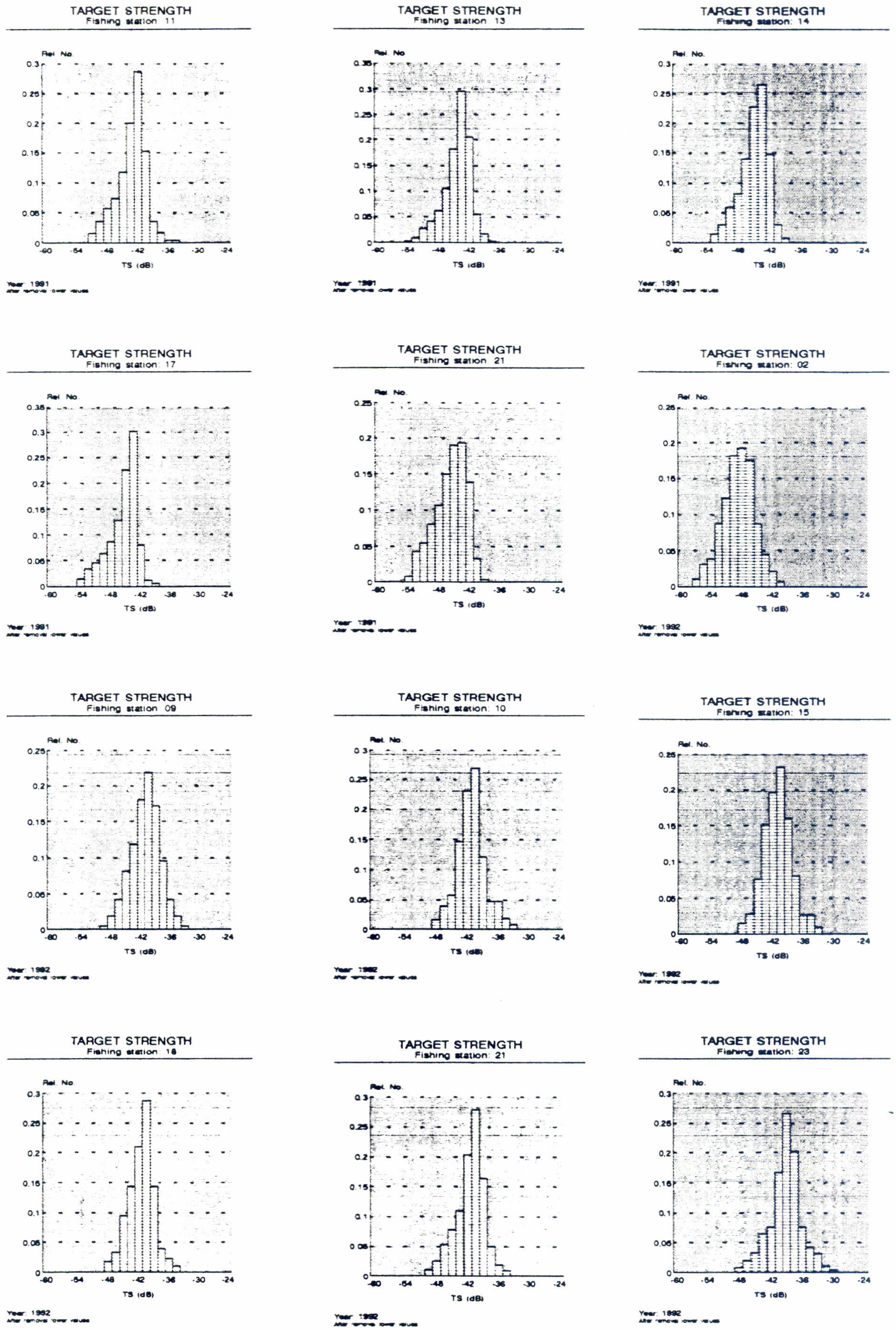
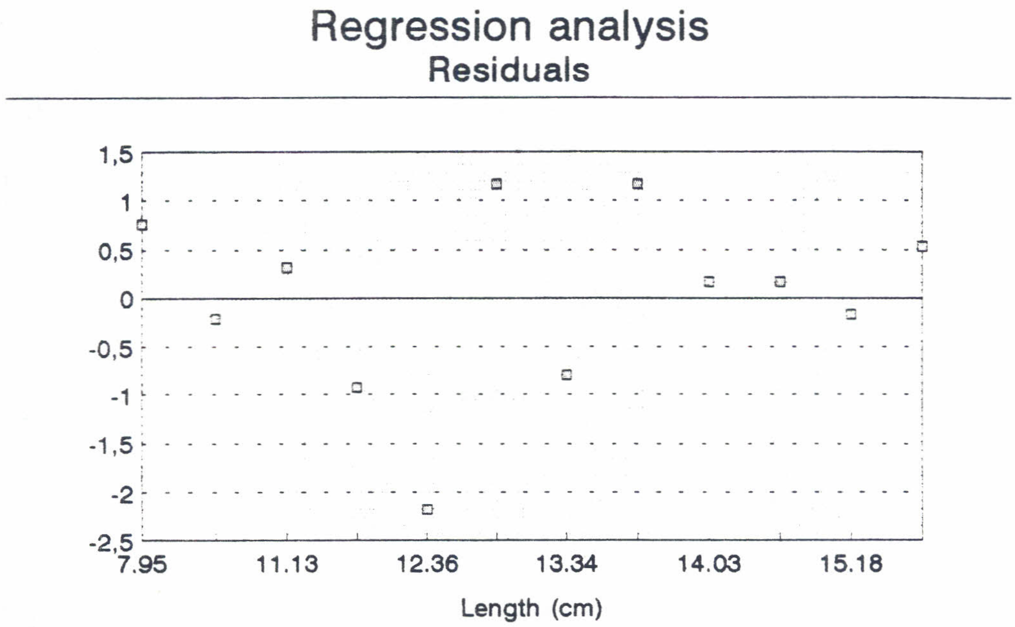


Figure 3: TS distributions before remove lower values.



<u>Figure 4</u>: TS distributions after remove lower values.



Including P2191

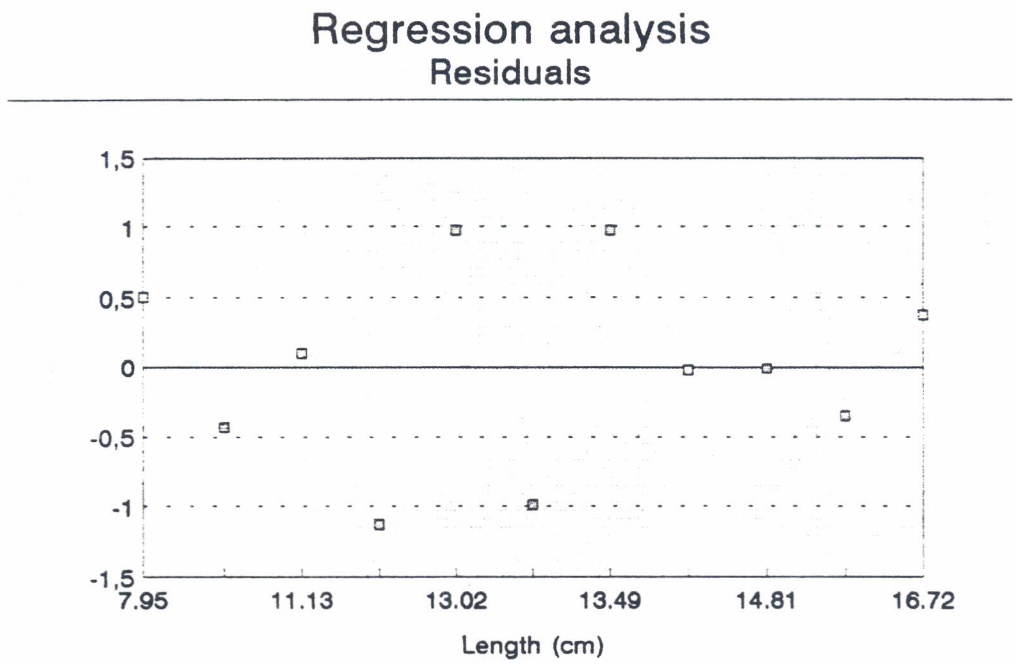


Figure 5: Examination of residuals in regression.