Echo-Integration during T-ECHO project cruises, in Adriatic and Catalan seas (1993-1995)

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SUMMARY : BioSonics vertical echosounder model 102, built in dual-beam technology, was used in the five cruises of T-ECHO project (AIR-1 CT 92 300314), three in the Catalan Sea (western Mediterranean, near the Ebro river delta) and two in the Adriatic Sea (northern fraction), as one of the basic operational devices on board of R/V García del Cid. Other acoustic equipment were a multibeam sonar RESON and the school classifier InesMoviedB, coupled to the BioSonics echosounder. The instrument disposes of three frequencies: 38, 120 and 200 kHz, but only the 38 kHz frequency permitted satisfying results throughout the whole period. Simultaneously, environment data were gathered continuously (ADCP, surface thermosalinometer) or at discrete points (CTD vertical profiler), separated by not more than 7 miles. Through this paper, all activities concerned with echointegration are described and a first approach to the marine system description based on the obtained echointegration values is presented. It is to notice the small ESDU chosen (0.1 nm on horizontal axis and 2 m on the vertical axis), thus the database covers not only the numeric process and analysis, but also the global representation of data as "image", at lesser scale than pelagic fish distribution, except for the small schools. To this respect, the use of TECHO_VIEWER software (which has many of the concepts of a GIS), for the study of the data is rather advantageous as it allows a quick and simultaneous screen visualisation of different cruises, transects, etc. as well as distribution of other parameters gathered simultaneously in the same surveys (environment, school classifications, etc.).

INTRODUCTION

One of the objectives of the research project known by the acronym T-ECHO (ref. AIR-1 CT92 300314) was the study of the relationships between spatial structure of small pelagic fish populations and environmental factors.

The proposed study area was the Adriatic Sea, specially its northern fraction, where 17 years of yearly cruises hold a unique acoustic historic data set. Combining the revision of such data set with the SST (Sea Surface Temperature) maps provided from satellite archives and scattered data from wind stress and Po river discharges, could forth a group of hypothesis to test in two new cruises (to be performed during the project execution period), and also to check them in a study case area, having some similarities, but also some differences, at the Catalan Sea (near the Ebro river delta), carrying out three extra cruises.

It will not be here argued why such planning had to be rearranged. But in fact, the foreseen new cruises were planned without any previous strategy than experience of involved teams. Thus, for Adriatic, the guidelines of the historic cruises made up the scheme in which Adriatic cruises were prepared. For the Catalan Sea, cruises were planned based on the experience in scale studies of hydrographic processes conducted by ICM participants.

The main investigation tools were acoustic, biological and hydrographic sampling and satellite information (for sea surface temperature synoptic maps).

One of the aims of this project was also the study of the relationships between population characteristics and oceanographic parameters at different spatial and temporal scales.

As the large scale study (analysis of historical data) failed, the remaining scales were medium and small scales. Borders between medium and small scale are rather ambiguous, specially when studying highly dynamic phenomena such as those taking place in the marine system. It was decided that interannual rhythms would be the higher level of time scale, and the lower one the day periodicity.

It was foreseen to perform five cruises, two in the Adriatic and three in the Catalan Sea. In the Adriatic two research vessels participated in the cruises: R/V Salvatore Lo Bianco (CNR) with priority for acoustic and biological sampling and R/V García del Cid (CSIC) with priority for environmental studies, but also being deployed with and gathering information from acoustic instruments. In the Catalan Sea one single research vessel (García del Cid) has undertaken the cruises, with the help of a chartered fishing vessel in order to obtain the biological samples.

Sampling techniques included gathering of environmental data by means of discrete CTD vertical casts and continuous current measurements with ADCP; on the acoustics side, continuous dual beam echosounding was performed, and some pelagic trawls were also done to assess species and size target composition.

Acoustic sampling was done with vertical echosounder and side looking SONAR (Bahri *et al.*, 1997). The ICM team inside T-ECHO project was involved in environmental sampling that included CTD casts (Salat *et al.*, 1997) and ADCP sampling, biological sampling (for species and size composition of targeted fish) and echointegration sampling (the present paper).

A dual beam BioSonics echosounder Mod 102 (Anonymous, 1990 and 1991) was operating during the five cruises. Calibrated output signal from this equipment was processed in two different ways (i) INES-MOVIES school analyser interface, and (ii) BioSonics ESP (Echo Signal Processor) allowing online echo-integration and TS processes. This report deals only with the echo-integration data.

MATERIAL AND METHODS

The basic instrument used for echointegration studies was the BioSonics Mod 102 echosounder based on dual beam technology with different frequency transducers. During all T-ECHO cruises a 38 kHz was used, operating at 2 s ping rate and 0.4 ms pulse rate. The insonified beam angles are 10° and 25°, for -3dB points on the narrow beam.

The transducer was mounted in a V-fin towed body, sailing at 4-6 meters depth; the towing was done by a single power and signal cable. The ensemble was of easy operation by means of a mobile crane hauling up the V-fin at each vessel stop for CTD stations, etc. The operating towed body was situated near the mid overall length of the vessel in order to decrease the acoustic noise input from the propeller and other vessel sources.

Figure 1 shows the scheme of the instrument deployment on board R/V García del Cid, also including the environment instrument devices regarding ICM responsibilities, except for InesMovieB. In fact one of the calibrated echo-sounder signal outputs was the input line for the InesMoviesB school analyser interface, in service during the four latest cruises (GICS-2, GICS-3, GIAS-2 and GIAS-3) by ORSTOM team, (Soria *et al.*, 1997).

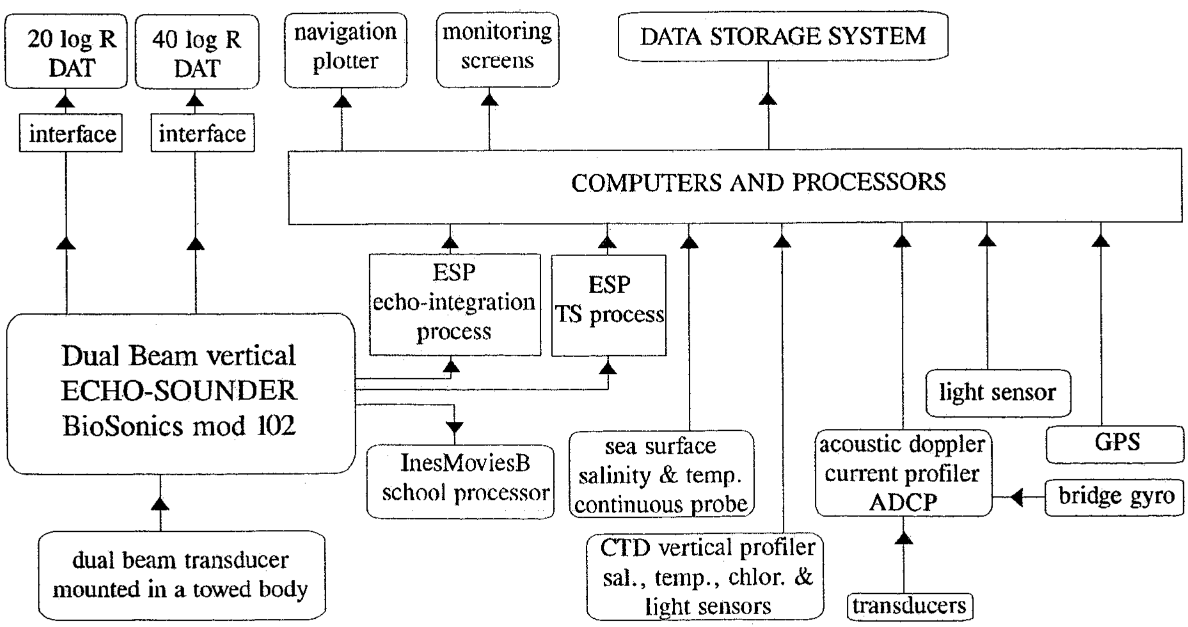

FIG. 1. - Scheme of the instrument deployment on board of R/V García del Cid during T-ECHO project cruises under responsibility of the ICM team. The school processor Inves-MoviesB was under responsibility of the ORSTOM team.

The second ESP processor, for on-line TS analysis, was installed only in late cruises, but from the first one, two DAT systems were storing in digital magnetic tapes the calibrated output signals for echo-integration and TS playback processes.

Calibration

During the development of T-ECHO project, the echosounder and transducer equipment were calibrated several times.

The first calibration was done at the BioSonics site (Seattle, USA) after the first cruise GICS-1; the reason was not only calibration but instrument complete performance checking. That calibration was performed by BioSonics staff by using a calibrated reference transducer in a small laboratory fresh water tank.

The other calibrations were done using the "calibration sphere" methodology by one of the author (A. Castellón). The first one was done at the experimental sea water tanks of IFREMER site in Plouzané (near Brest, France), and the second one on board the R/V García del Cid, in a relatively calm bay of Vulcano Island, north of Sicily Island (Western Mediterranean).

As the transducers are mounted in a towed V-fin body, it is rather difficult to stabilise the system at sea, even in very fine weather conditions. Thus, the transducer was removed from its case and installed in a proper frame: in IFREMER experimental tanks, the transducer was mounted in a dedicated crane designed by Anne Lebourges and the process was carried out in laboratory conditions. In Vulcano Island, the transducer was mounted in a special frame located at one side of the vessel (starboard).

Calibration in Brest and Vulcano were done collecting data of echoes from a tungstene carbide sphere lowered to predetermined depth by means of three very thin nylon filaments. Signals were processed by BioSonics ESP dual beam processing software and stored on computer, as well as in a DAT system for extra post-process replay if needed.

Data was collected following BioSonics recommendations: (i) Calculate the expected TS (dB) of standard target and translate that value into expected echo sounder output voltage; (ii) Collect field calibration data on standard target; (iii) Calculate TS of standard target's field calibration data using echo signal processor (ESP); (iv) Compare expected TS with calculated TS; (v) Apply correction factors to SL and G1 of the acoustic system, if necessary, through the sonar equation:

$$VL = SL + (G_1 + RG) + TS - 2B$$

where VL is the Voltage Level (dB||V), SL is the Source Level (dB||1 μPa, ref. 1m), G_1 is the Receiver Sensitivity (dB V/μPa, ref. 1 meter), RG is receiver gain (in dB), TS is Target strength and $2B$ is the beam pattern Factor (for target on axis 2B=0). Then voltage in Volts can be calculated as : $V = 10^{VL/20}$.

Previous to accepting corrections, the data gathered were filtered with a SQL language from the database output files by ESP_viewer BioSonics program for the variables: "Depth filters" and "Off axis filters".

The correction factor is the difference in dB between TS from sphere and TS measured; the Source Level is then modified with this value.

Calibration in Seattle

The results of the echosounder and transducer system calibration done at BioSonics factory laboratories in August 15th, 1993 is shown in Table 1.

Table 1. - Results of calibration performed at BioSonics site (August 15th, 1993). A: Echosounder settings; B: transmitter settings *versus* Source Level; C: receiving sensitivity

A		
	Frequency	38 kHz
	Receiver Gain	0 dB
	Bandwidth	5 kHz
	TVG Range	0-250 m.
	a	0 (fresh water)

B	dB	SL dBμPa ref. 1m
	0	220.619
	-3	217.718
	-06	214.915
	-10	211.077
	-13	208.161

C	receiver channel	dBV/μPa
	1 narrow 40 log R	177.526
	1 narrow 20 log R	149.683
	2 wide 40 log R	177.078
	2 wide 20 log R	149.201
	Simul. 20 log R	149.742

Table 2. Instrument settings and experiment conditions during the sphere calibration at IFREMER tank.

Frequency	38 kHz
Transmitter Gain	0 dB
Bandwidth	5 kHz
TVG Range	0-250 m.
Blank distance	2 m
Pulse Length	0.4 ms
ping per second	1
depth of sphere	9.3 m
sound speed	1500 m/s
nominal sphere TS	-42.4 dB

Table 3. The settings on ESP software were (from the calibration files).

SRCLEV	220.61
RECGAIN	0.0
XMIT	0.0
GAIN 1 20 logR	-149.67
GAIN 1 40 log R	-177.52
GAIN 2 20 log R	-149.20
GAIN 2 40 log R	-177.07
GAIN simul 20 log R	-149.74
WBDROP	1.304600

Table 4. Sphere TS experimental measurements (TS variables are expressed in dB): valid samples, mean value, range and standard deviation.

Valid N	548
Mean TS	-43.37
Minimum TS	-45.8597
Maximum TS	40.7137
Std. Dev.	.599752

Calibration in Ifremer

The instrument and software settings as well as the environment characteristics affecting the experiment during the calibration by the sphere method done at IFREMER sea water tank, on March 28th 1994, are shown in Table 2 and Table 3. Sound speed has been computed from salinity and water temperature parameters.

From the sonar equation it was expected to measure a target voltage of 1.08, according to:

$$VL_{sphere\text{-}calc.} = 220.619 + (-177.526 + 0) - 42.4$$

$$VL_{sphere\text{-}calc.} = 0.693 \text{ dB} \,||\, \text{V}$$

$$10^{0.693/20} = 10^{0.03465} = 1.08 \text{ V}$$

and in fact 1.12 volts was the experimental oscilloscope measure.

Table 5. Instruments settings and experiment conditions during the sphere calibration at Vulcano Island.

Frequency	38 kHz
Transmitter Gain	0 dB
Bandwidth	5 kHz
TVG Range	0-250 m.
Blank distance	2 m
Pulse Length	0.4 ms
pings per second	2
depth of sphere	8.55 m
sound speed	1500 m/s
nominal sphere TS	-42.4 dB

Table 6. Single target criteria.

limit	½ of PL	0.4 and 0.6 volts
measure at	¼ of PL	0.4 and 0.72 volts

Table 7. Sphere TS experimental measurements (TS variables are expressed in dB): valid samples, mean value and range, during the Vulcano calibration (three data set were performed)

	data set 1	data set 2	data set 3
Valid N	492	887	1466
Mean TS	-45.92	-45.91	-45.72
Minimum TS	-41.88	-32.96	-41.53
Maximum TS	-49.78	-54.80	-51.86

In Table 4 are shown the results of the calibration measurements over 548 effective samples.

Thus from nominal TS (-42.4) of the sphere at the above mentioned sound speed (1500 m/s), it must be substracted the experimental value found (43.37) in order to obtain the correction factor, that is 0.97 dB less. New Source Level will be:

$$SL_{new} = 220.619 - 0.97 = 219.72 \text{ dB}$$

which has been applied to the acoustic equations for computings on GICS-2 and GIAS-2 cruise data.

Calibration at Vulcano Island

The instrument settings as well as the environment characteristics affecting the experiment during the calibration by the sphere method done at Vulcano Island, on September 24th 1995, are shown in Table 5. Software settings are the same as in Table 3. Criteria for effective single target echo detection are shown in Table 6.

During the sphere calibration three set of measurements were done; results are shown in Table 7.

Following the same procedure than previously:

$TS_{measured}$=-45.92+6 dB (RG)=-39.9632 dB

Correction factor=-42.4-(-39.9632)=-144 dB

SL_{new}=SL_{old}-correction factor=

=220.619+2.44=223.06

and it has been applied to the acoustic equations for computings on GICS-3 and GIAS-3 cruise data.

Echosounder survey settings

Echosounder settings are conditioned by sampling objectives. It might rise a conflict if "good" echoes (strong echoes above ambient noise level) from small individual fish is the preference, simultaneously with gathering information for fish schools study. In such a case a priority must be established. During T-ECHO cruises such conflicts appeared; thus, changes were done in the echosounder settings. During GICS-3 and GIAS-3 receiver gain was set to -6 dB to avoid some saturation of big schools echoes

During the five T-ECHO cruises different echosounder settings were used, but some of the parameters remained unchanged during the whole project surveys; they are shown in Table 8.

Table 8. Common echosounder settings for all five T-ECHO cruises

TVG Range	250 m
Band Width	5 kHz
Blanking distance	2 meters
Range	250 meters
Transmitter gain	0 dB
Trigger interval	2 ping/second
Pulse width	0.4 ms
Sound velocity	1500 m/s

Other parameters were changed due to several reasons. Table 9 shows the most important changes in the settings. It should be noticed that first cruise (GICS-1) was, in some way, a test and instrument training survey.

The data post-processing of echointegration, with BioSonics technology, permits some changes in parameters from calibration. ESP software defines "A" constant as :

$$A=(\pi\ \tau\ c\ \sigma_{bs}\ p_o^2\ g_x^2\ b^2(\theta))^{-1}$$

where π is 3.14159.., τ is the pulse width in seconds, c is the speed of sound (ms^{-1}) σ_{bs} is the average back scattering cross section (m^2fish^{-1}), p_o is the RMS transmitted pressure measured at one meter from the transducer (μPa), g_x is fixed through system gain measured at one meter from the transducer (volts/μPa), and $b(\theta)$ is the beam pattern factor.

Table 9. Processing parameters of echo-sounder that changed during cruise, or part of it.

cruise	GICS-1	GICS-1	GICS-1	GICS-2	GICS-3	GIAS-2	GIAS-3
legs	1 to 4	4 to 10	10 to 20	1 to 28	1 to 28	1 to 15	1 to 14
Src. Lvl.	221.70	221.70	221.90	220.62	220.62	217.72	220.62
Rec. Gain	0	0	0	0	-6	0	-6
PW	0.60	1.00	1.00	0.40	0.40	0.40	0.40
BPF	0.00259	0.00101	0.00259	0.00420	0.00259	0.00420	0.00259
G 1 20	-149.60	-148.40	-149.30	-149.68	-149.68	-149.68	-149.68
G 1 40	-177.50	-176.40	-177.30	-177.53	-177.53	-177.53	-177.53
G 2 20	-149.60	-148.60	-149.30	-149.20	-149.20	-149.20	-149.20
G 2 40	-177.50	-176.40	-177.30	-177.08	-177.08	-177.08	-177.08
GS 20	-149.60	-148.50	-149.30	-149.74	-149.74	-149.74	-149.74
Old *A* const.	2.67E-01	2.29E-01	1.16E-01	1.03E-05	6.68E-05	2.01E-05	6.68E-05
New *A* const	8.43E-06	1.77E-06	4.51E-06	7.08E-04	6.68E-05	5.29E-05	6.68E-05
Noise v	0.18	0.18	0.18	0.05	0.05	0.05	0.05
Strata m	10	10	10	2.5	2	2.5	2
Sigma used	3.16E-05	2.00E-05	3.90E-05	1.00E-00	1.00E-00	1.00E-00	1.00E-00

Then, with computer tools it is possible to "recalibrate" all the data before transforming Relative Density into Absolute Density. For this reason, σ_{bs} was set to 1.0 in all the cruises, except of GICS-1.

Through this way, the relative density is defined as the sum of sampled squared voltage in each strata divided by the product of the number of processed pings and the number of samples in each strata minus the number of missed samples in each strata during the time interval (ESDU). Multiplying this relative density by the *A* constant, absolute density is obtained.

In fact, the results presented in this paper are no real Absolute Densities, as they are not scaled to fish densities. But, as they are scaled for $\sigma_{bs}=1$ they can be considered as absolute densities, as kind of hydrographic parameter comparable through the cruises.

Echointegration parameters

In the first cruise, GICS-1, the ESDU size was established as 1 nautical mile and strata width was set to 10 meters. In the post-processing it appeared clearly that this ESDU definition was in contrast with the small spatial scale as was defined object of research.

For the remaining cruises (GICS-2, GICS-3, GIAS-2, GIAS-3) the ESDU was defined having 0.1 nautical mile. During GICS-2 and GIAS-2 the strata definition was 2.5 meters, and in GICS-3 and GIAS-3, the strata height was set to 2 meters. These new definitions increase the resolution of echointegration data as it will be shown later.

Survey Design

T-ECHO project surveys were carried on in two areas: (i) Catalan Sea, and (ii) Northern Adriatic Sea.

The Catalan Sea area is part of the western Mediterranean (Schmidt, 1912), between a little north of the France/Spain border and Cape La Nao. The studied area in T-ECHO cruises is the subregion limited in the north by the Golf de Sant Jordi, the south border being close to the port of Castellón. Included in the area is a wide continental shelf (30-40 miles wide by 90 miles long) and receives in its northern part freshwater from the Ebro. In the T-ECHO project documents this study area is named indifferently Catalan Sea or GICS area.

The vessel's track was designed as parallel transects separated seven miles, approximately, from the coast until the slope, offshore. The transects were nearly perpendicular to the coast line. Each cruise consisted of two consecutive coverages of the study area, the first one was sailed from north to south, and the second, south to north. During the first coverage all instruments were deployed and a dense CTD cast grid (each seven miles) was performed, in spite of little interference for the Sonar from the ADCP. During the second coverage, it was omitted one of each two CTD cast, and the ADCP was switched off in order to obtain better lateral multibeam sonar detections. The transect lines (also known as "legs") were the same for each coverage and cruise.

The selected strategy may allow to obtain results on time variability that will aid in the interpretation of spatial variability of structures. Also it will permit a more accurate interpretation of the effects of vertical diel migration.

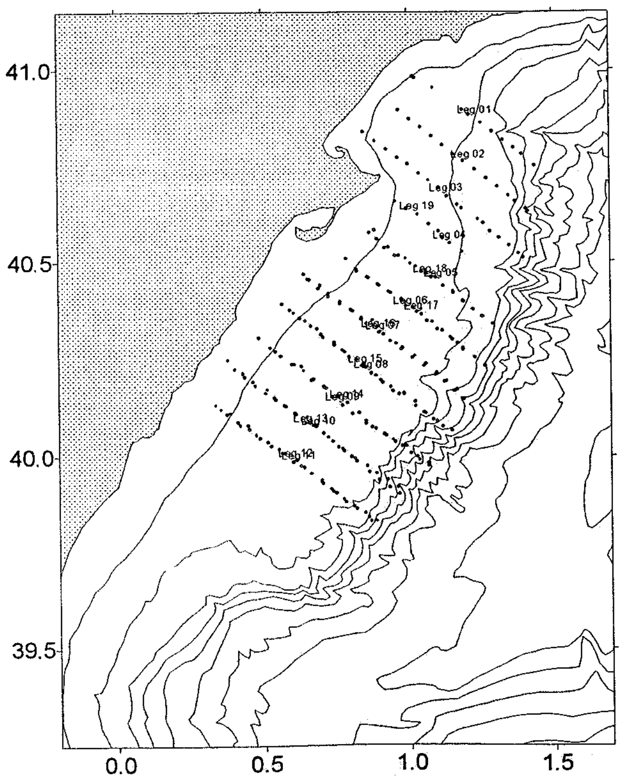

FIG. 2. - Fraction of the Catalan Sea (Western Mediterranean), known as GICS area, where the GICS set of cruises were carried out. To note the Ebro river mouth in the northern part of the area and the wide continental shelf. Isobath lines are for depths of 50, 100, 200, 400, 600, 800, 1000, 1200, 1400 and 1600 m. The points represent the ESDU positions (size 1 nautical mile) for GICS-1 cruise (May 1993), with two coverages.

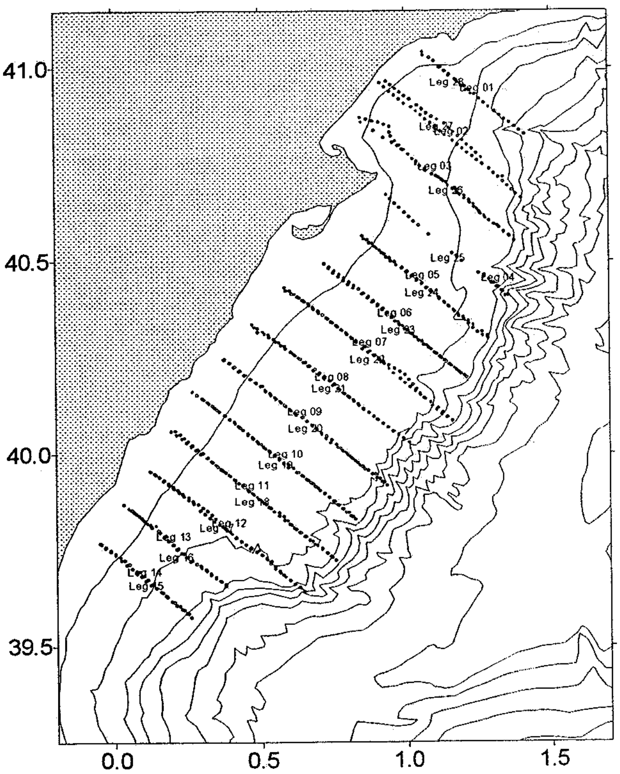

FIG. 3. - Map of GICS-2 cruise (May 1995), with two coverages. Points are plotted at each 10 ESDUs (of 0.1 nautical mile) position.

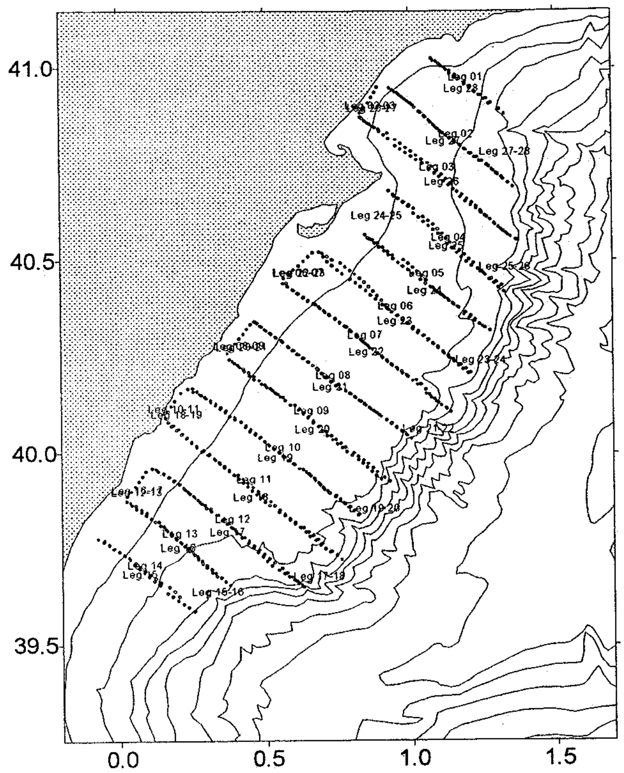

FIG. 4. - Map of GICS-3 cruise (May 1995), with two coverages. Points are plotted at each 10 ESDUs (of 0.1 nautical mile) position.

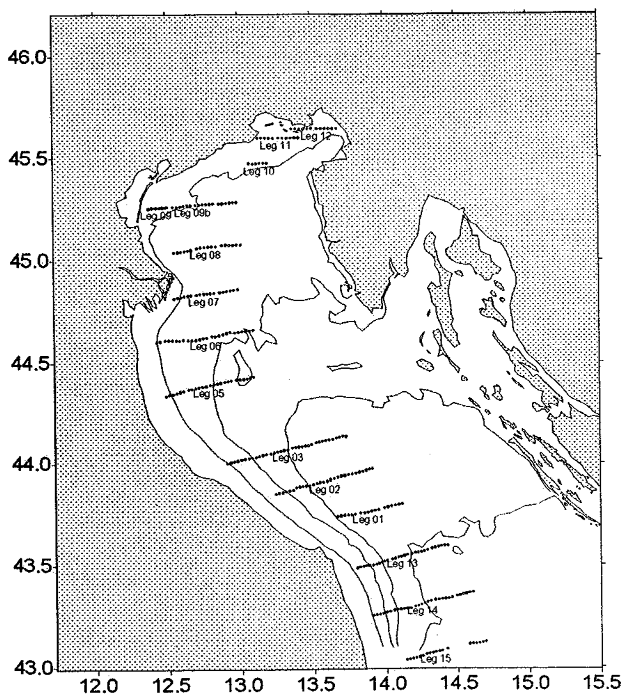

FIG. 5. - Map of North Adriatic with isobath lines at depths of 20, 40, 60 and 80 m. Points are plotted at each 10 ESDUs (of 0.1 nautical mile each). Cruise GIAS-2, September 1994. Due to a plot error, transect 04 is not shown.

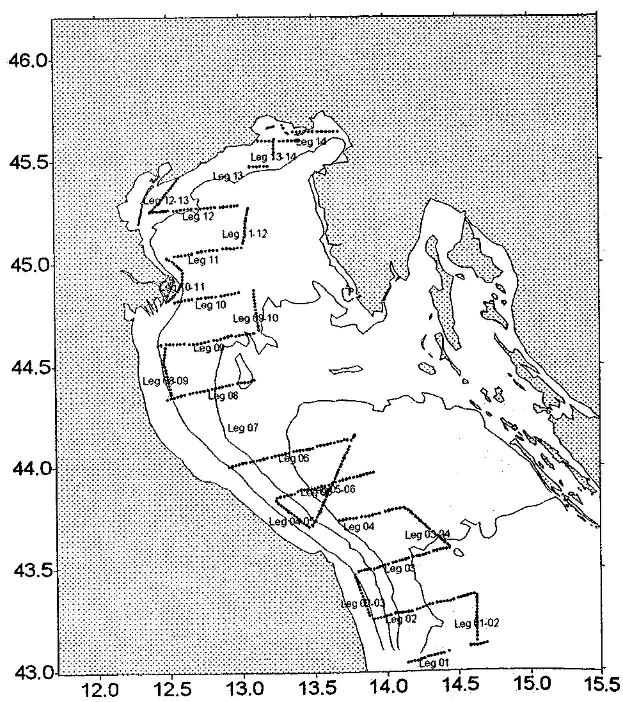

FIG. 6. - Map of North Adriatic with isobath lines at depths of 20, 40, 60 and 80 m. Points are plotted at each 10 ESDUs (of 0.1 nautical mile each). Cruise GIAS-3, September 1995. Due to a plot error, transect 07 is not shown.

The figures 2, 3 and 4 show transect position and names for each cruise in Catalan Sea (GICS area): cruises GICS-1, GICS-2 and GICS-3)

A "magic rectangle" experiment was also performed (in some cruises between the two coverages, in others at the end of the cruise) with high intense sampling over a restricted area (usually a rectangle) for very small spatial and temporal variability studies, during one or two days. The results of these experiments are not presented here.

In North Adriatic the vessel track was also over shore perpendicular transects, from the coast line till the international border line; in the extreme north Adriatic, only one transect from West to East was done, ending at Trieste harbour. Only one coverage was done, sailing together and simultaneously with the R/V Salvatore Lo Bianco in the aim of surveying the same area per day. The Italian vessel sailed at higher speed and her transects were in zigzag.

At the middle of GIAS-2 cruise a magic rectangle was performed; at the end of GIAS-3 it was performed another small scale experiment called "spiritual line" (Salat *et al.*, 1997). The results of such experiments are not presented here

Figures 5 and 6 correspond to cruises GIAS-2 and GIAS-3, in the Adriatic Sea (1994 and 1995, respectively).

Data Processing

BioSonics ESP generated files were converted into ASCII DBF (DataBase) files using BioSonics program ESP Viewer. This new files (one per leg) were filtered using SQL language filters to avoid strata with wrong bottom detections. The number of valid samples was used.

Special software was also developed for removing graphically bottom effects on echointegration and for completeness of latitude and longitude values. Also timing errors were corrected. At the end, for each transect a CSV (ASCII Comma Separated Values) file was obtained.

The following step was the input of CSV data files into the TECHO_VIEWER (Castellón, 1997) to obtain structured data base files.

The variables used are :
"TIME", "DAY", "LATITUDE", "LONGITUDE", "REPORT", "DEPTH", "BEGIN", "END", "SVS", "RELDENS", and "ACONST", being BEGIN and END the limits of strata, SVS the sum of squared voltage samples, and RELDENS the relative density for the current stratum and report (ESDU), computed by the following formula:

$$RD_{ir} = SV_{ir}^2\ M_i\ /\ (PP_r\ N_i) - MS_{ir}$$

where SV_{ir} is the SVS for strata i and report r, M_i is a multiplier (not used in T-ECHO) for strata i, PP_r is the number of pings processed for report r, N_i the number of samples for stratum i, and MS_{ir} the number of samples missed due to bottom intrusion in stratum i and report r.

ACONST is the A constant as described above.

The final variable after calibration corrections and transformations, RELDENS (relative density), is multiplied by ACONST in order to obtain the Absolute Density. As explained before, the values reported in the present paper in fact are Absolute Densities "scaled" for the σ_{bs} instrument parameters (σ_{bs} set to 1).

Once TECHO_VIEWER had created the structured Data Base for echointegration data, the last correction step by graphic editing was relatively easy.

The graphic capabilities of TECHO_VIEWER allow to show graphically on the screen all data of a single transect, and all transects of the cruise if there is enough room in RAM. The graphic editor of TECHO_VIEWER allows to remove some remaining bottom effects on the echointegration values, to add new bottom on pings where bottom was lost, etc.

It was also easy to see the bottom detection error due to false bottom detection, noise coming from second bottom detection, etc. In these cases data were not corrected, but analysis stop close to the appearing of the second bottom detection, near the slope in fact at the end of the transect line.

Finally TECHO_VIEWER exported GRD files for Golden Software Surfer process (all echointegration maps presented in this paper) and CSV data files for extra numerical processes.

RESULTS

Through this paper some results and figures are presented. They must be considered as preliminary in the sense that not all the noise has been removed from files (but the fraction with noise from second echo detection have not been numerically computed, i.e. legs 2,6 in GICS-3/1), and σ_{bs} echointegration parameter has a value of 1.0, meaning that all results and graphs are acoustically comparable from cruise to cruise, but not from the biological point of view, species and size composition. Furthermore, to avoid, at present stage, the troubles originated by different noise source related with increasing depth, only the ESDU values corresponding to bottom depths less than 120 m have been kept for analysis.

It is also to be noticed that data from GICS-1 cruise is not directly comparable to the remaining data set, as ESDU size and σ_{bs} had different values (see table 9), and other troubles related with this cruise, as referred before, but anyway, in most cases the respective figures are also shown.

Data analysis

Figures 7 through 14 show the frequency distribution histograms of Mean Density per cruise and coverage, referred as to the sum of the relative density values of all strata of each ESDU divided by the bottom depth in meters, for all T-ECHO cruises.

Figures 15 through 22 show the frequency distribution histograms of Log Mean Density per cruise and coverage, defined as to the log of the sum of the relative density values for all strata of each ESDU, divided by the number of strata. Both Mean Density and Log Mean Density are related to volume (m^{-3}).

Figures 23 trough 30 show the frequency distribution histograms of Log Total Density per cruise and coverage, defined as the log of the sum of the relative density values of all strata of each ESDU; as it is defined, it is related to areas (m^{-2}).

Figures 31 through 38 show the frequency distribution histograms for log of Relative Density for each individual strata grouped by transects in each cruise and coverage: GICS-1, GICS-2, GICS-3, GIAS-2 and GIAS-3. In this set of histograms, values corresponding to day-light are presented in red coloured histogram bars, and those corresponding to night values are in black colour histogram bars. In each figure for an easy reading, histograms have been organised plotting them with a latitude gradient from the upper part of the page as North and down right part of the pages as South.

All these figures help to assess the trial effect for first cruise, increasing data goodness as time was passing, in fact the second coverage of GICS-1 was rather better than the first. The rest of the cruises present a global data distribution rather homogeneous, meaning at least that all bias effects were constant and data could be accepted for scientific analysis.

Even these rough figures may help to characterise the system as it was sampled. The differences between Log Mean Density on first and second coverages for GICS-2 and GICS-3 cruises could illustrate a rapid biological response to an environment change. It is also clear the latitude heterogeneity patterns in the sampled areas, in the Catalan Sea and in the Adriatic, as it may be followed through figures 31 to 38.

Such set of figures also show the well known effect of diel variations of echoresponse according to the target behaviour: densities during night have been always greater than those on daylight for comparable transects, but daylight density value distributions had always a wider range than those from night. This effect has not yet been corrected for the horizontal maps, as at this stage all the process is at a preliminary status, but it will be done as one of the first steps to be further accomplished.

Transects

In figures 30 through 42 are presented the distribution of Relative Density per each strata and ESDU, for each transect of GICS-2 (two coverages), GICS-3 (two coverages), GIAS-2 and GIAS-3 cruises. In spite that these printed figures have been proccessed from the TECHO_-VIEWER export to CSV numerical files and then imported to Surfer and plotted as images, with a predeterminated colour palette values, they are as they appear in TECHO_VIEWER program screen (Castellón, 1997). All these figures are oriented to the ESDU closest to the shore line and distance referenced, and as the colour palette is common, all of them are inter-comparable. Only in Adriatic the transects have been grouped in small (less than 50 m) or great (more than 50 m) depths in order to get a better resolution.

This mode of presentation is in fact a result, as it shows globally the filtered-corrected data in a highly ergonomic way, making it easy to find the registered phenoma and facilitating informatically paths for their description, comparison and interpretation. Also as images that they are, this presentation mode opens a new window for scientific work as they are at same data integration level than other scientific common data sets (i.e. satellite, etc.).

2-D maps

Figures 43 through 46 show horizontal distribution of Log Mean Density in comparison with Log Total Density, as previously defined, for GICS-2, GICS-3, GIAS-2 and GIAS-3 cruises and separate coverages. These balloon plots, with no interpolation, show the patchy patterns of scatterers distribution, as pelagic fish usually have. As indicated before, values are not corrected for diel integral variation, thus this effects must be subtracted visually from the maps.

Figures 47 and 48 show Log Total Density interpolated horizontal maps for the same cruises as mentioned in the previous paragraph. It is clearly noticed, in spite of diel effects, that higher GICS-3 presented higher values than previous cruises, but the distribution patterns (a North-South effect, and a shore-offshore effect) are still noticeable in both cruises and coverages: this may be the basic structure for the small pelagic fish distribution in the area. In the Adriatic Sea, horizontal distribution trends follow the same patterns as shown by Azzali (1997): higher values near the Po river mouth, some patches near the coast and scattered high values through the area, in the vicinity of selected points of the border line, or near the shore, in contrast with the extreme elevated values on the northwestern fraction.

Biomass

A first approach to biomass estimation has been done for GICS-2 cruise, using TS values from the literature according to the biological composition of samples (species and sizes). Figure 50 shows the main pelagic species repartition in the area (*Sardina pilchardus*, *Engraulis encrasicolus* and *Sardinella aurita*, the remaining species were considered as "other pelagic species"), from pelagic trawling stations. The area was divided in three depth strata (50, 100 and 200 m). Results are shown in fig 49. Main commercial species in the area (*E. encrasicolus*) is more abundant in the northern part of the area, in the vicinity of the Ebro delta and in the expanding continental shelf, near the slope; young specimens are near the shore and mean size is greater offshore. The size pattern distribution is similar for *Sardina*; for *Sardinella* greater specimens were found near the Ebro delta.

Roughly, biomass was distributed in three main areas: in the northern part, the continental shelf becomes wider, coinciding with an area of peculiar hydrographic characteristics (Salat, *et al.*, 1997), in the southern part of the study area, near the shelf, and in the central-southern part of the area but near the shore.

DISCUSSION AND CONCLUSIONS

It could be subject to strong criticism the high acoustic threshold used (0.05 V), as small signals (from big plankton or very small fish) were not gathered, but such decision was forced due to the signal to noise ratio encountered during the test trials.

The methodology designed (specially after GICS-1 cruise) appears adequate for the scale studies undertaken. The small ESDU chosen (in both axes vertical and horizontal) brings the possibility of a twofold acoustic approach, the classical one through the study of absolute densities distribution, but also the small scale one, as the resolution data is 0.1 nm in horizontal and 2 m in vertical, much below the concentrations of fish specimens. In this respect data are rather comparable with InesMoviesB school interface analyser, except for the small schools.

During all the cruises two DATs were recording the signal from 20 logR and 40 logR calibrated outputs, and during the last ones, an extra ESP also was processing signal and generating files for TS single echo analysis. The task of such analysis (tape playback and files) is not yet done (basically as it was foreseen as a project objective), but relationships of TS distributions related with densities and environmental factors will be of major interest.

The small acoustic ESDU designed is in the order of magnitude of the ESDU for other environment or biological parameters, as ADCP, sonar, etc. Thus, such kind of research (the small scale studies) will be performed, as soon as the exploratory analysis (UFO as an example, Castellón, 1997) has been positive, specially in relation with the integrated environmental factors (sea water density field, currents, etc.).

This task will be immediately undertaken, after the administrative end of the project, as it is only now that information is available, tools have been fully developed, and a comprehensive generalistic overview is accessible.

ACKNOWLEDGEMENTS

The authors wish to express their gratitude to all the participants in T-ECHO project, specially the ORSTOM team (F. Gerlotto, P. Freon, T. Bahri, M. Soria and J.M. Stretta) who shared (in part or totally) the vessel during the cruises, promoting intense cooperation in diverse fields. Moreover F. Gerlotto supervised an *allocation de recherche* ORSTOM financement for two of the authors (Castellón and Rucabado), during which most of the needed tools were developed.

The authors also wish to express their appreciation to all cruise participants who shared responsibilities, all of them involved in some way with the acoustic instrumentation, as the towed body was hauled up and lowered from the sea at each vessel stop. M. Lloret, J. Pinar, J. Sánchez-Pardo, C. Castellón, E.O. Linares (IDO, Cuba), L. Cárdenas (FLASA, Venezuela), among others.

Two researchers from IRPeM participated in GICS-1 cruise on board the R/V García del Cid: M. Azzali (only in part) and J. Kalinowski, integrated in the acoustic team.

The crew of the research vessel García del Cid did their best in assisting us at any time and moment. The authors wish to express their understanding for the crew's labour strike, just at the beginning of GIAS-1 cruise (September 1993), although for this reason this cruise failed, and was substituted by GIAS-3 in 1995.

The crane for manoeuvring the towed body was designed and tested by Forner Oceanics Co.

Ifremer gave facilities for an instrument calibration in its experimental tank; A. Lebourges (ORSTOM) assisted us during calibration.

BioSonics Inc. and its European office gave their assistance in a few critical moments for instruments checking.

Biological samples were obtained by the fishing vessel Maria dels Angels owned by Berto & Co. SL. (Port de la Selva, Girona). The skipper (Mr. Manu Perelló) and his crew worked with unlimited effort at their best and fine capabilities. Biological samples were collected and processed by our colleagues René Torres and Sergi Tudela (GICS-2 cruise) and René Torres and Antoni Lombarte (GICS-3 cruise). Part of these biological samples was also processed for their own research interest, in order to obtain academic degrees.

Mr. Cipriano Salvador, head of the Provincial Offices of the Spanish State Marine Fisheries Department, gave generously permission for the biological sampling.

Just a recognition word for Mr. José Antonio Fernández, manager of ICM who trespassed on 1993. The authors are also indebted to Ms. Rita Arias, at present manager of ICM and responsible of the research vessel, for all her facilities in carrying out the complex work this was.

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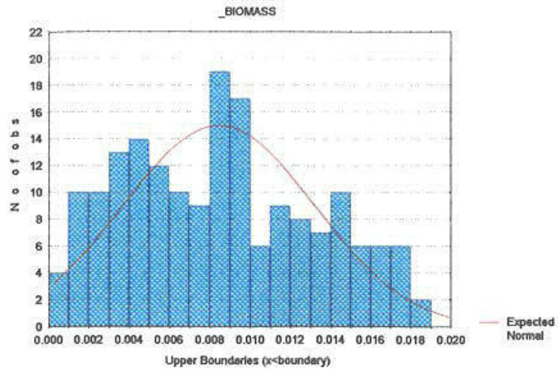


FIG. 7. - Mean Density for GICS-2 cruise, 1st coverage.

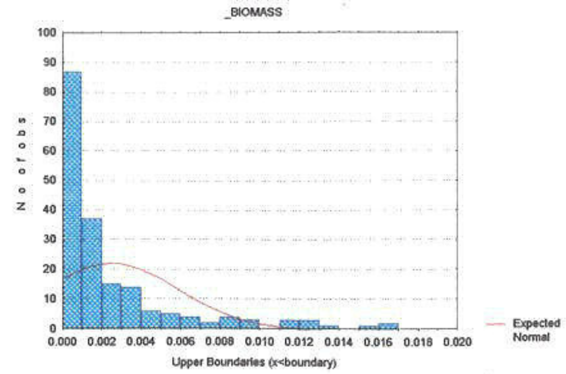


FIG. 8. - Mean Density for GICS-1 cruise, 2nd coverage.

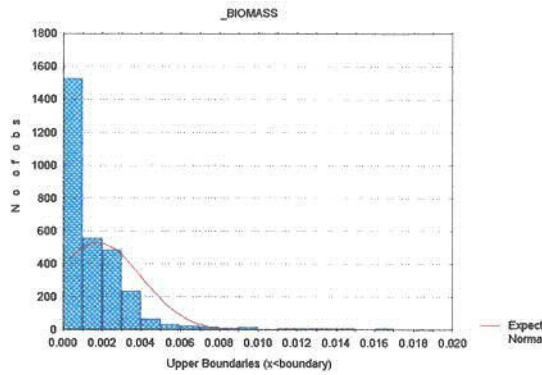


FIG. 9. - Mean Density for GICS-2 cruise, 1st coverage.

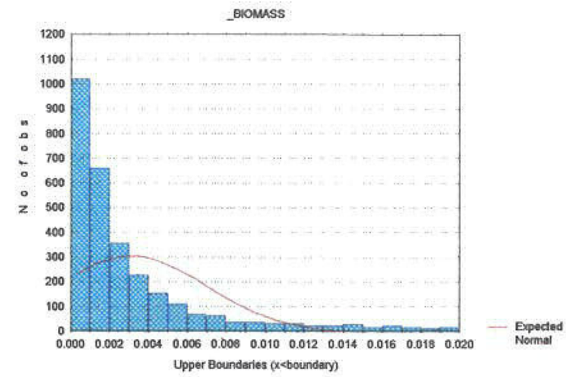


FIG. 10. - Mean Density for GICS-2 cruise, 2nd coverage.

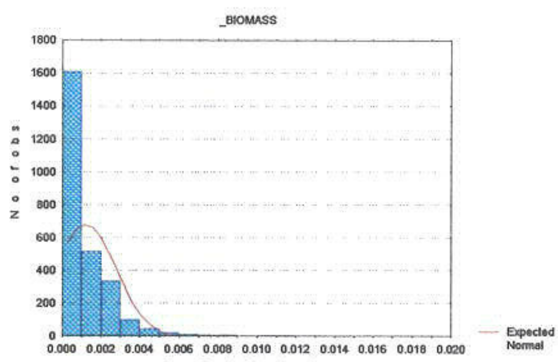


FIG. 11. - Mean Density for GICS-3 cruise, 1st coverage.

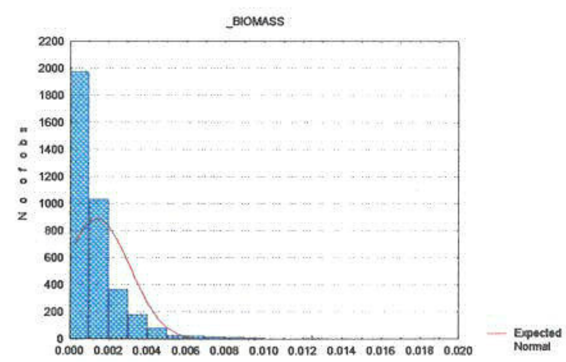


FIG. 12. - Mean Density for GICS-3 cruise, 2nd coverage.

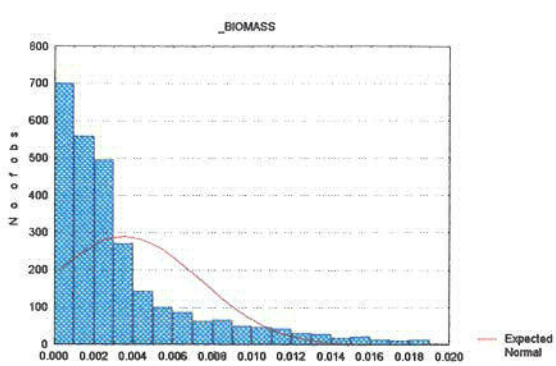


FIG. 13. - Mean Density for GIAS-2 cruise.

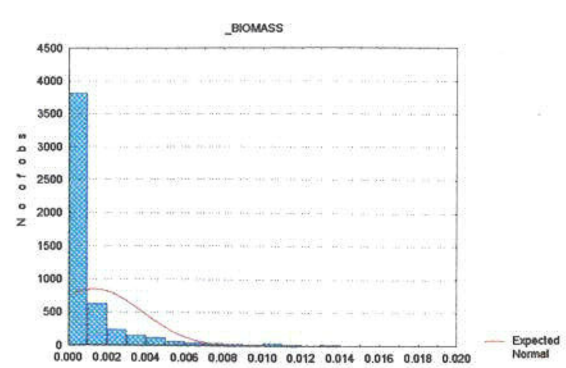


FIG. 14. - Mean Density for GIAS-3 cruise.

NOTE to Figs. 7 to 14.: Frequency distribution of Mean Density. Mean Density refers to the sum of the relative density values of all strata of one ESDU, divided by the bottom depth in meters, and is related to volume (m^{-3})

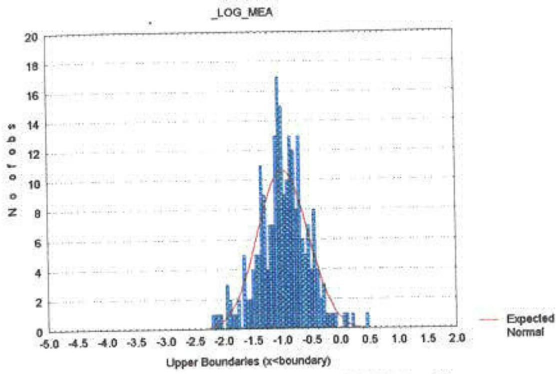


FIG. 15 - Log Mean Density for GICS-1, 1st coverage.

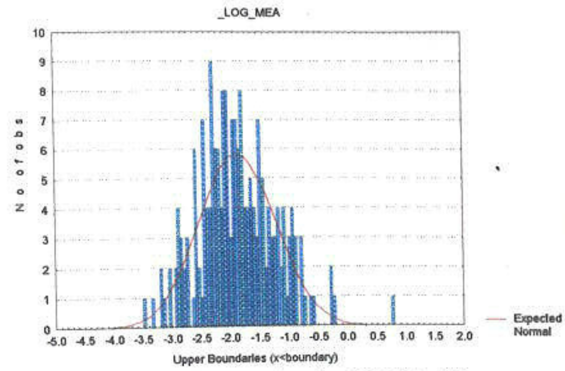


FIG. 16. - Log Mean Density for GICS-1, 2nd coverage.

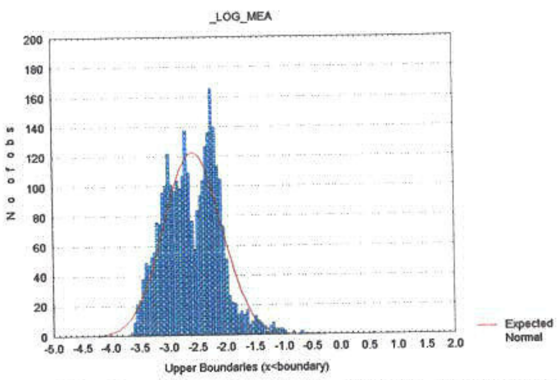


FIG. 17. - Log Mean Density for GICS-2, 1st coverage.

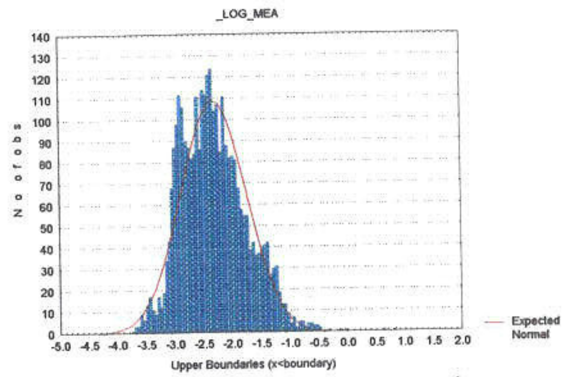


FIG. 18 - Log Mean Density for GICS-2, 2nd coverage.

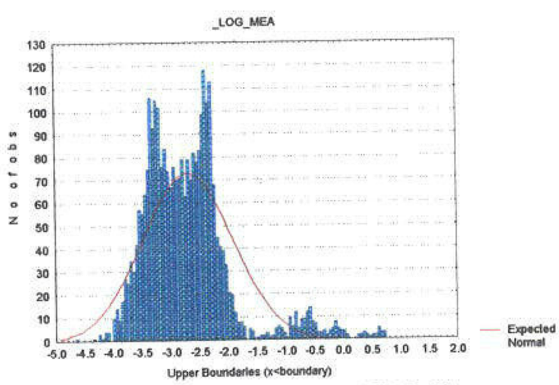


FIG. 19 - Log Mean Density for GICS-3, 1st coverage.

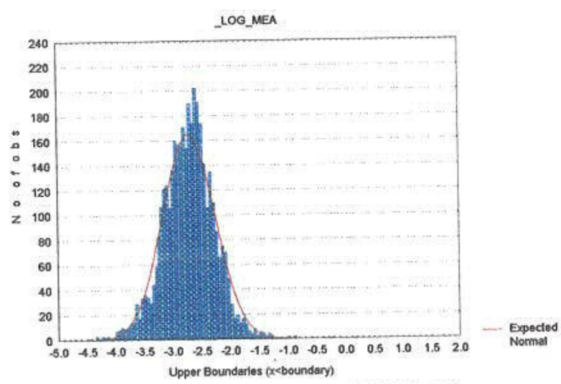


FIG. 20 - Log Mean Density for GICS-3, 2nd coverage.

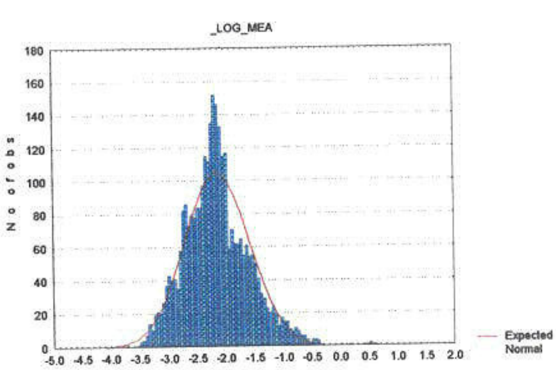


FIG. 21 - Log Mean Density for GIAS-2 cruise.

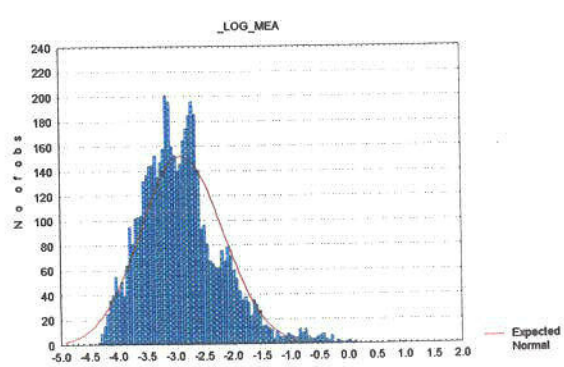


FIG. 22 - Log Mean Density for GIAS-3 cruise.

NOTE to Figs. 15 to 22. Frequency distribution of Log Mean Density. Log Mean Density refers to the log of the sum of the relative density values for all strata of one ESDU, divided by the number of strata, and is related to the volume (m^{-3})

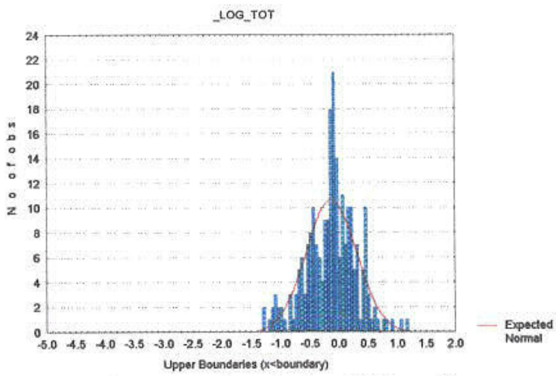


FIG. 23. - Log Total Density for GICS-1, 1st coverage.

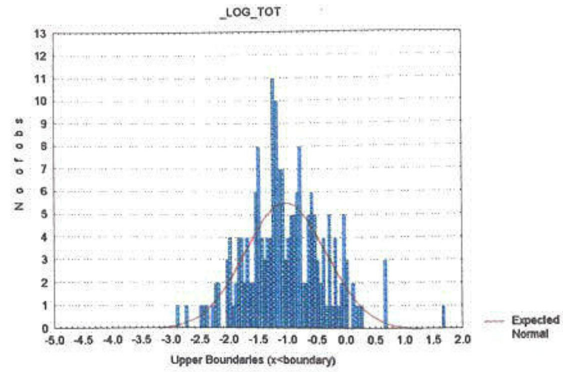


FIG. 24. - Log Total Density for GICS-1, 2nd coverage.

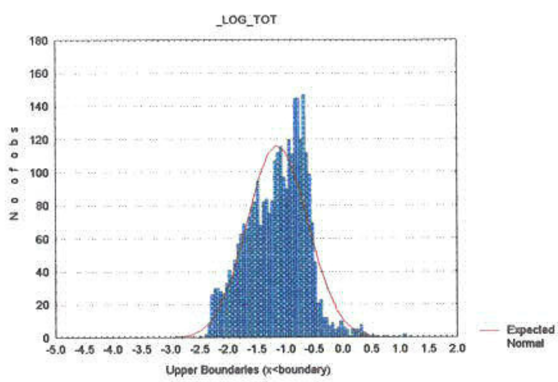


FIG. 25. - Log Total Density for GICS-2, 1st coverage.

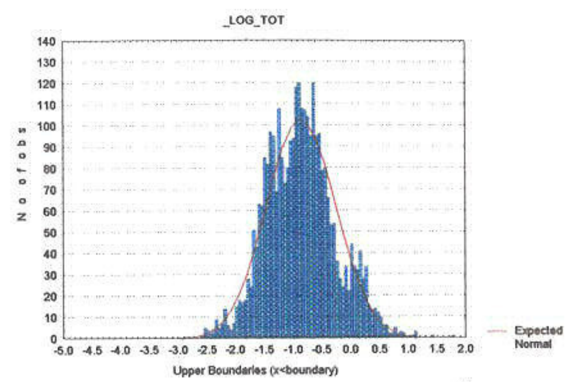


FIG. 26. - Log Total Density for GICS-2, 2nd coverage.

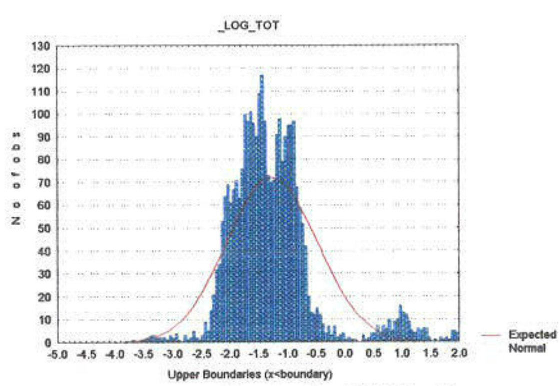


FIG. 27. - Log Total Density for GICS-3, 1st coverage.

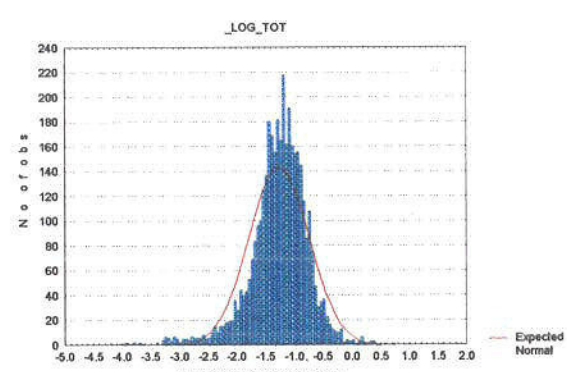


FIG. 28. - Log Total Density for GICS-3, 2nd coverage.

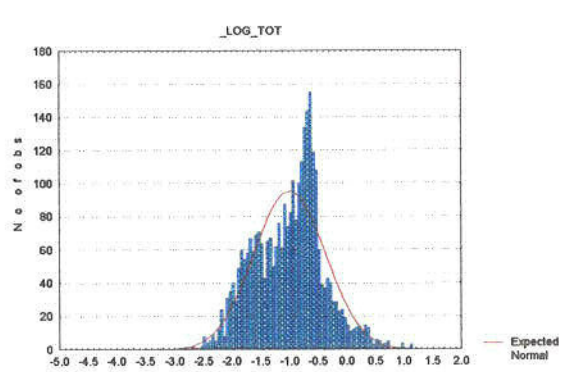


FIG. 29. - Log Total Density for GIAS-2 cruise.

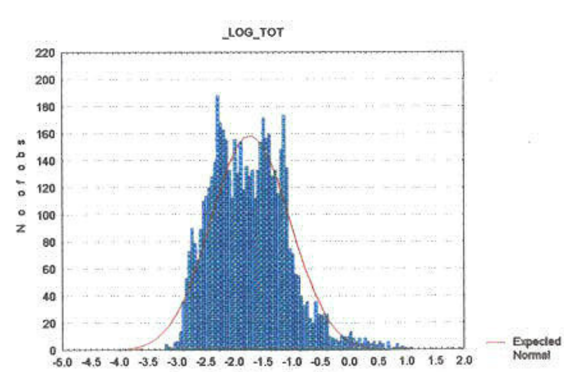


FIG. 30. - Log Total Density for GIAS-3 cruise.

NOTE to Figs. 23 to 30.: Frequency distribution of Log Total Density. Log Total Density refers to the log of the sum of the relative density values of all strata of one ESDU, and is related to area (m^{-2})

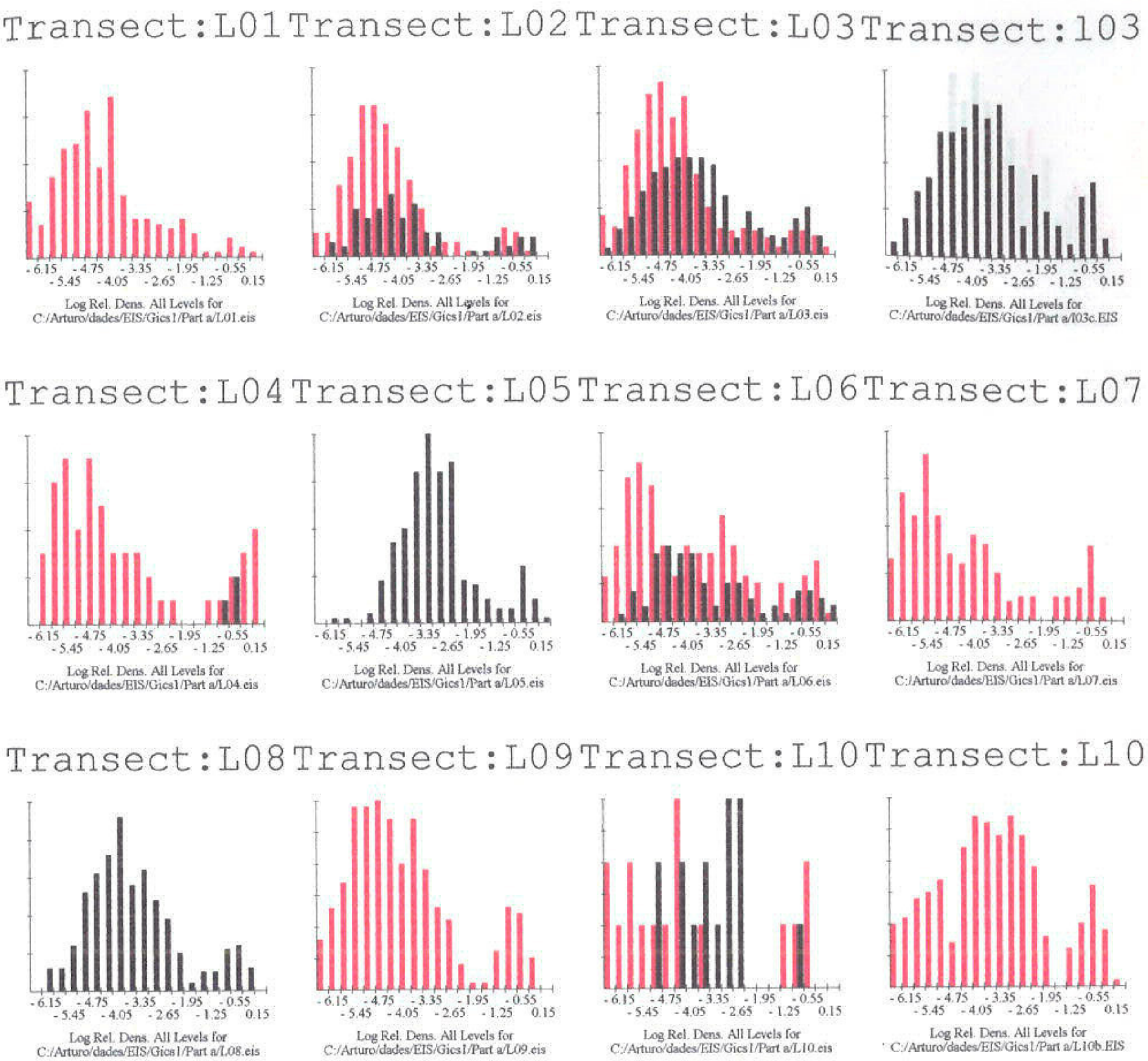


FIG. 31. - All strata frequency distribution histograms of Log of Relative Density for GICS-1 cruise, for all (1 to 10) transects belonging to the first coverage (upper left corner is North, and lower right corner of the figure is South). Red bars correspond to daylight frequency histograms and black bars to night frequency histograms.

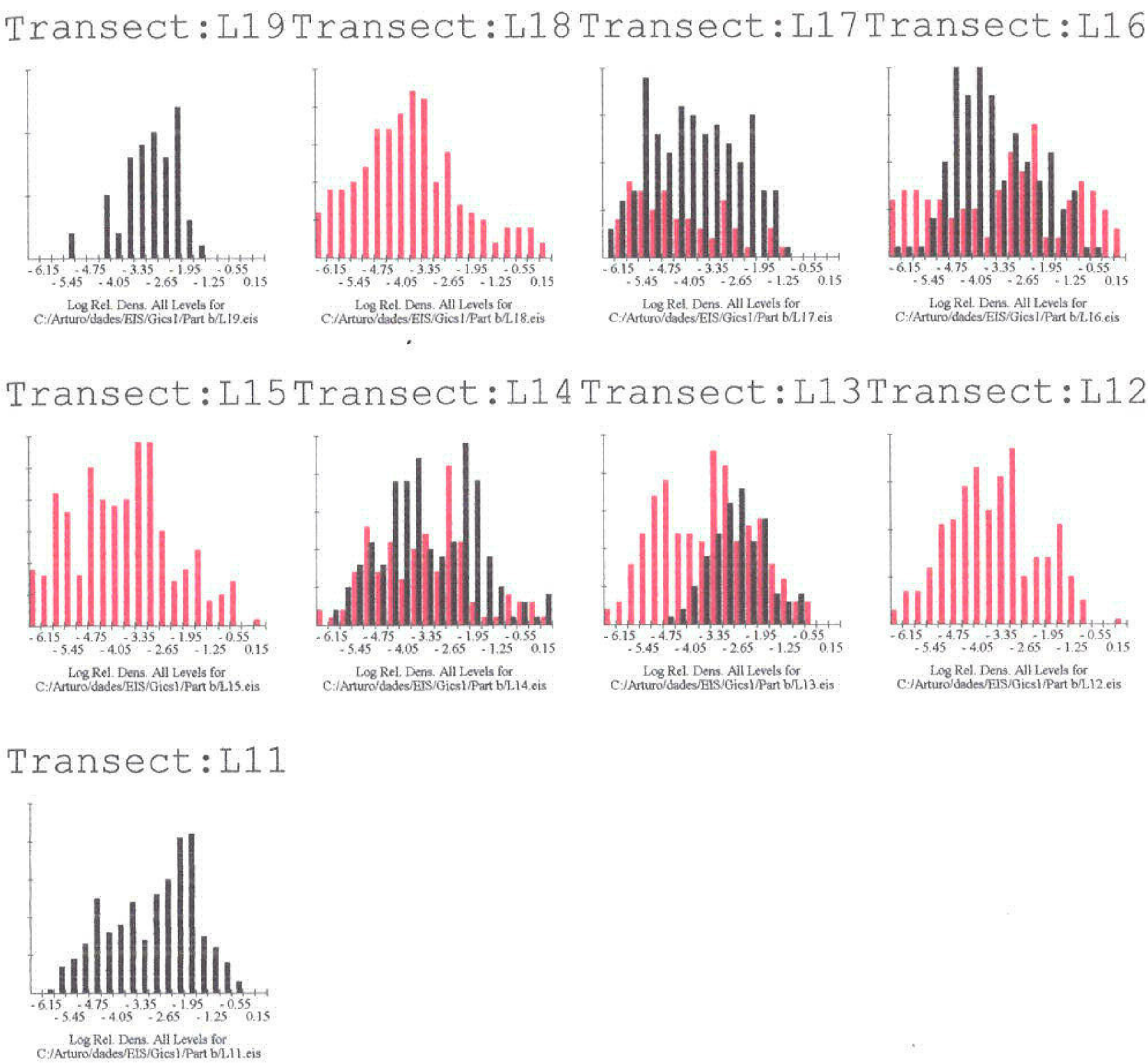


FIG. 32. - All strata frequency distribution histograms of Log of Relative Density for GICS-1 cruise, for all (11 to 19) transects belonging to the second coverage (upper left corner is North, and lower right corner of the figure is South). Red bars correspond to daylight frequency histograms and black bars to night frequency histograms.

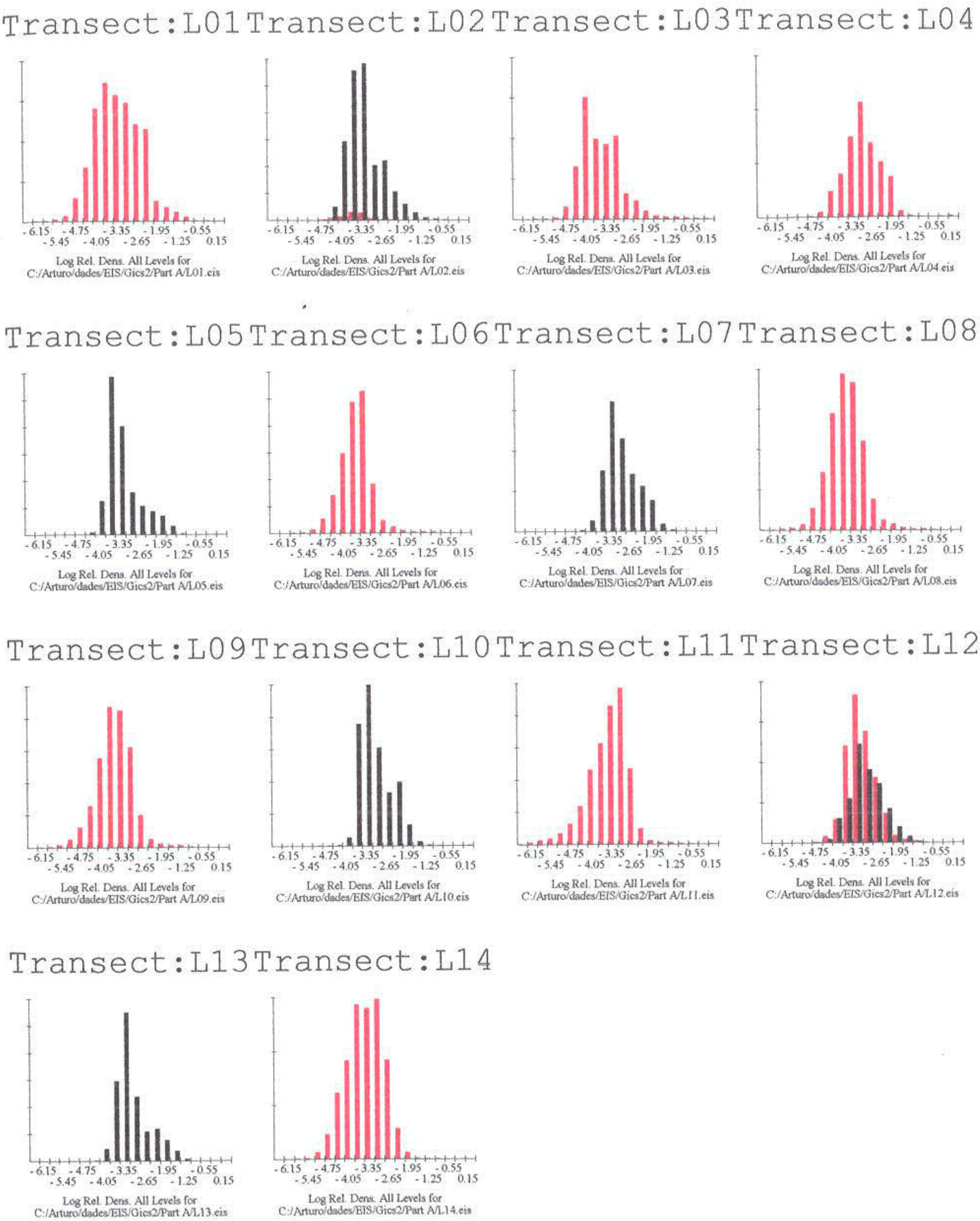


FIG. 33. - All strata frequency distribution histograms of Log of Relative Density for GICS-2 cruise, for all (1 to 14) transects belonging to the first coverage (upper left corner is North, and lower right corner of the figure is South). Red bars correspond to daylight frequency histograms and black bars to night frequency histograms.

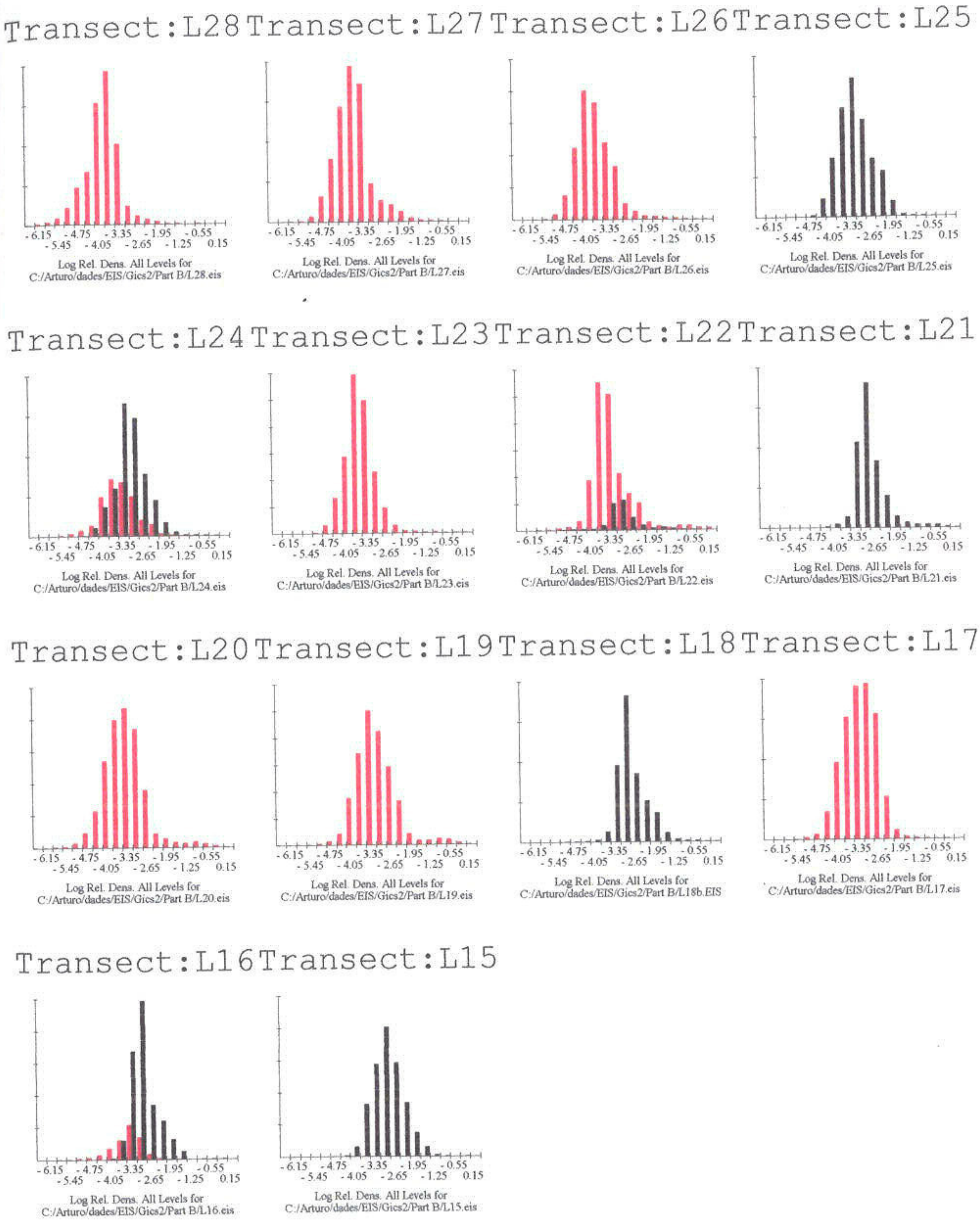


FIG. 34. - All strata frequency distribution histograms of Log of Relative Density for GICS-2 cruise, for all (15 to 28) transects belonging to the second coverage (upper left corner is North, and lower right corner of the figure is South). Red bars correspond to daylight frequency histograms and black bars to night frequency histograms.

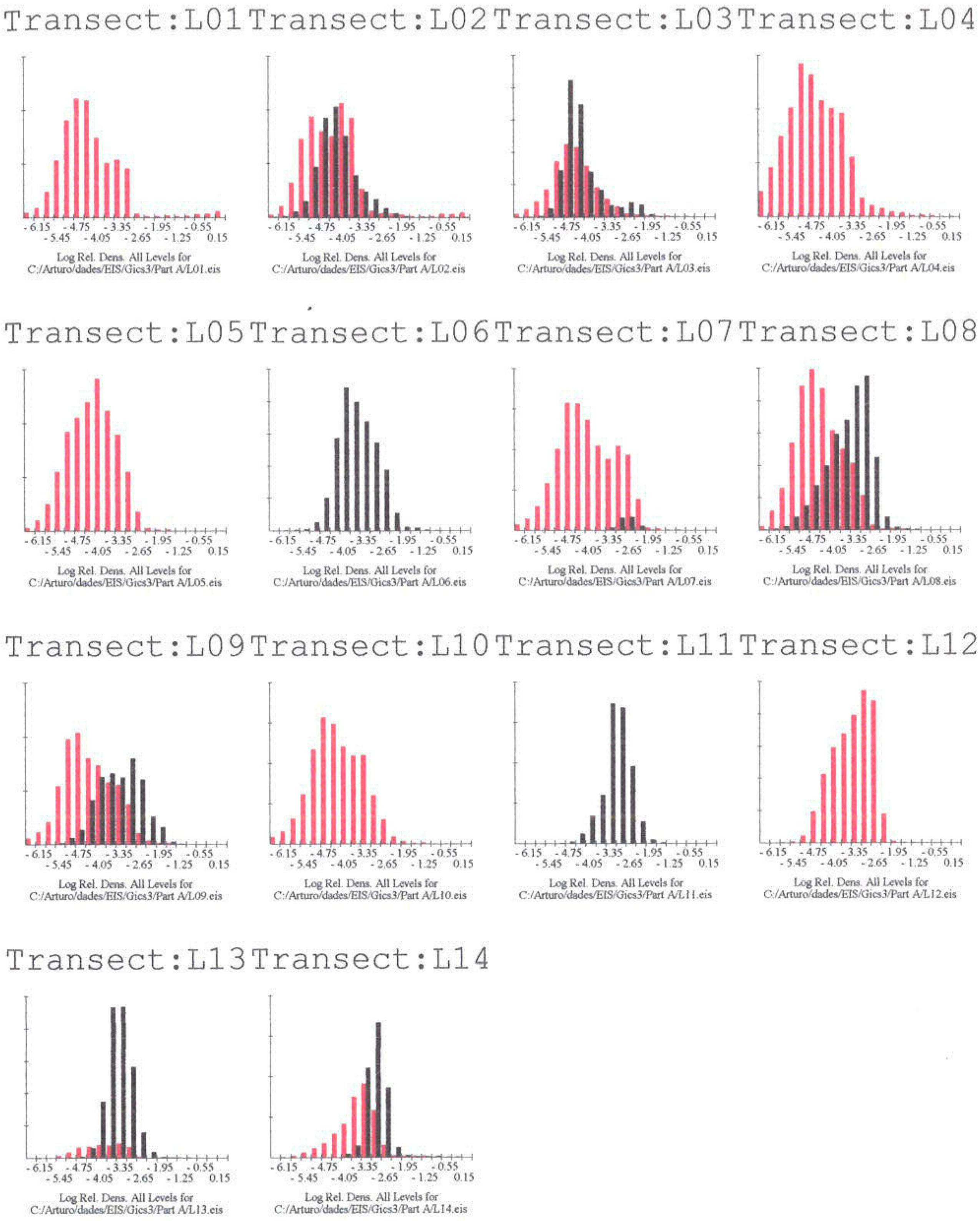


FIG. 35. - All strata frequency distribution histograms of Log of Relative Density for GICS-3 cruise, for all (1 to 14) transects belonging to the first coverage (upper left corner is North, and lower right corner of the figure is South). Red bars correspond to daylight frequency histograms and black bars to night frequency histograms.

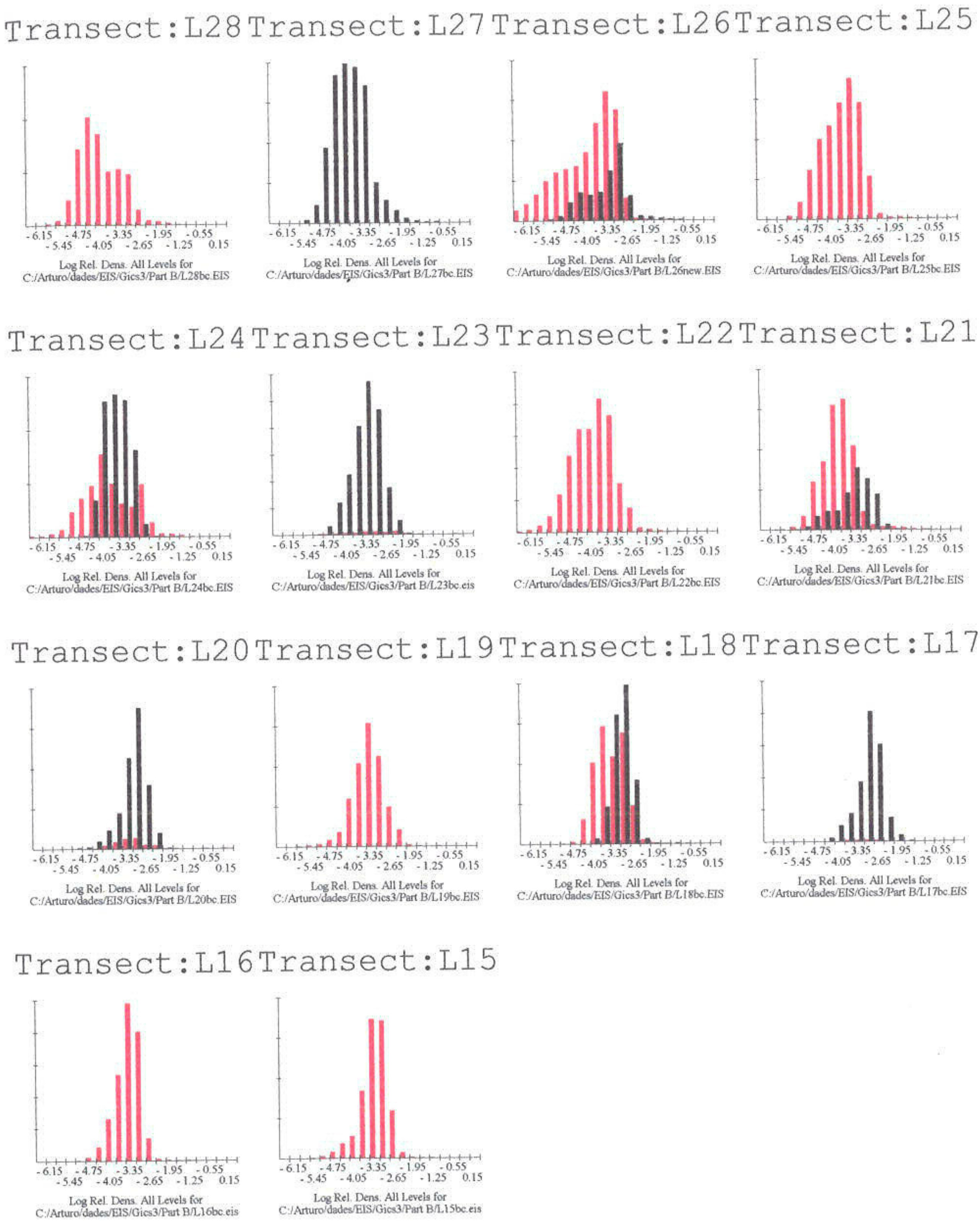


FIG. 36. - All strata frequency distribution histograms of Log of Relative Density for GICS-3 cruise, for all (15 to 28) transects belonging to the second coverage (upper left corner is North, and lower right corner of the figure is South). Red bars correspond to daylight frequency histograms and black bars to night frequency histograms.

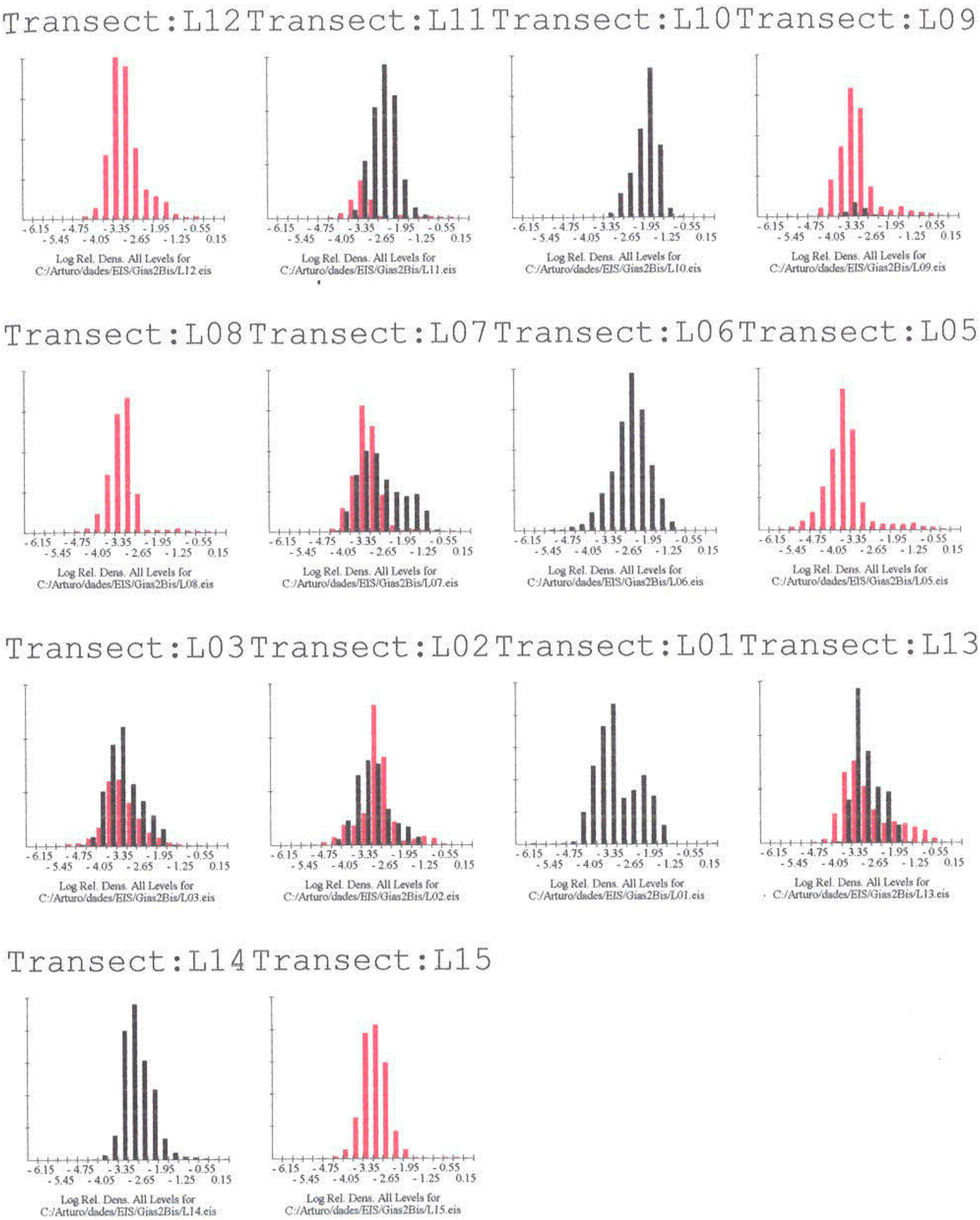


FIG. 37. - All strata frequency distribution histograms of Log of Relative Density for GIAS-2, for all (1 to 15) transects (upper left corner is North, and lower right corner of the figure is South).
Red bars correspond to daylight frequency histograms and black bars to night frequency histograms.

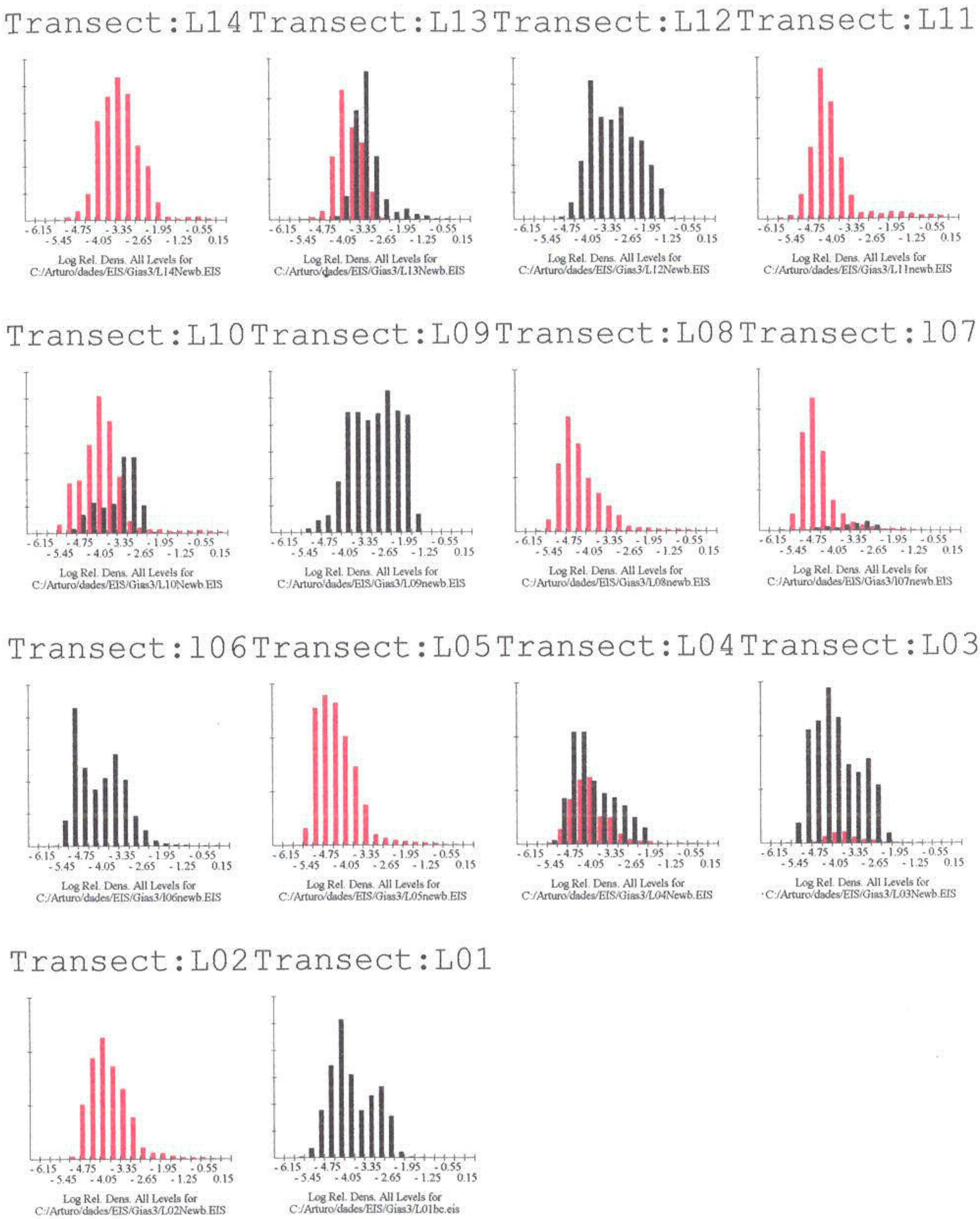


FIG. 38. - Frequency distribution histograms of Log of Relative Density for GIAS-3, for all (1 to 14) transects (upper left corner is North, and lower right corner of the figure is South).
Red bars correspond to daylight frequency histograms and black bars to night frequency histograms.

FIG. 39. - Cruise GICS-2, 1st coverage (May 1994)

Acoustic relative density distribution - Catalan Sea

Vertical axis: Depth (in meters); horizontal axis: distance (in nautical miles) from/to reference point; colour scale: log of acoustic relative density. Transect naming convention: ckr_lnn: c for Catalan sea cruise, k is cruise number, r is coverage number, l is Leg identifier label and nn is leg number.

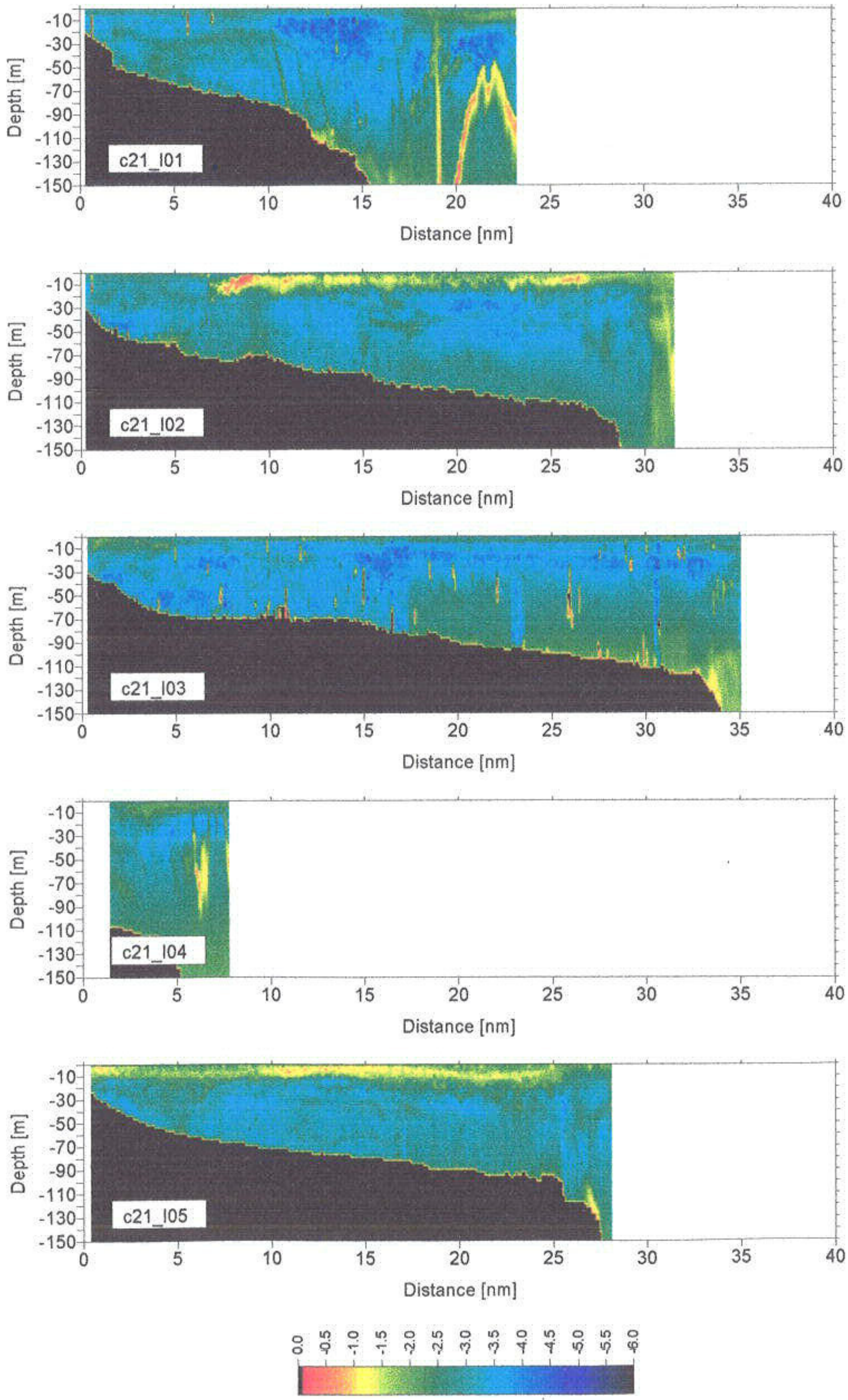


FIG. 39 (cont.). - Cruise GICS-2, 1st coverage (May 1994)

Acoustic relative density distribution - Catalan Sea

Vertical axis: Depth (in meters); horizontal axis: distance (in nautical miles) from/to reference point; colour scale: log of acoustic relative density. Transect naming convention: ckr_lnn: c for Catalan sea cruise, k is cruise number, r is coverage number, l is Leg identifier label and nn is leg number.

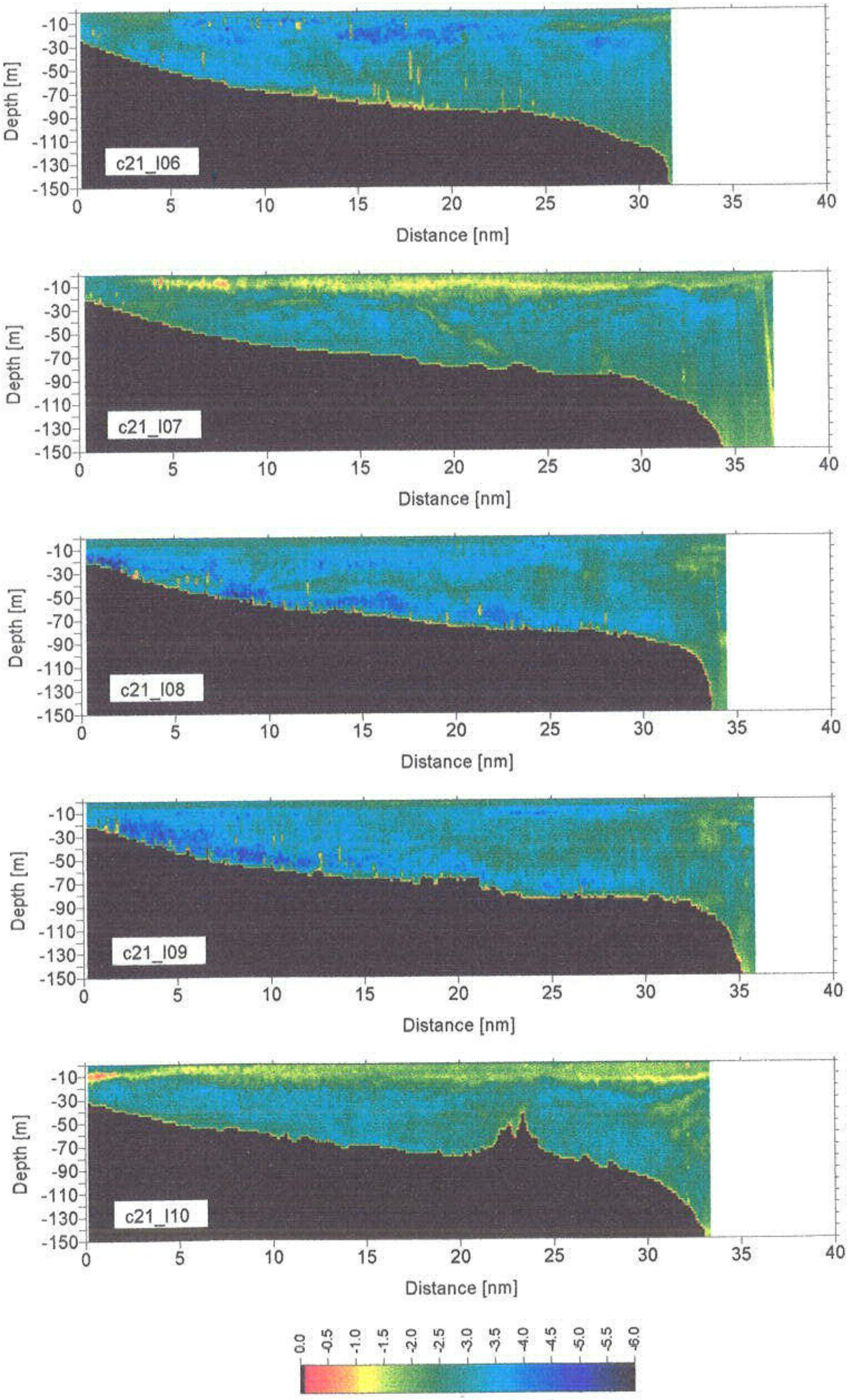


FIG 39 (cont.). - Cruise GICS-2, end of 1st and start of 2nd coverage (May 1994)

Acoustic relative density distribution - Catalan Sea

Vertical axis: Depth (in meters); horizontal axis: distance (in nautical miles) from/to reference point; colour scale: log of acoustic relative density. Transect naming convention: ckr_lnn: c for Catalan sea cruise, k is cruise number, r is coverage number, l is Leg identifier label and nn is leg number.

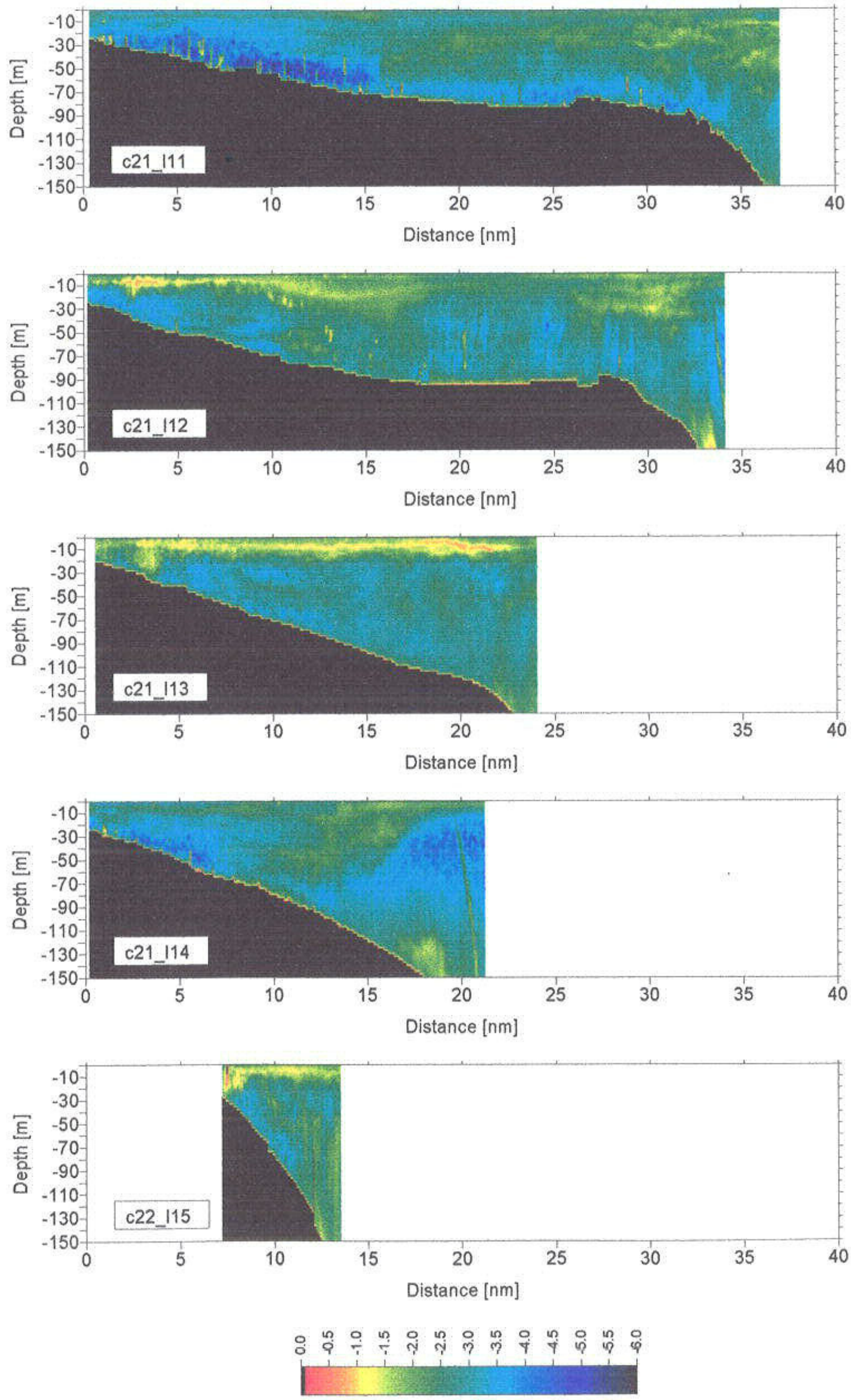


FIG. 39 (cont.). - Cruise GICS-2, 2nd coverage (May 1994)

Acoustic relative density distribution - Catalan Sea

Vertical axis: Depth (in meters); horizontal axis: distance (in nautical miles) from/to reference point; colour scale: log of acoustic relative density. Transect naming convention: ckr_lnn: c for Catalan sea cruise, k is cruise number, r is coverage number, l is Leg identifier label and nn is leg number.

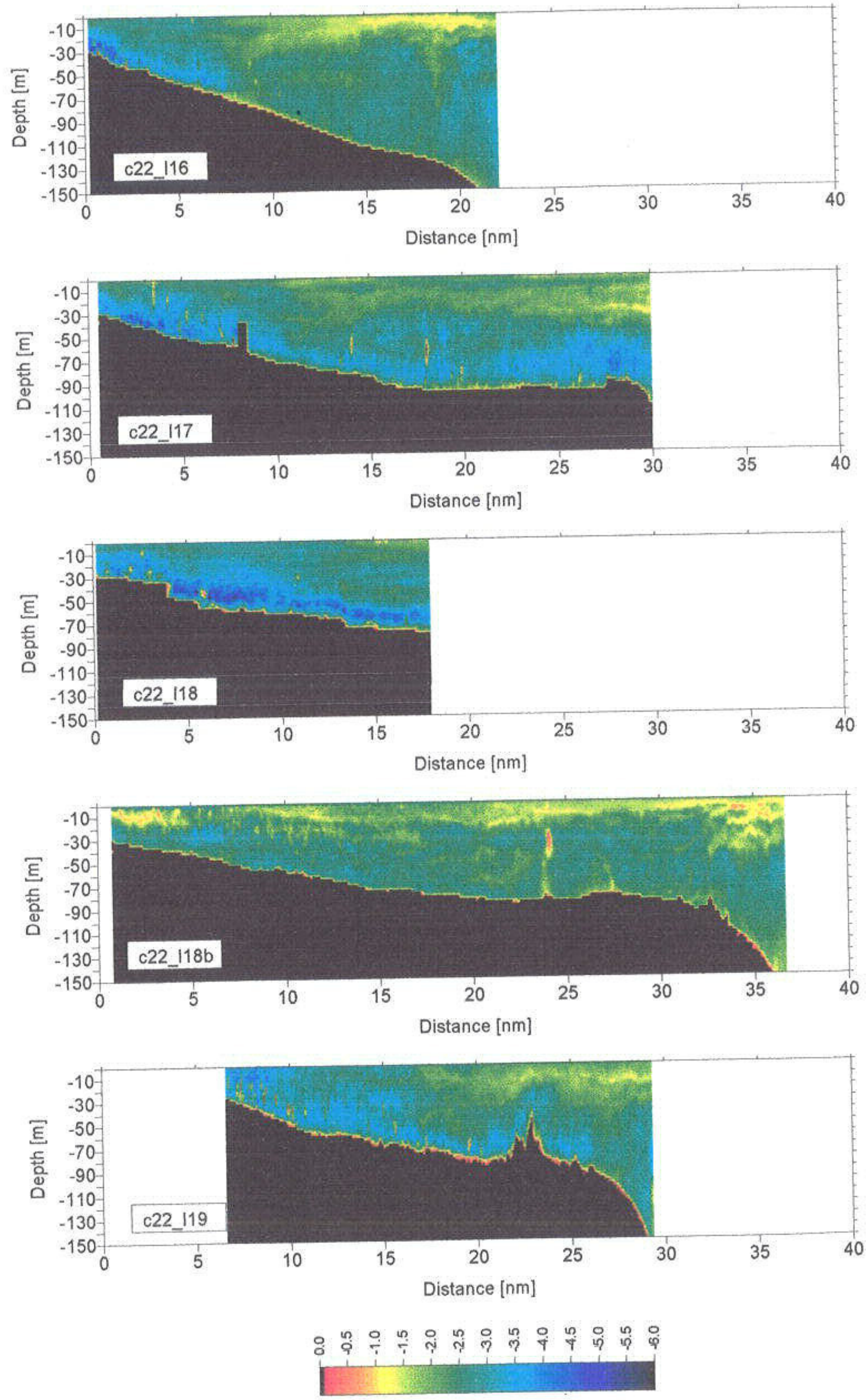


FIG. 39 (cont.). - Cruise GICS-2, 2nd coverage (May 1994)

Acoustic relative density distribution - Catalan Sea

Vertical axis: Depth (in meters); horizontal axis: distance (in nautical miles) from/to reference point; colour scale: log of acoustic relative density. Transect naming convention: ckr_lnn: c for Catalan sea cruise, k is cruise number, r is coverage number, l is Leg identifier label and nn is leg number.

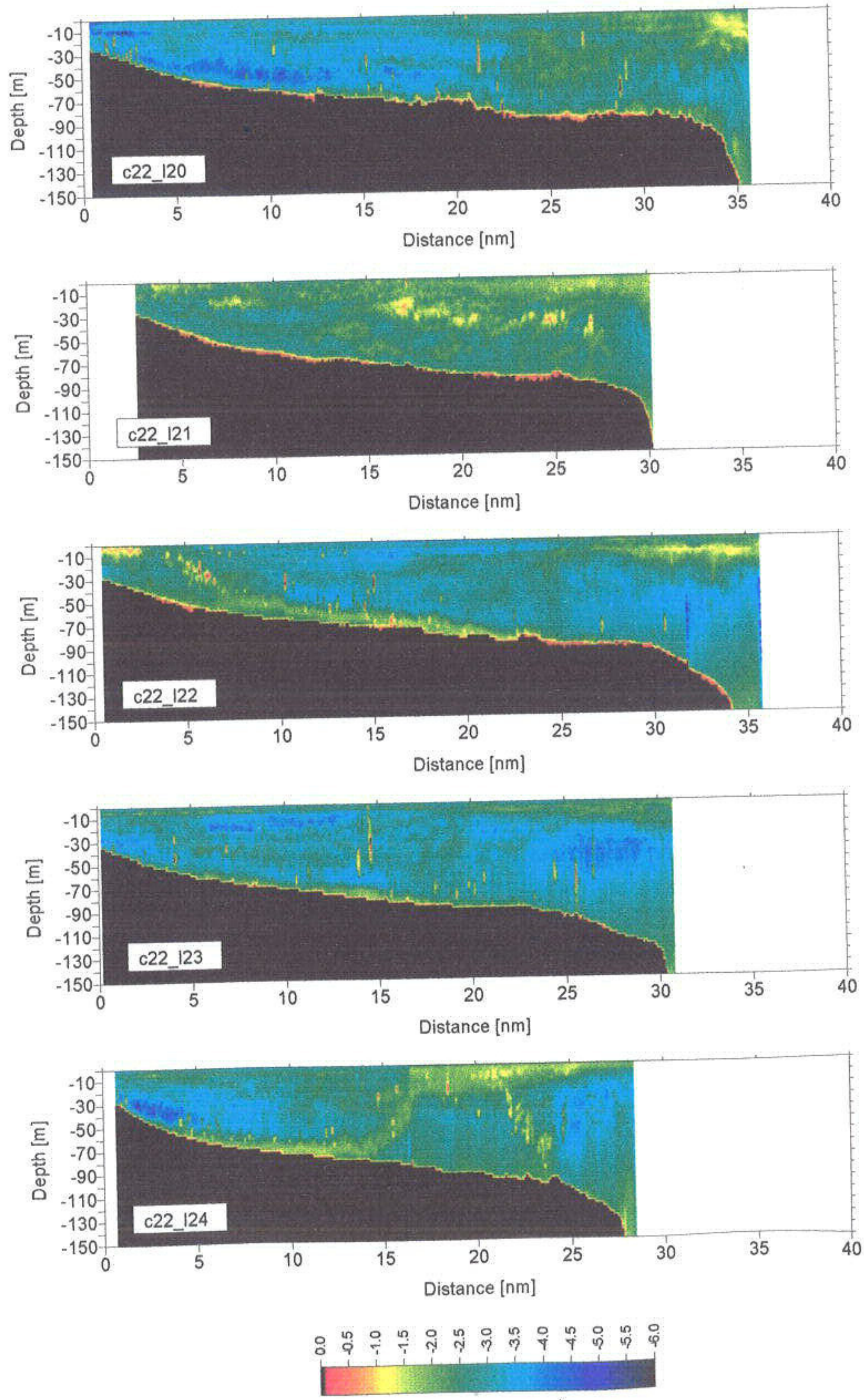
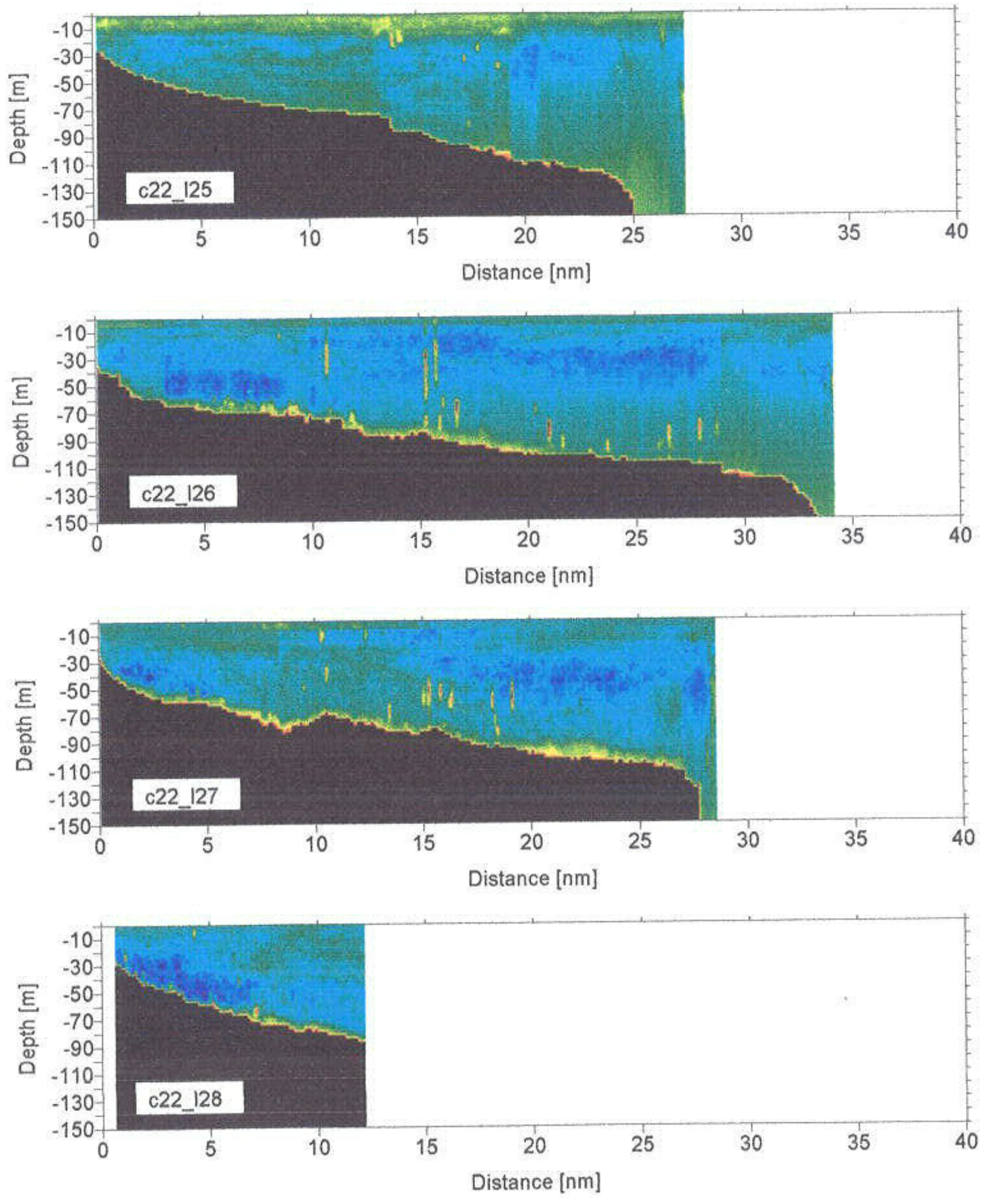


FIG. 39 (cont.). - Cruise GICS-2, 2nd coverage (May 1994)

Acoustic relative density distribution - Catalan Sea

Vertical axis: Depth (in meters); horizontal axis: distance (in nautical miles) from/to reference point; colour scale: log of acoustic relative density. Transect naming convention: ckr_lnn: c for Catalan sea cruise, k is cruise number, r is coverage number, l is Leg identifier label and nn is leg number.



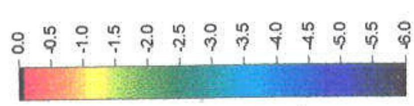


FIG. 40. - Cruise GICS-3, 1st coverage (May 1995)

Acoustic relative density distribution - Catalan Sea

Vertical axis: Depth (in meters); horizontal axis: distance (in nautical miles) from/to reference point; colour scale: log of acoustic relative density. Transect naming convention: ckr_lnn: c for Catalan sea cruise, k is cruise number, r is coverage number, l is Leg identifier label and nn is leg number.

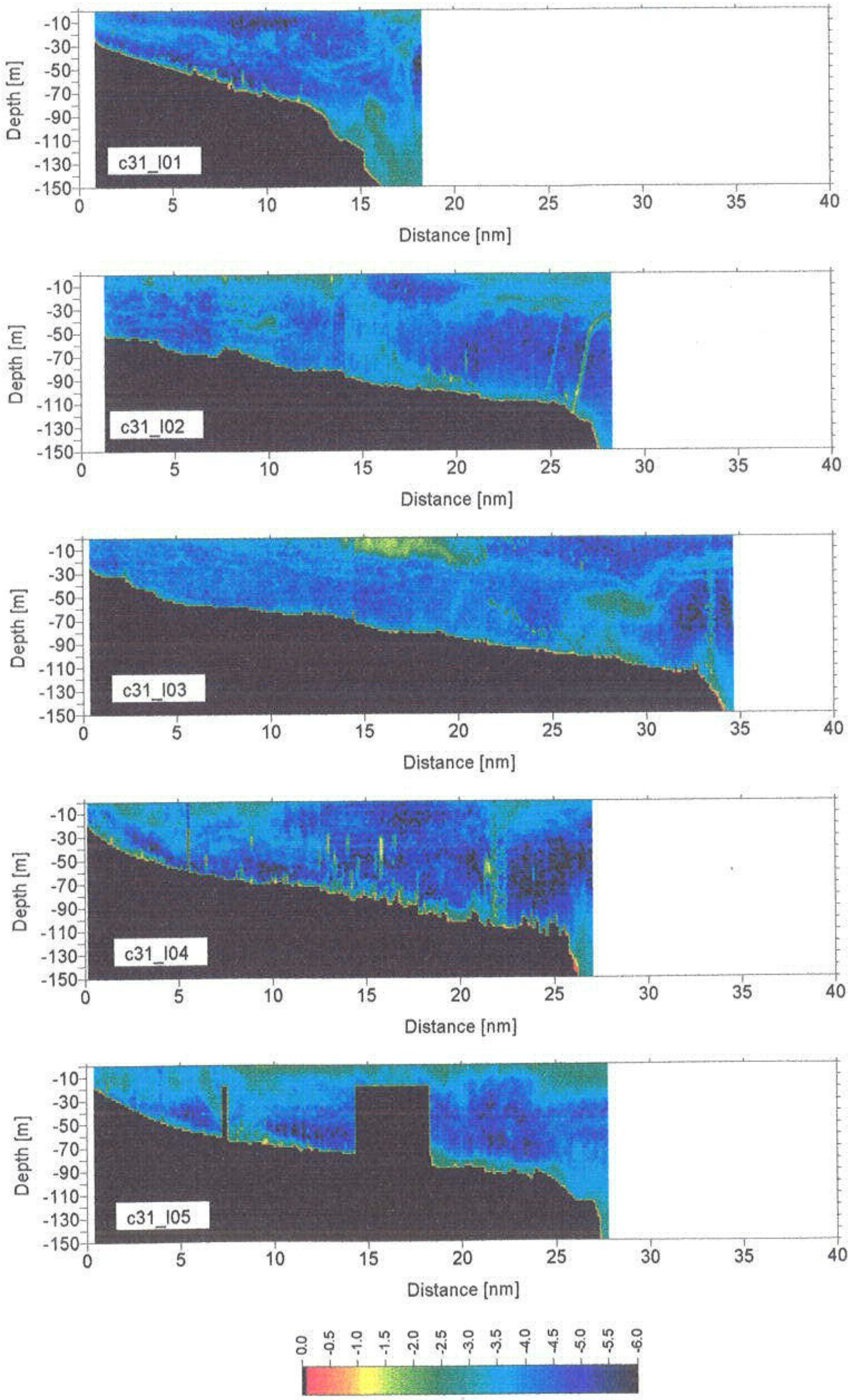


FIG. 40 (cont.). - Cruise GICS-3, 1st coverage (May 1995)

Acoustic relative density distribution - Catalan Sea

Vertical axis: Depth (in meters); horizontal axis: distance (in nautical miles) from/to reference point; colour scale: log of acoustic relative density. Transect naming convention: ckr_lnn: c for Catalan sea cruise, k is cruise number, r is coverage number, l is Leg identifier label and nn is leg number.

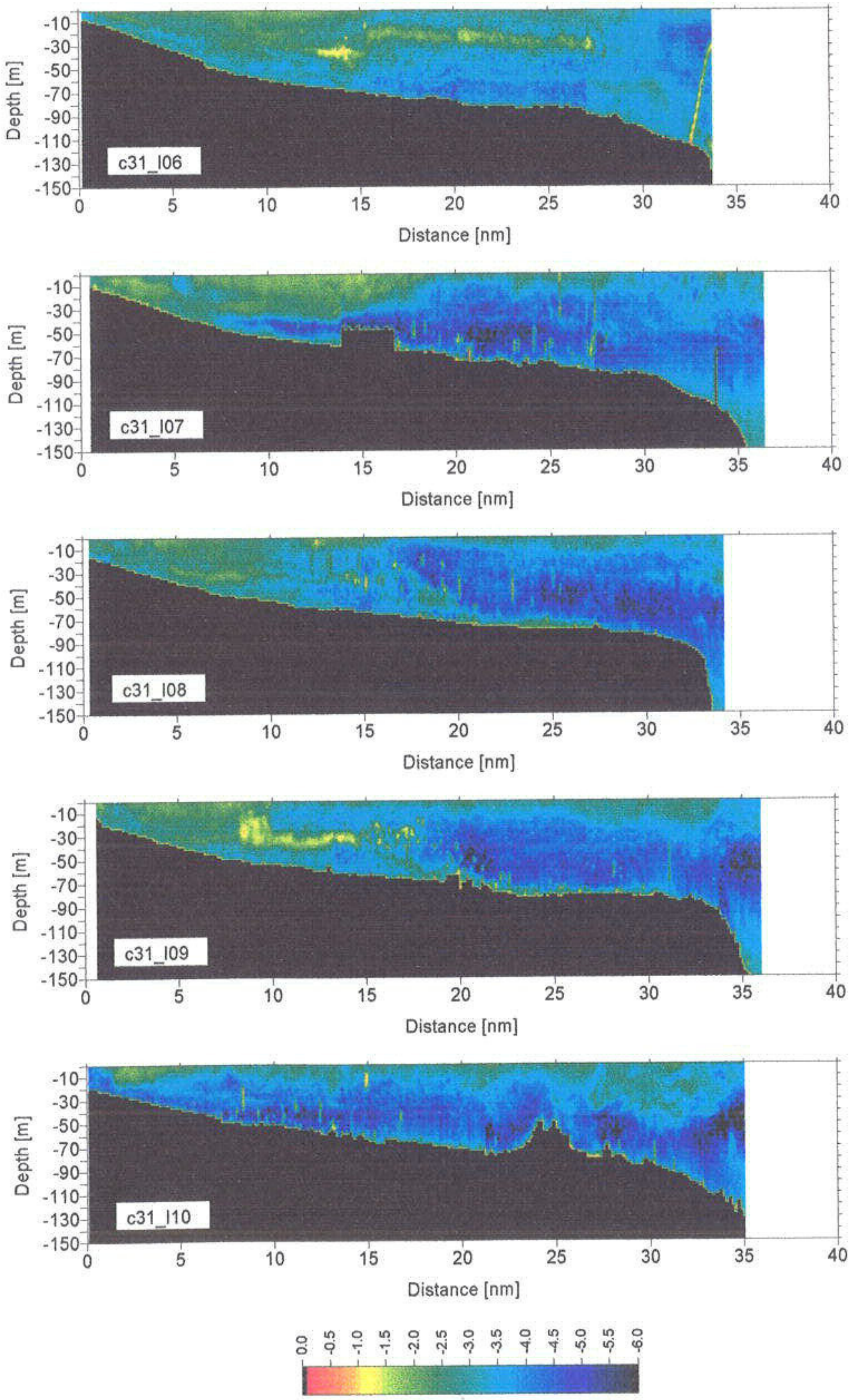


FIG. 40 (cont.). - Cruise GICS-3, end of 1st and start of 2nd coverage (May 1995)

Acoustic relative density distribution - Catalan Sea

Vertical axis: Depth (in meters); horizontal axis: distance (in nautical miles) from/to reference point; colour scale: log of acoustic relative density. Transect naming convention: ckr_lnn: c for Catalan sea cruise, k is cruise number, r is coverage number, l is Leg identifier label and nn is leg number.

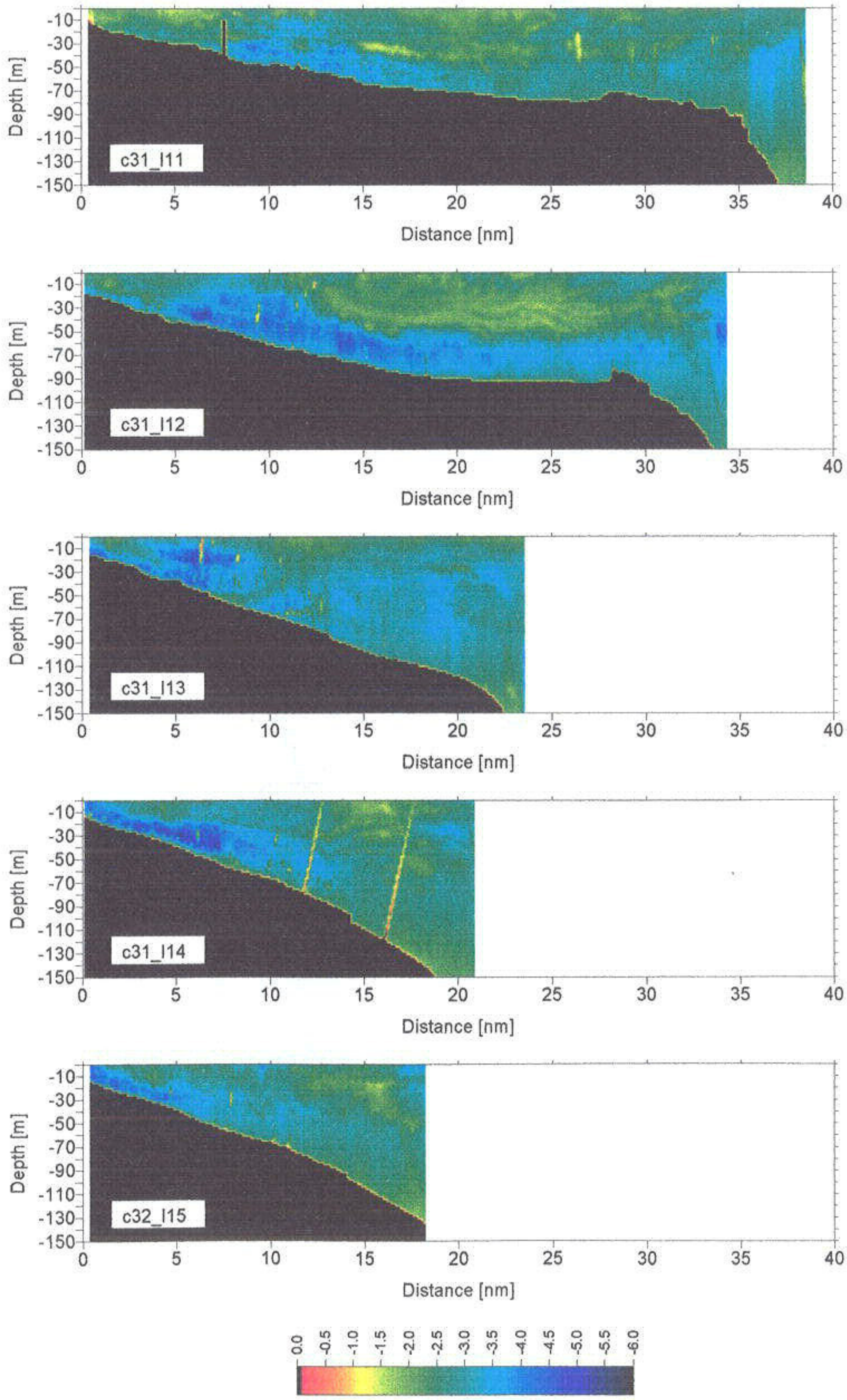


FIG. 40 (cont.). - Cruise GICS-3, 2nd coverage (May 1995)

Acoustic relative density distribution - Catalan Sea

Vertical axis: Depth (in meters); horizontal axis: distance (in nautical miles) from/to reference point; colour scale: log of acoustic relative density. Transect naming convention: ckr_lnn: c for Catalan sea cruise, k is cruise number, r is coverage number, l is Leg identifier label and nn is leg number.

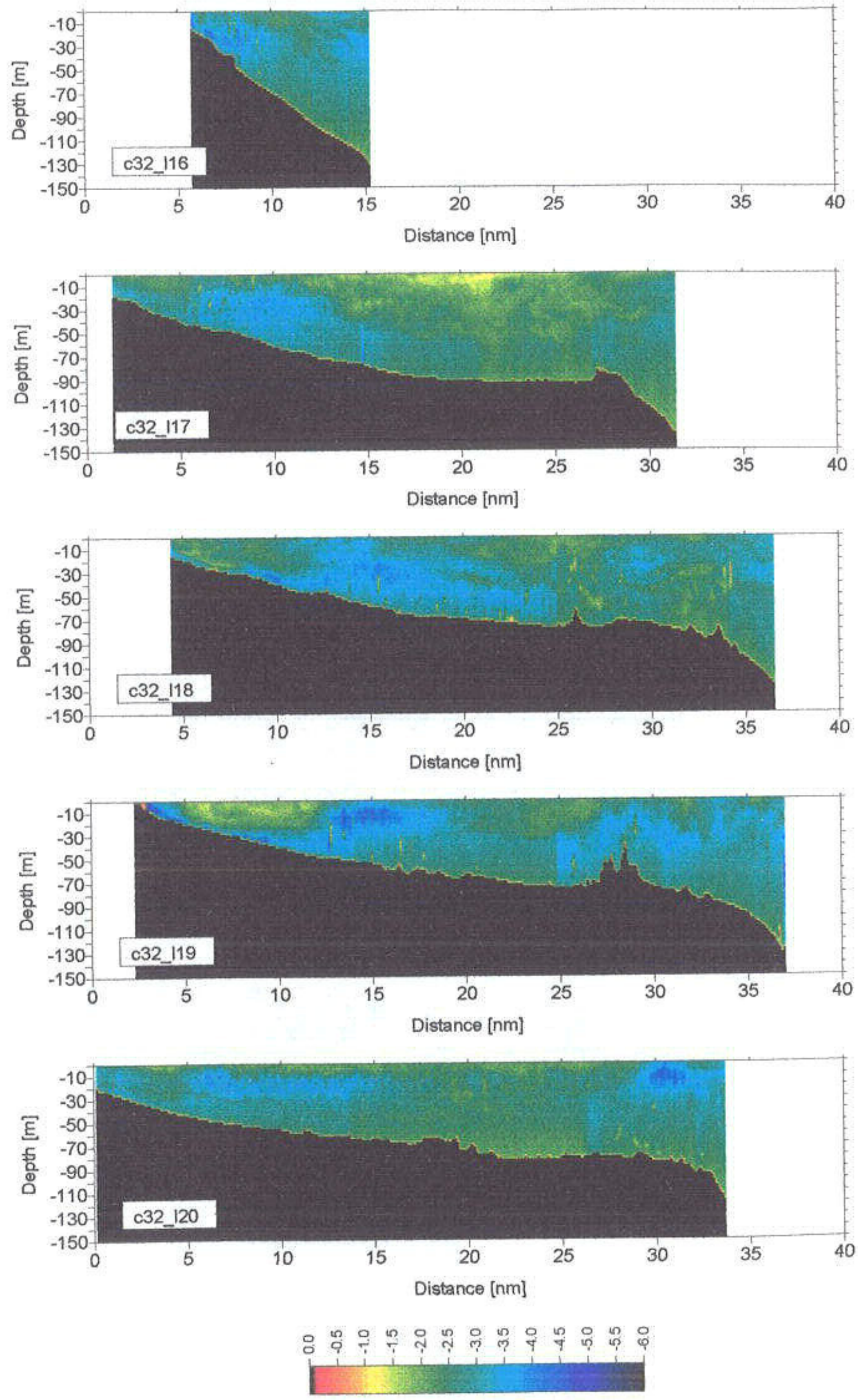


FIG. 40 (cont.). - Cruise GICS-3, 2nd coverage (May 1995)

Acoustic relative density distribution - Catalan Sea

Vertical axis: Depth (in meters); horizontal axis: distance (in nautical miles) from/to reference point; colour scale: log of acoustic relative density. Transect naming convention: ckr_lnn: c for Catalan sea cruise, k is cruise number, r is coverage number, l is Leg identifier label and nn is leg number.

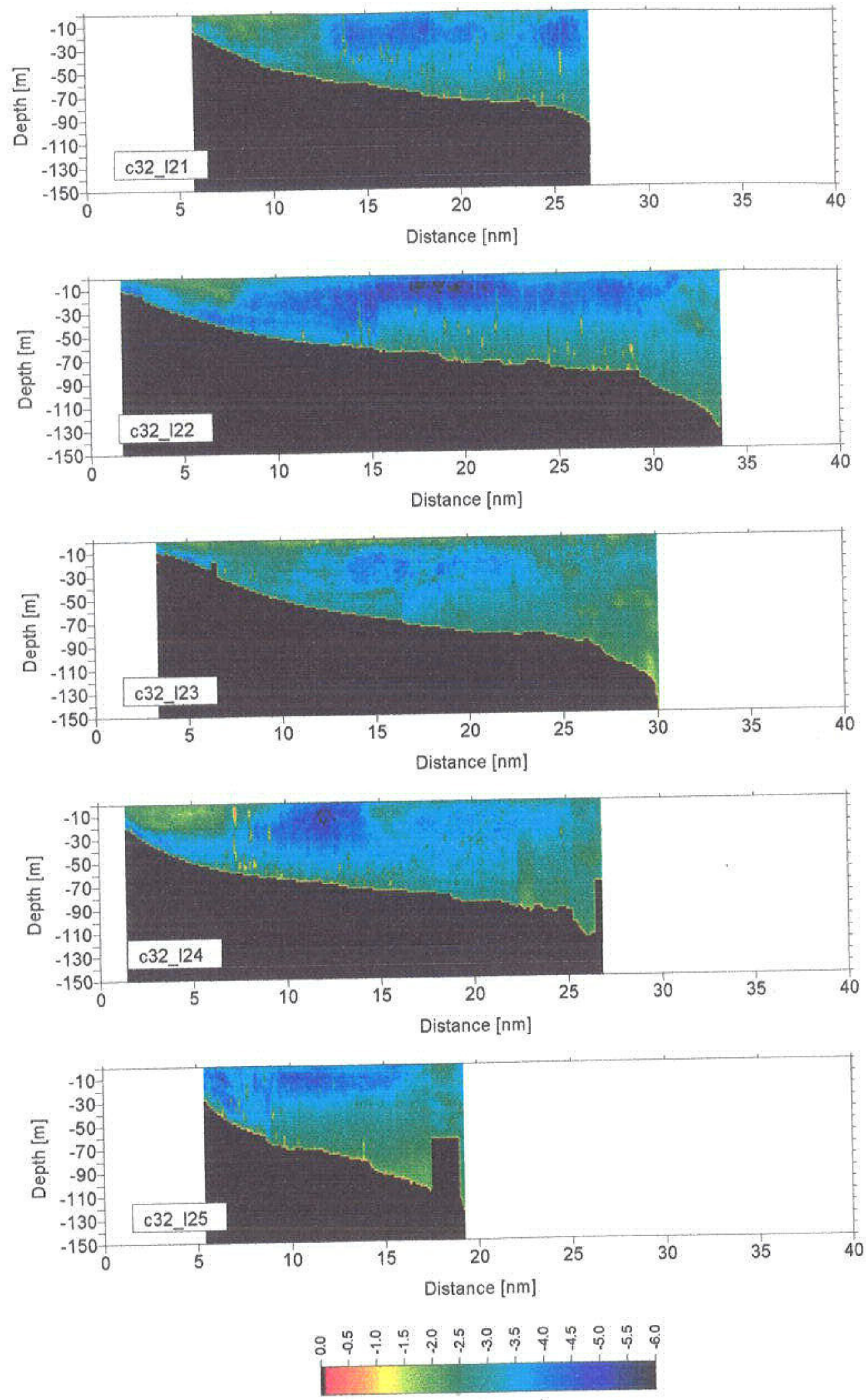


FIG. 40 (cont.). - Cruise GICS-3, 2nd coverage (May 1995)

Acoustic relative density distribution - Catalan Sea

Vertical axis: Depth (in meters); horizontal axis: distance (in nautical miles) from/to reference point; colour scale: log of acoustic relative density. Transect naming convention: ckr_lnn: c for Catalan sea cruise, k is cruise number, r is coverage number, l is Leg identifier label and nn is leg number.

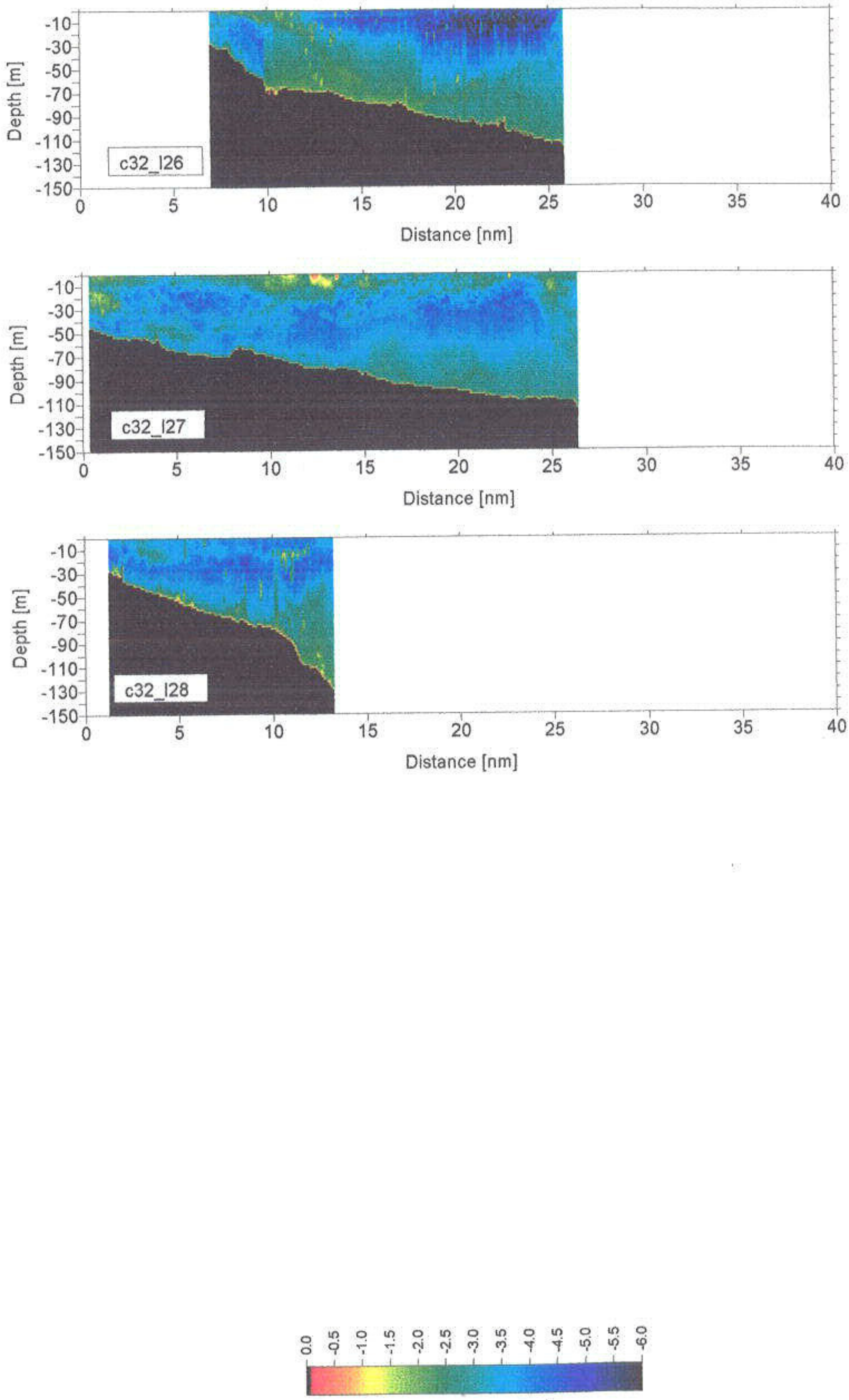


FIG. 41. - Cruise GIAS-2 (September 1994)

Acoustic relative density distribution - Adriatic Sea

Transects (legs) with bottom depth less than 50 m

Vertical axis: Depth (in meters); horizontal axis: distance (in nautical miles) from/to reference point; colour scale: log of acoustic relative density. Transect naming convention: ak_lnn: a for Adriatic sea cruise, k is cruise number, l is Leg (or transect) identifier label and nn is leg number.

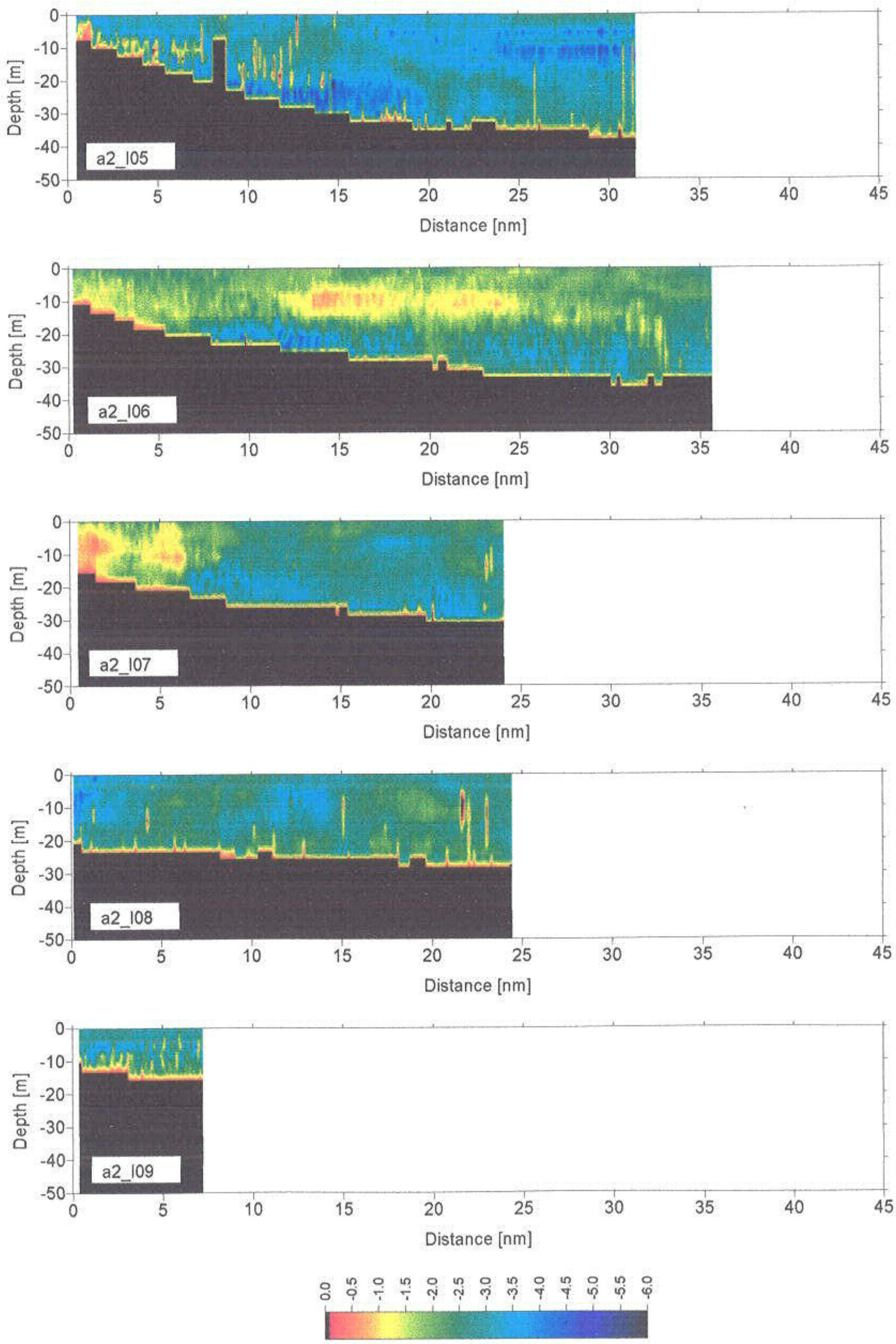


FIG. 41 (cont.). - Cruise GIAS-2 (September 1994)

Acoustic relative density distribution - Adriatic Sea

Transects (legs) with bottom depth less than 50 m

Vertical axis: Depth (in meters); horizontal axis: distance (in nautical miles) from/to reference point; colour scale: log of acoustic relative density. Transect naming convention: ak_lnn: a for Adriatic sea cruise, k is cruise number, l is Leg (or transect) identifier label and nn is leg number.

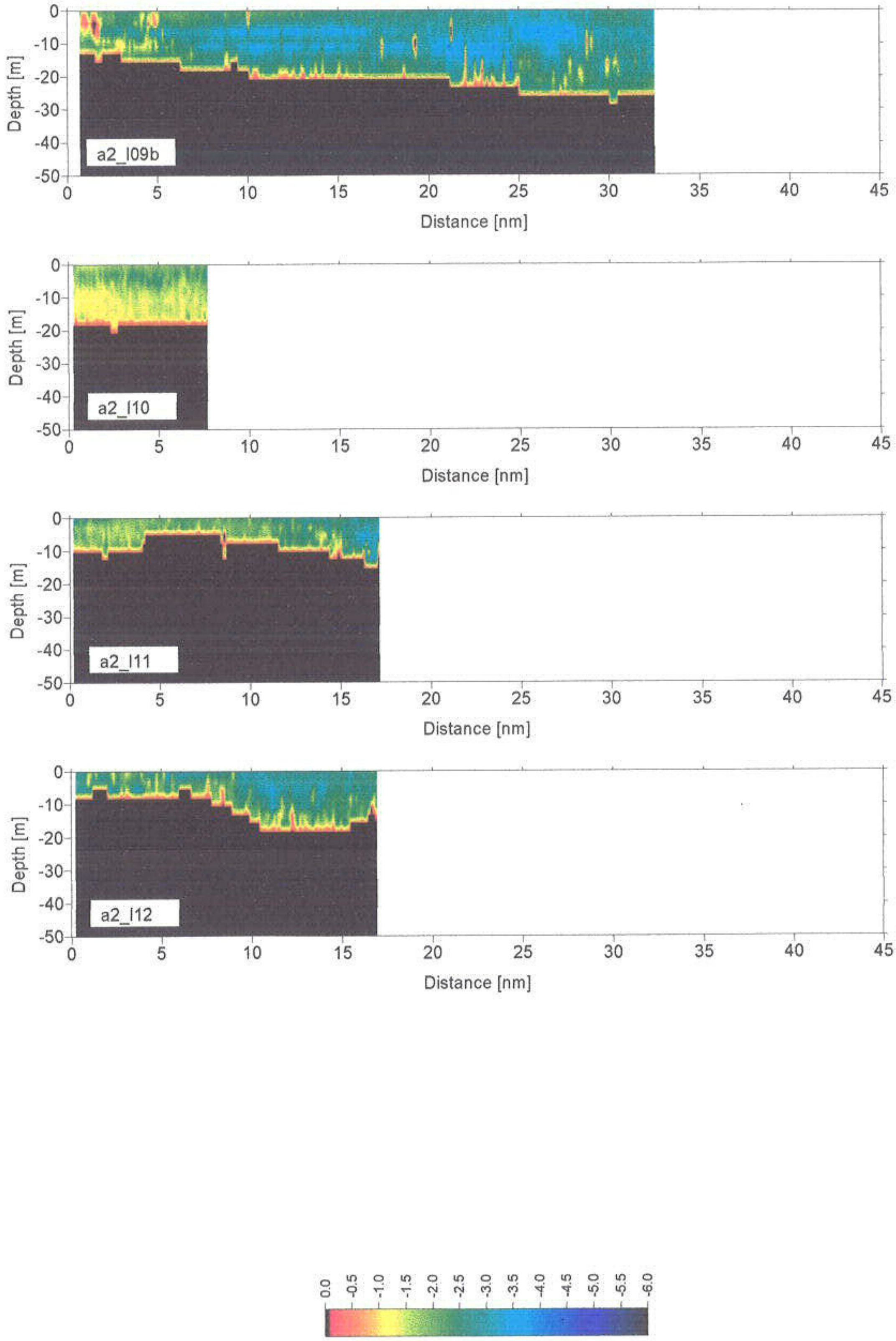


FIG. 41 (cont.). - Cruise GIAS-2 (September 1994)

Acoustic relative density distribution - Adriatic Sea

Transects (legs) with bottom depth more than 50 m

Vertical axis: Depth (in meters); horizontal axis: distance (in nautical miles) from/to reference point; colour scale: log of acoustic relative density. Transect naming convention: ak_lnn: a for Adriatic sea cruise, k is cruise number, l is Leg (or transect) identifier label and nn is leg number.

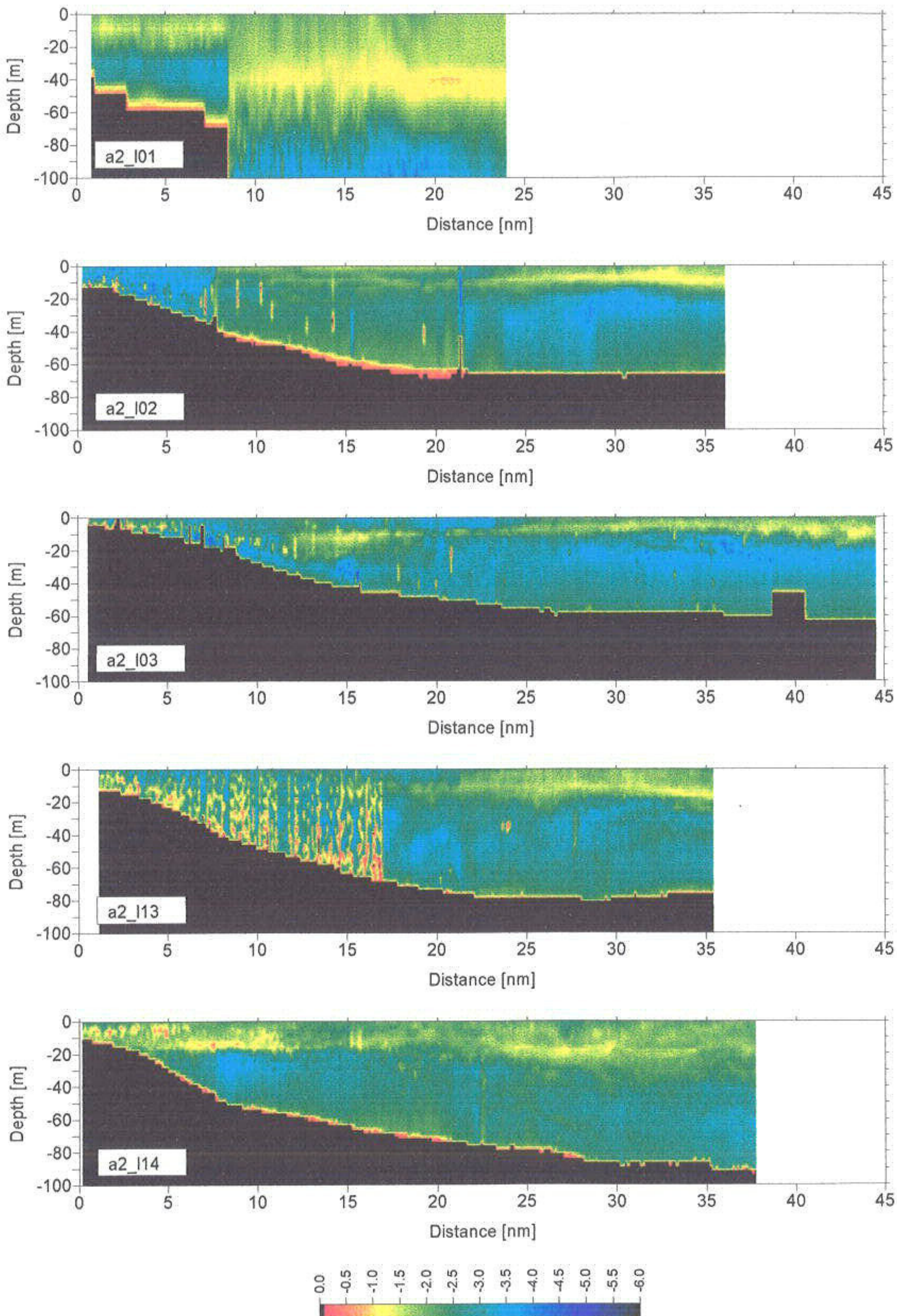
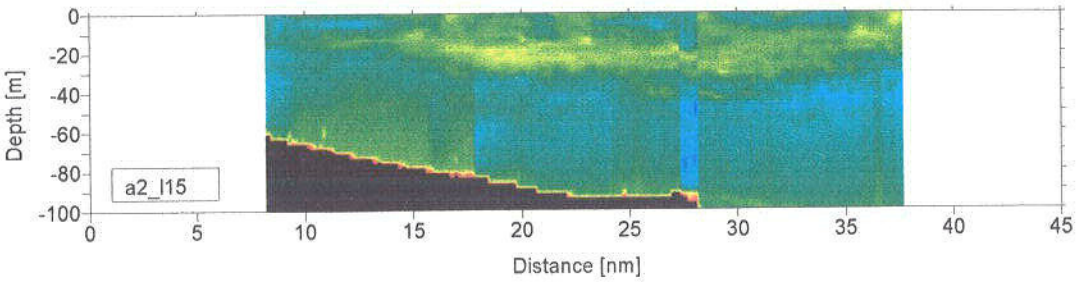


FIG. 41 (cont.). - Cruise GIAS-2 (September 1994)

Acoustic relative density distribution - Adriatic Sea

Transects (legs) with bottom depth more than 50 m

Vertical axis: Depth (in meters); horizontal axis: distance (in nautical miles) from/to reference point; colour scale: log of acoustic relative density. Transect naming convention: ak_lnn: a for Adriatic sea cruise, k is cruise number, l is Leg (or transect) identifier label and nn is leg number.



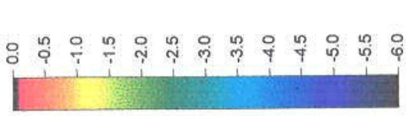


FIG. 42. - Cruise GIAS-3 (September 1995)

Acoustic relative density distribution - Adriatic Sea

Transects (legs) with bottom depth less than 50 m

Vertical axis: Depth (in meters); horizontal axis: distance (in nautical miles) from/to reference point; colour scale: log of acoustic relative density. Transect naming convention: ak_lnn: a for Adriatic sea cruise, k is cruise number, l is Leg (or transect) identifier label and nn is leg number.

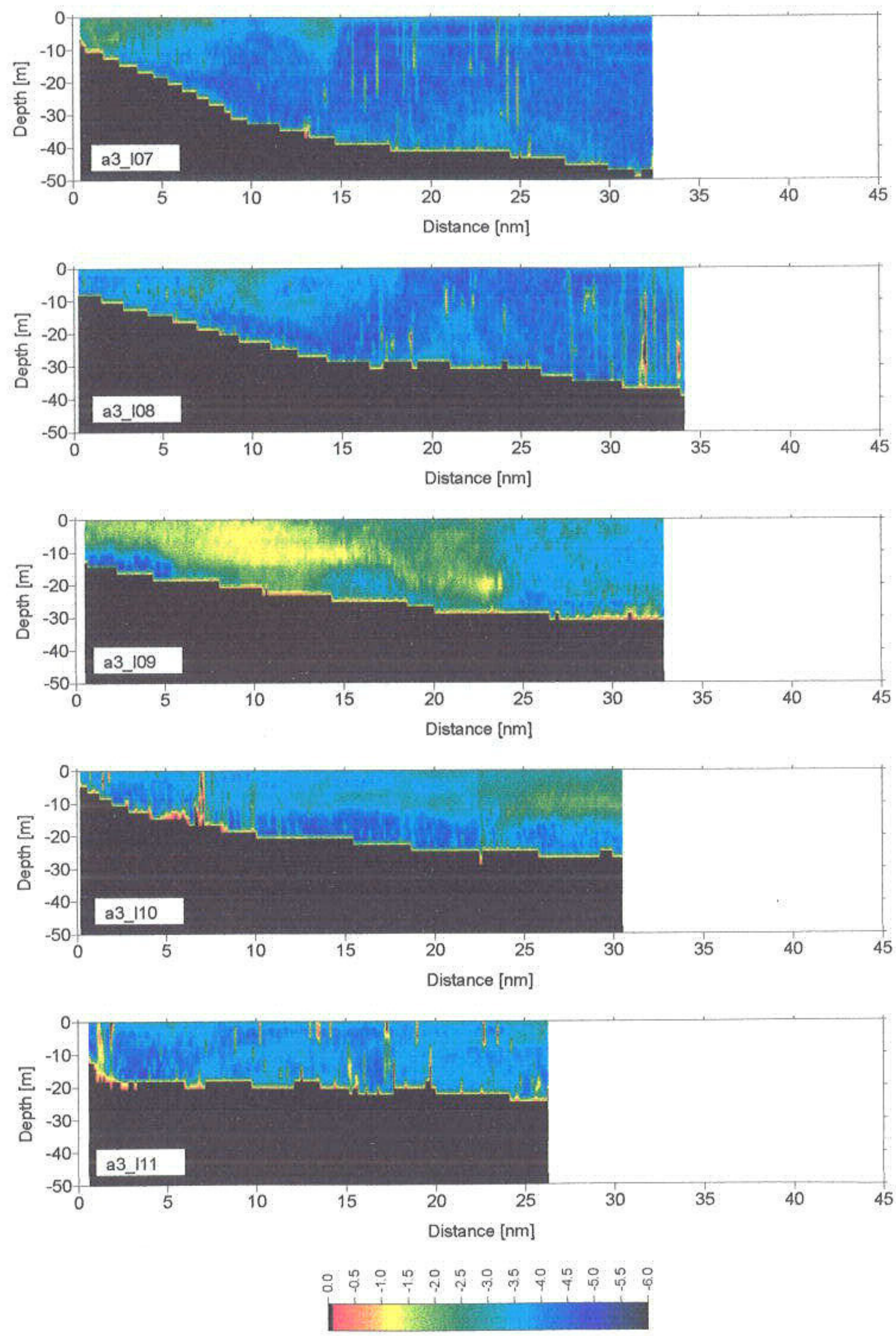
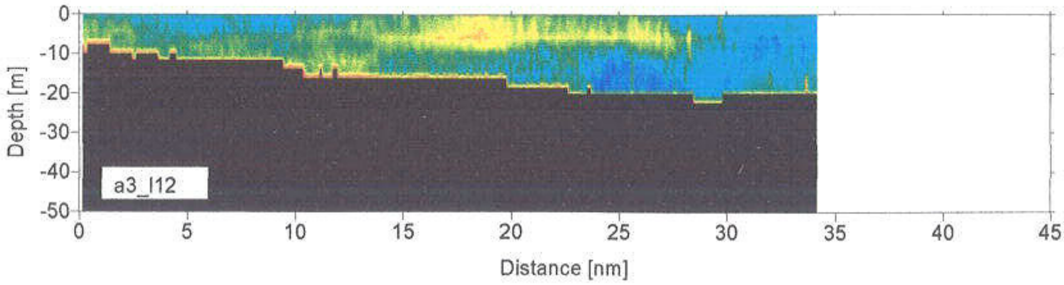


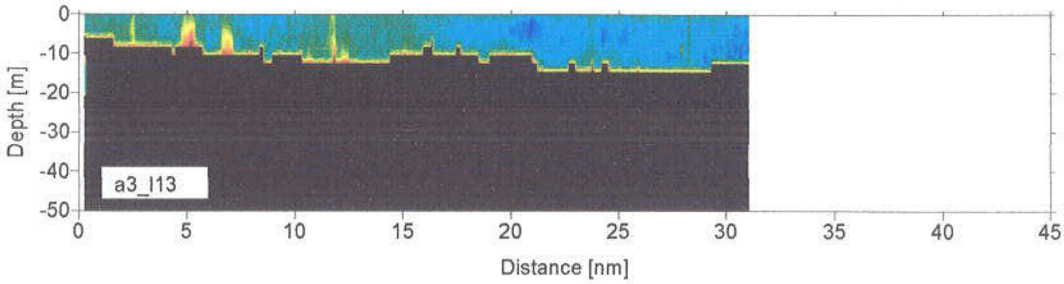
FIG. 42 (cont.). - Cruise GIAS-3 (September 1995)

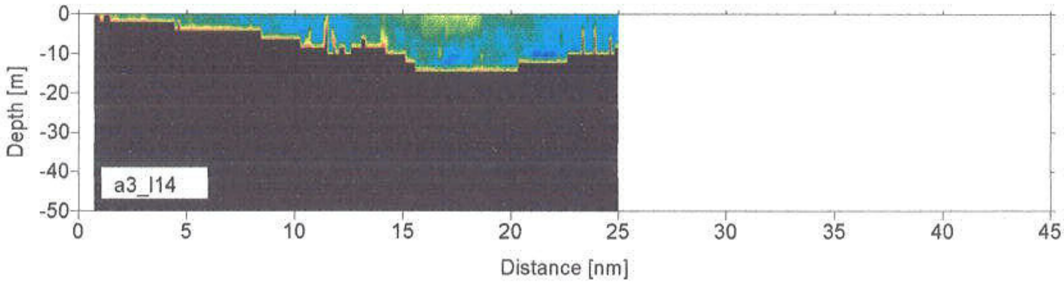
Acoustic relative density distribution - Adriatic Sea

Transects (legs) with bottom depth less than 50 m

Vertical axis: Depth (in meters); horizontal axis: distance (in nautical miles) from/to reference point; colour scale: log of acoustic relative density. Transect naming convention: ak_lnn: a for Adriatic sea cruise, k is cruise number, l is Leg (or transect) identifier label and nn is leg number.







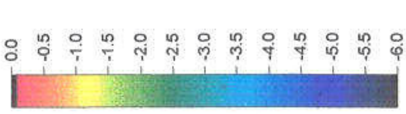


FIG. 42 (cont.). - Cruise GIAS-3 (September 1995)

Acoustic relative density distribution - Adriatic Sea

Transects (legs) with bottom depth more than 50 m

Vertical axis: Depth (in meters); horizontal axis: distance (in nautical miles) from/to reference point; colour scale: log of acoustic relative density. Transect naming convention: ak_lnn: a for Adriatic sea cruise, k is cruise number, l is Leg (or transect) identifier label and nn is leg number.

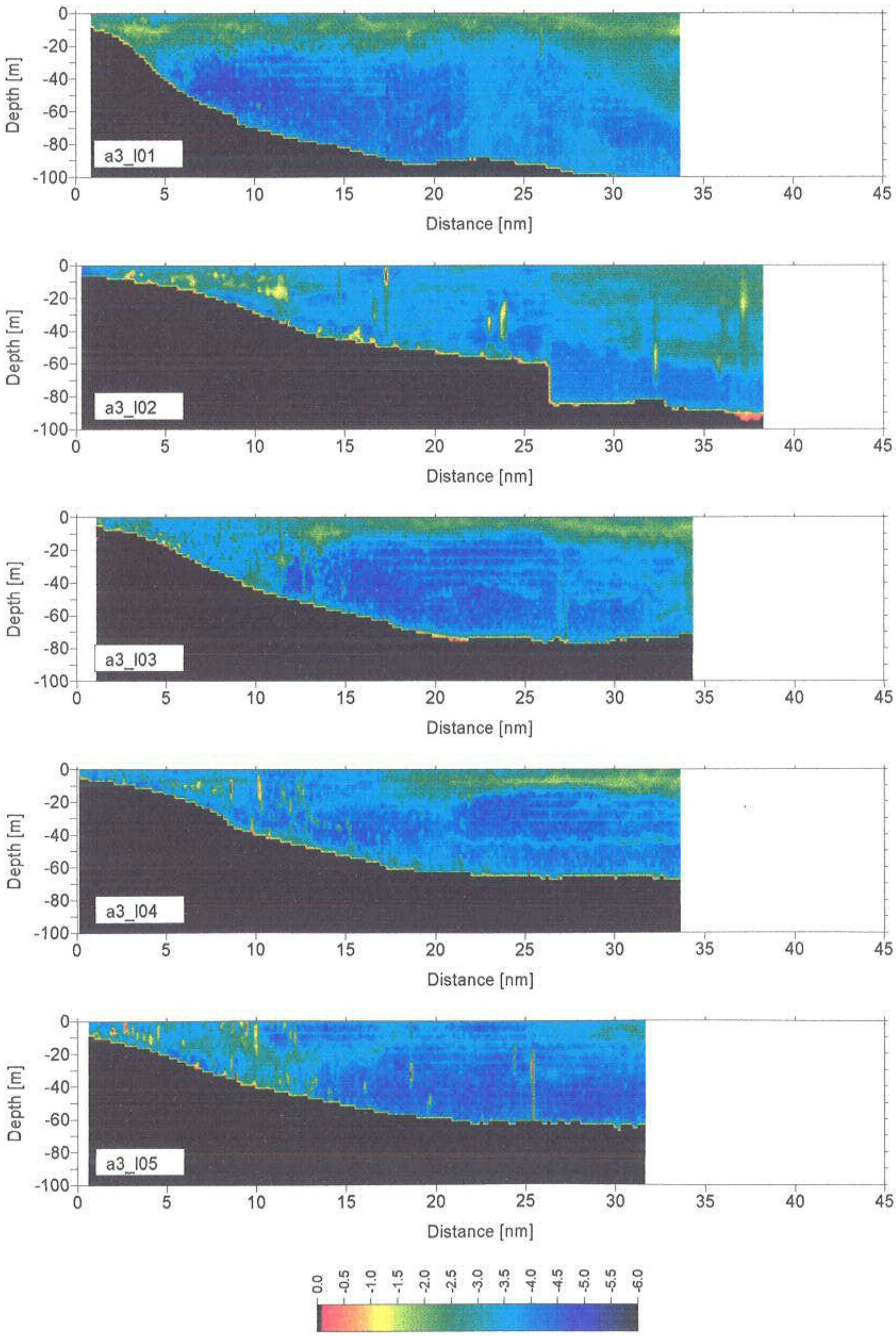
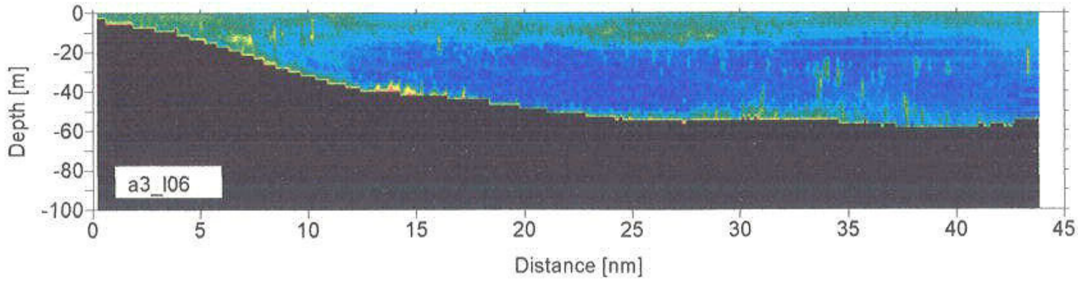


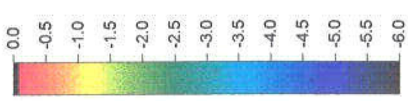
FIG. 42 (cont.). - Cruise GIAS-3 (September 1995)

Acoustic relative density distribution - Adriatic Sea

Transects (legs) with bottom depth more than 50 m

Vertical axis: Depth (in meters); horizontal axis: distance (in nautical miles) from/to reference point; colour scale: log of acoustic relative density. Transect naming convention: ak_lnn: a for Adriatic sea cruise, k is cruise number, l is Leg (or transect) identifier label and nn is leg number.





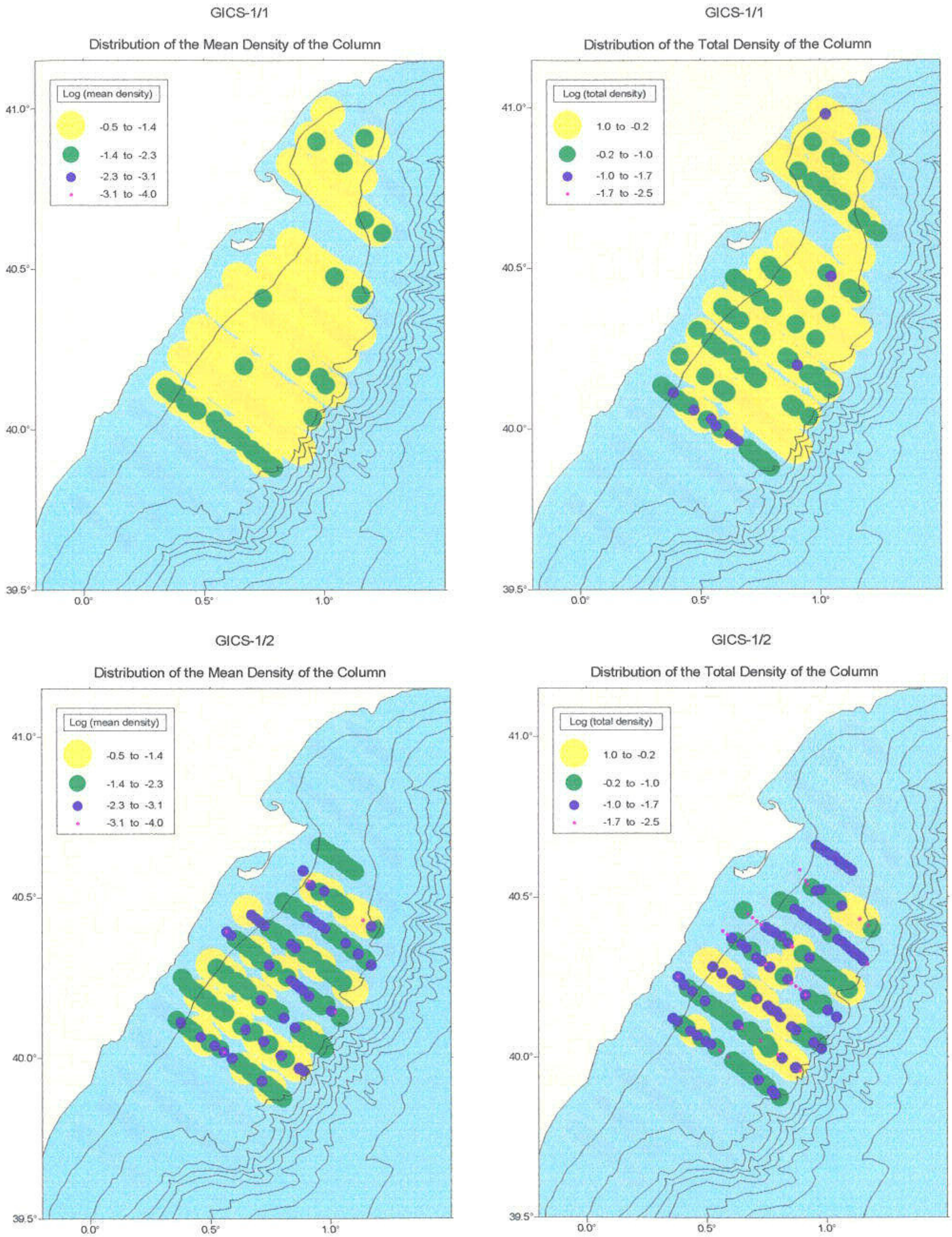


FIG. 43. - 2-D maps for GICS-1, first (top) and second (bottom) coverages, horizontal distribution of Log mean Density (left) and Log Total Density (right).

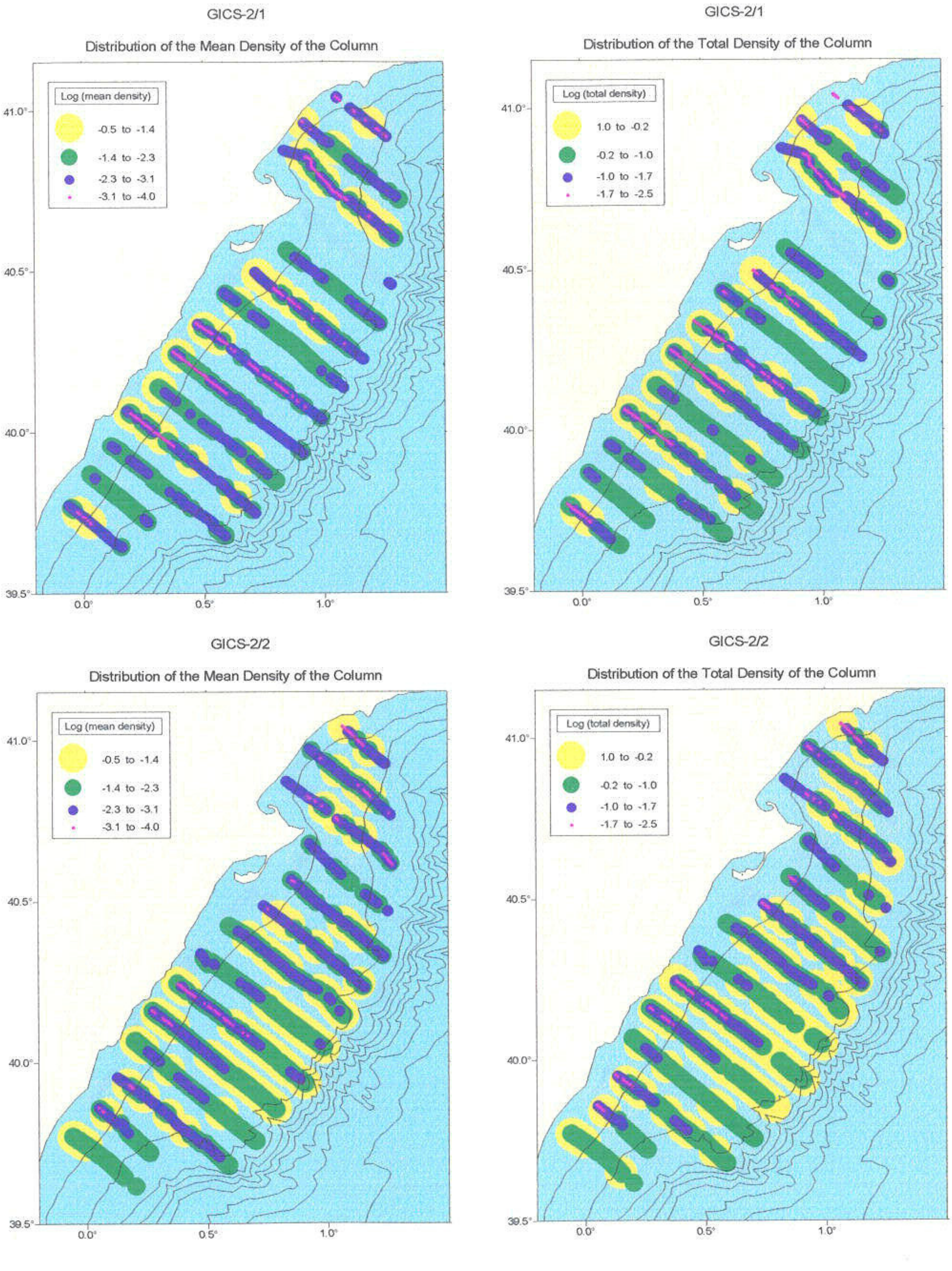


FIG. 44. - 2-D maps for GICS-2, first (top) and second (bottom) coverages, horizontal distribution of Log mean Density (left) and Log Total Density (right).

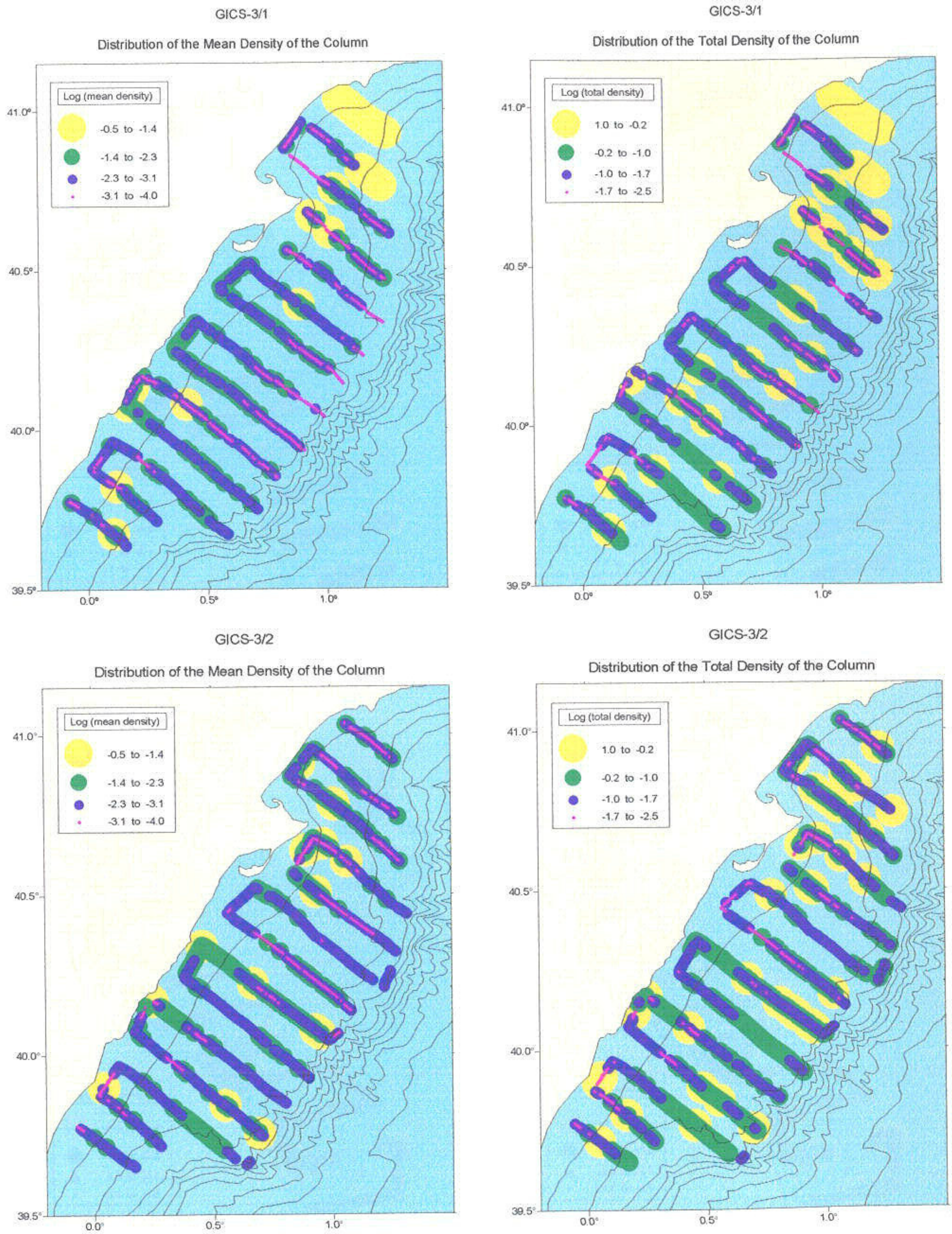


FIG. 45. - 2-D maps for GICS-3, first (top) and second (bottom) coverages, horizontal distribution of Log mean Density (left) and Log Total Density (right).

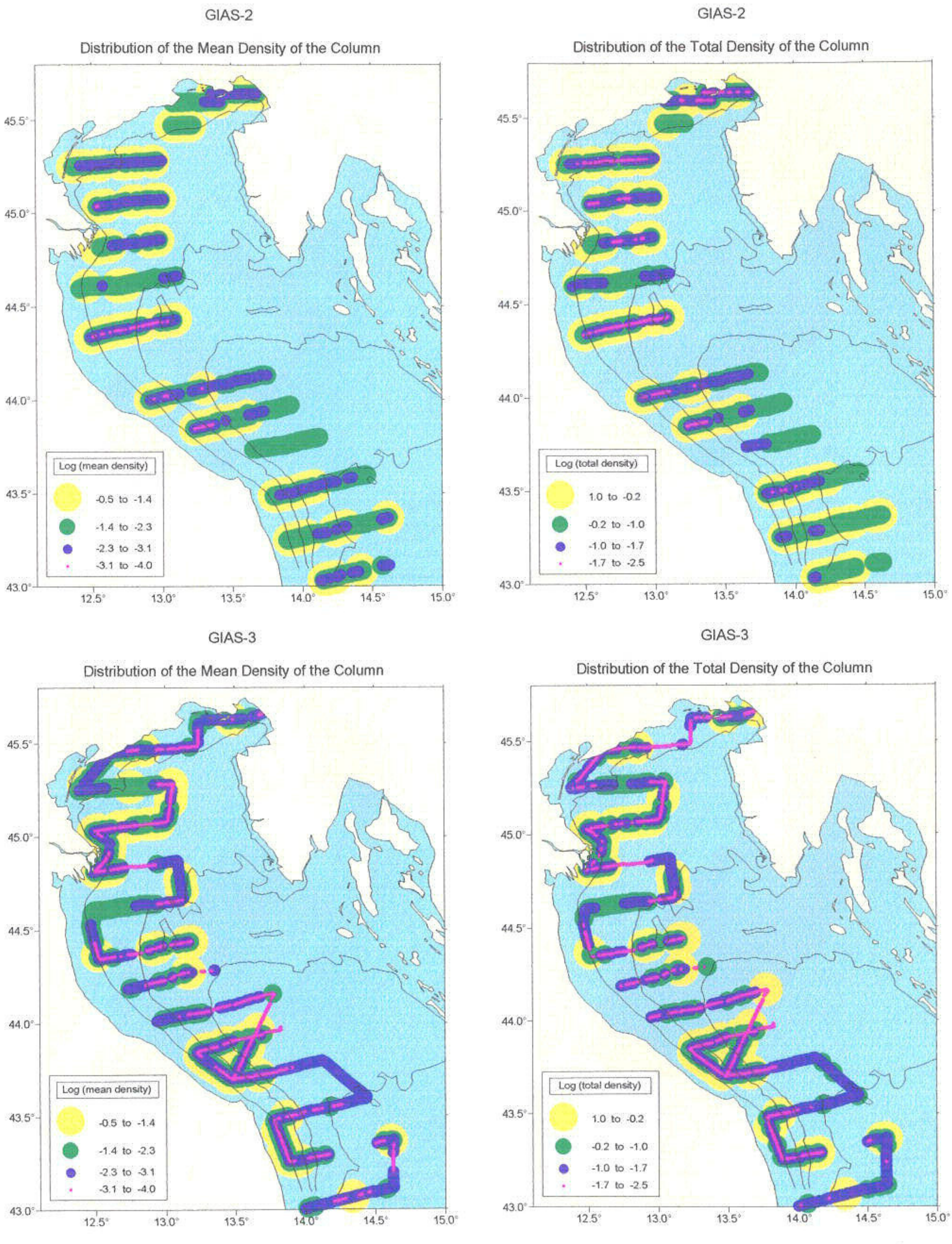


FIG. 46. - 2-D maps for GIAS-2 (top) and GIAS-3 (bottom), horizontal distribution of Log mean Density (left) and Log Total Density (right).

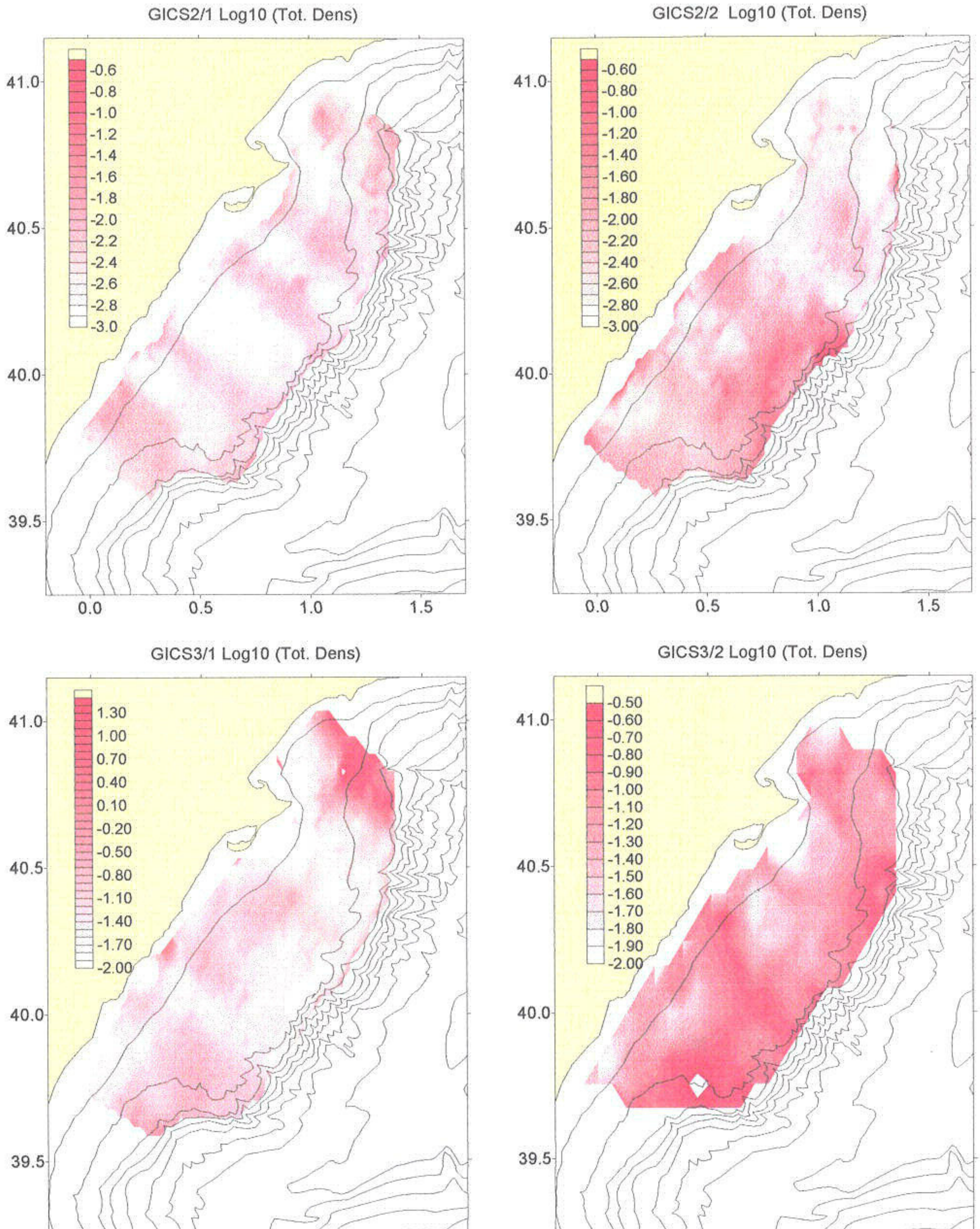


FIG. 47. - 2-D maps of interpolated horizontal distributions of Log Total Density for first coverage (left) and second coverage (right) of GICS-2 (top) and GICS-3 (bottom) cruises. Note that colour palette values are not equal for GICS3 cruise coverages.

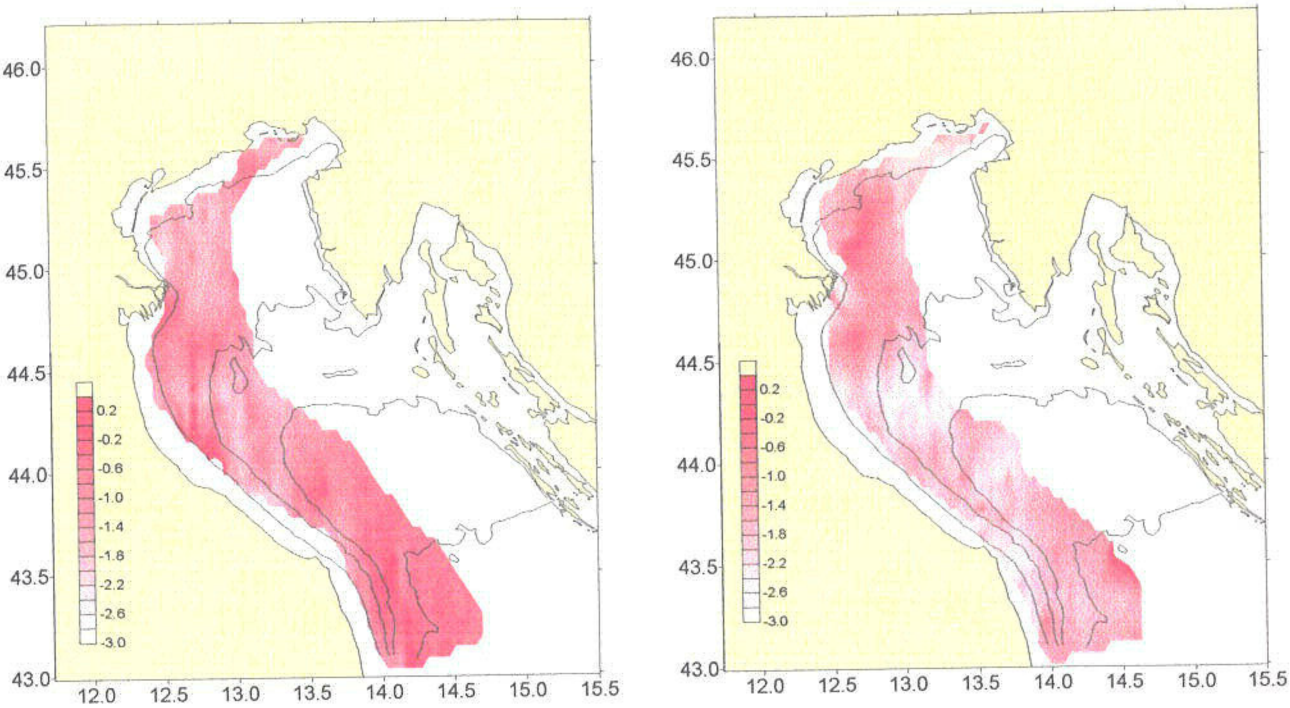


FIG. 48. - 2-D maps of interpolated horizontal distributions of Log Total Density for cuises in Adriatic Sea: GIAS-2 (left) and GIAS-3 (right).

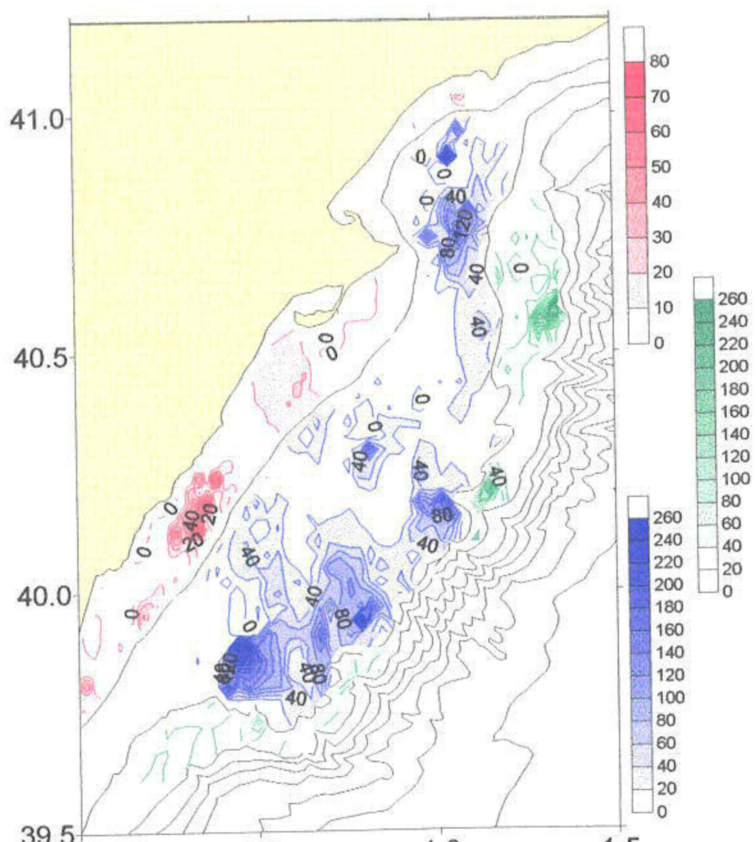


FIG. 49. - Total Biomass estimated for GICS-2 cruise per depth strata: red 50, blue 100 and green 200 m. Figures are Tons per squared nautical mile.

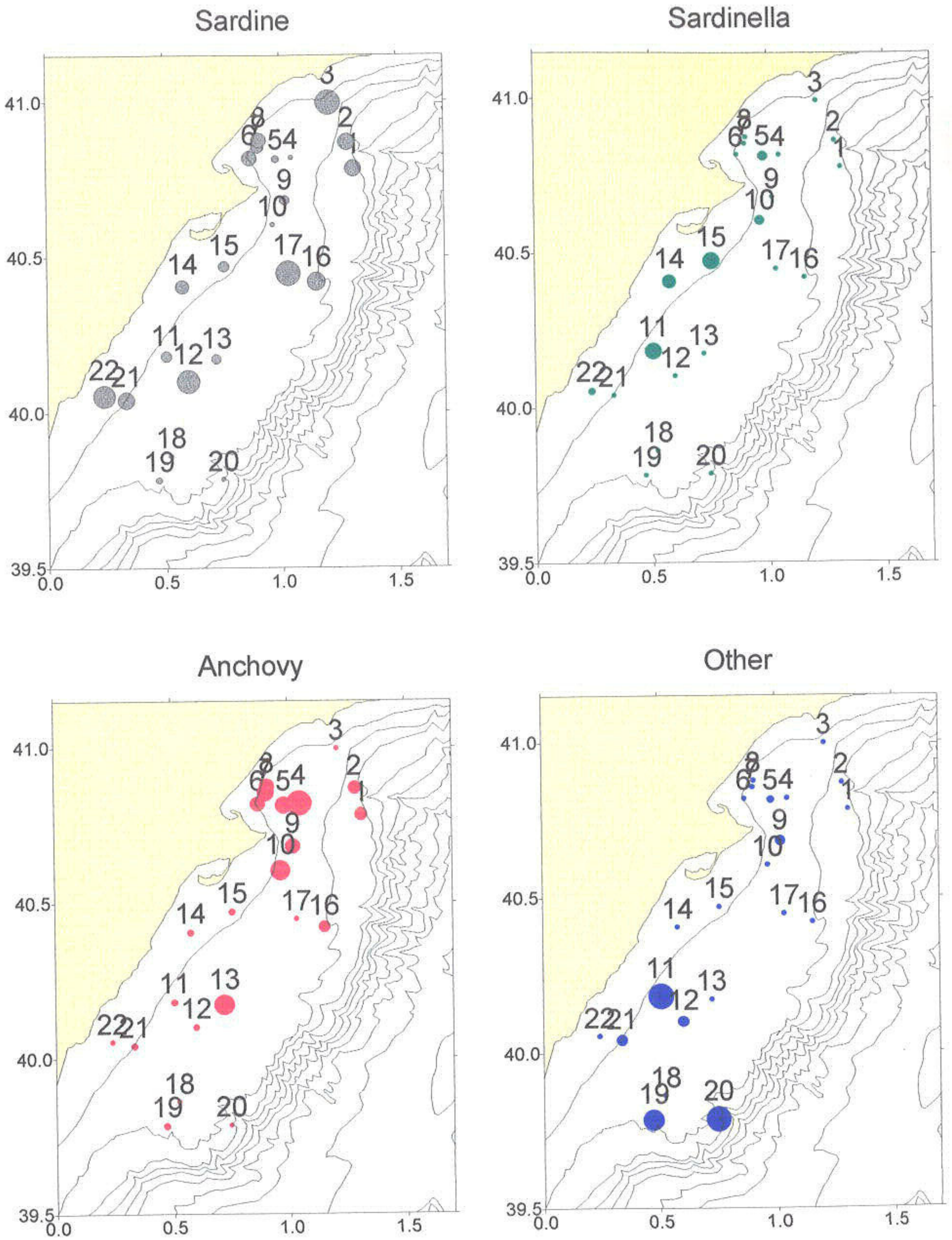


FIG. 50. - Species composition from GICS-2 biological sampling: Sardine (*Sardina pilchardus*), Anchovy (*Engraulis encrasicholus*), Sardinella (*Sardinella aurita*) and other species (Mackerel, Horse mackerel, etc.). Size of symbols is proportional to species contribution to the total catch.